TECXOTIC

MATE

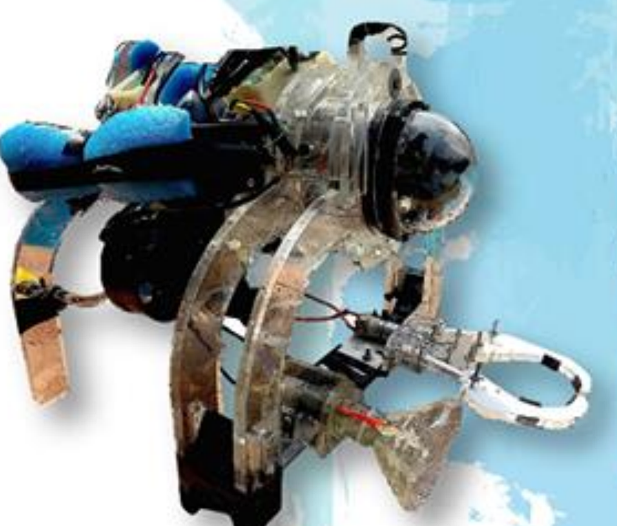
2017

BALAM

Tecnológico de Monterrey

INSTITUTO TECNOLÓGICO Y DE ESTUDIOS SUPERIORES DE MONTERREY

CAMPUS CUERNAVACA



MEMBERS

Miguel Figueroa- Chief Executive Officer
Eduardo Alaniz- Vice President
Raúl Sánchez- Mechanics Design Leader
Abraham Torres- Programming Leader
Agustín Sandoval- Design Engineer
David Trulín- Design Engineer
Jesús Guerrero- Design Engineer
Manuel Paz- Design Engineer
Alejandro Roa- Design and Electronics Engineer
Eduardo Nava- Electronics Engineer
Enrique Carvajal- Electronics Engineer
Kim Yañez- Electronics Engineer
Luis Miguel Lomelí- Electronics Engineer
Gloria Campos- Manufacturing Engineer
Orlando Cleto- Manufacturing Engineer
Angélica Güemes- Programming Engineer
José Pablo Montoya- Programming Engineer
Pamela Vitela- Marketing Specialist
Mónica Domínguez- Marketing Specialist

Roles

1. Miguel Figueroa: **CEO** 6th semester student of Mechatronics Engineering
2. Eduardo Alaniz: **Vice President** 8th semester student of Mechatronics Engineering
3. Raúl Sánchez: **Mechanics Design Leader** 6th semester student of Industrial Engineering
4. Abraham Torres: **Programming Leader** 4th semester student of Computer Systems Engineering
5. Agustín Sandoval: **Design Engineer** 4th semester student of Mechatronics Engineering
6. David Trulín: **Design Engineer** 4th semester student of Mechatronics Engineering
7. Jesús Guerrero: **Design Engineer** 2nd semester student of Mechatronics Engineering
8. Manuel Paz: **Design Engineer** 4th semester student of Mechatronics Engineering
9. Alejandro Roa: **Design and Electronics Engineer** 6th semester student of Industrial Engineering
10. Eduardo Nava: **Electronics Engineer** 2nd semester student of Mechatronics Engineering
11. Enrique Carvajal: **Electronics Engineer** 6th semester student of Mechatronics Engineering
12. Kim Yañez: **Electronics Engineer** 4th semester student of Mechatronics Engineering
13. Luis Miguel Lomelí: **Electronics Engineer** 4th semester of Mechatronics Engineering
14. Gloria Campos: **Manufacturing Engineer** High School student
15. Orlando Cleto: **Manufacturing Engineer** 6th semester student of Industrial Engineering
16. Angélica Güemes: **Programming Engineer** 2nd semester student of Computer Systems Engineering
17. José Pablo Montoya: **Programming Engineer** 4th semester student of Computer Systems Engineering
18. Pamela Vitela: **Marketing and Communications Specialist** 6th semester student of Marketing and Communication
19. Mónica Domínguez: **Marketing and Communications Specialist** 6th semester student of Marketing and Communication
20. David García: **Mentor** Mechatronics Engineering Program Director

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I. Introduction

A. Abstract

Balam is a Remotely Operated Vehicle (ROV) designed to work in the deep waters of the Port of Long Beach. It comes fully equipped with tools that allows to complete exploration missions and scientific studies.

This ROV was designed and manufactured by Texotic, a company that involves different areas of technology such as mechanical and software engineering, logistics, administration and marketing, all of this areas working together on developing solutions to marine technology problems.

This technical report describes the process and design of this multidisciplinary project, which was distributed in four principal areas: Mechanical Design, Control system, Electrical System and Manufacturing. Balam is the result of months of planning, designing and testing. With its innovative design along with the electronic communication improvement, Balam is the most optimal ROV for the exploration trips.

II. Design rationale

A. Mechanical Design

To design the ROV for this year we based on our previous vehicle. First, what we wanted to achieve was to make the prototype stable in the water, that's why we tried to use light materials, so we used acrylic and aluminum for the frame. We were worried about the possible failure of one or more thrusters, so we planned different configurations for them, so if it is needed we can change their position.

The cameras system we created is efficient giving the pilot enough angle to watch the environment of the ROV, two of them are set inside the acrylic dome, the third camera is outside the electronics cylinder, this to have another perspective of what is happening.

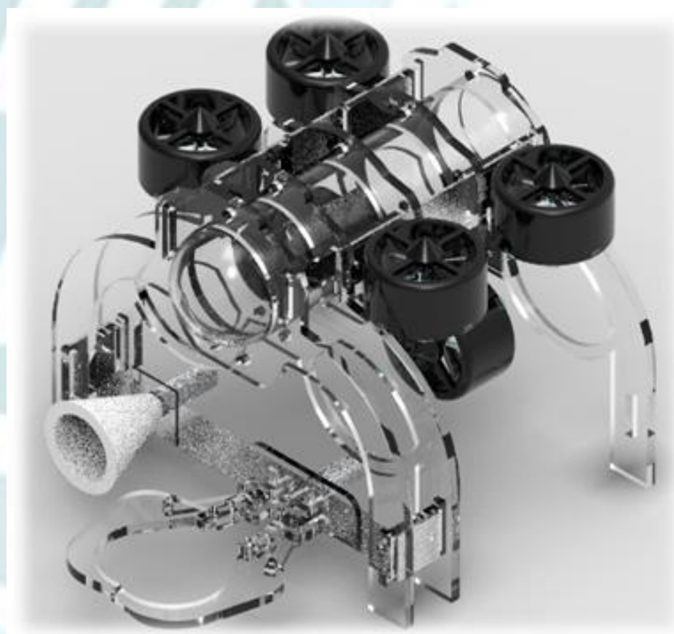

Figure 1. Balam's Cad design

The central acrylic cylinder is perfect for our design as it fits our needs, if the cylinder can be our float, it could be easier to distribute the total weight of the ROV having enough space to locate other floats. The dome is essential for the ROV as it contains and protects two cameras that cover the front and most important part of the vehicle, giving the pilot a great angle of vision outside the structure.

Frame

The support structure of the ROV is composed by 5 acrylic plates holding the central cylinder, the purpose of three of this plates is to make the structure stand in any surface and to hold the aluminum bar for the tools. There are two other plates each one holding the aluminum plate for the side thruster. The acrylic cylinder is the core of the vehicle supporting all the plates and containing the electronics with the cameras. Even if the frame of the ROV breaks or needs to be substituted it is easy to change the pieces for new ones. They are even easy to manufacture, we just need available material, this may be not a common situation considering never needed to change pieces. That’s why we consider our frame´s resistance is enough for the missions in the competition. These primary plates have 9mm thick, the rest of the plates have 6mm thick.

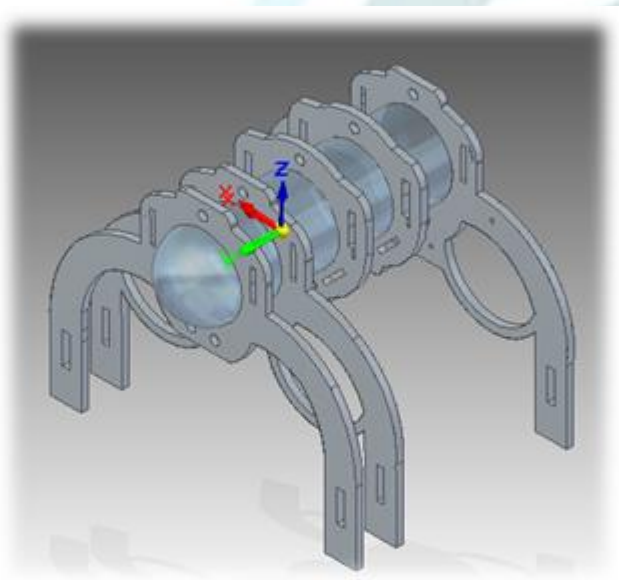

Figure 2. Balam’s Solid Works Design

Structure

We wanted to use the acrylic cylinder as the floating system, that’s why we located it at the top of the structure, and then distribute the total weight of the ROV building in the rest of the structure and mechanisms (gripper and engines).

The components we used were easy to manufacture, and effortless to replace them in case of failure, another important feature is their lightness. This machinery makes the ROV easy to assembly and dismantle.

The maximum depth the ROV has been taken is 4.7 meters, but the data sheet specifies the acrylic cylinder is design to submerge maximum 100 meters under water. We also put to work the acrylic cylinder as our pressure housing, we did not manufacture it, it was bought.

For isolating the electronics, the cylindrical container has two o-rings, they are plastic rings that prevent water leaking, specifically they isolate the electronic box converting the cylinder into a floating system.

Figure 3. Blue Robotics T200 Thruster

To move the vehicle we used two T-100 and four T-200 Blue Robotics thrusters.

The total weight of our ROV, including the power supply and communication wire is 18 kilograms.

Ballast System

Our ballast system works thanks to the distribution of the different components (motors, claws, camera, etc.), besides with the help of the air that there is inside of the electronics box and another important thing is: the air hoses and floats.

Stability is the property of a body to remain in stable equilibrium or to return to that state after suffering a disturbance, it´s important, because if the ROV has stability, the missions would be easier to perform as the vehicle remains smooth to control.

System Design

It is designed to work with different thruster placements along the ROV, with the intention of working with less thrusters if one of them burns or breaks down. If any part brakes, it can be replaced easily for a new one. Finally, due to its buoyancy and lightness, its performance increases making easier to the pilot to control the ROV, our design is what in physics is known as inverted pendulum, as the heavier parts are above the mass center, it naturally rotates under water, but we solved this with our buoyancy and stability system.

The safety systems have proved to work expeditiously, water does not filt inside the vehicle and it is perfectly isolated to prevent system crashing. We looked for a waterproof and a secure component to isolate the ROV, so we used epoxy resin. The acrylic cylinder also has its own sealing system, to develop these components we used the tools and machines available in our school for example,3D printers, laser cutters, lathe, etc, most of the electronic components where bought. We decided to implement the design of the acrylic cylindrical container from the ROV of the last competition, to reduce costs, we decided to use last year thrusters and with the money we saved we spent it for different components.

Originality

We consider that the most innovative concept of our ROV is its ease to be repaired and modified to perform its missions even if one or two thrusters do not work. The way it was built and designed allows any user to manufacture the vehicle

Although our ROV uses commercial components, we manufactured most of its parts, except for the acrylic cylinder, the thruster, the speed controllers, and the engines for the tools. The motherboard we used was an Intel Galileo, it was a donation from Intel.

To give stability to the vehicle, we only used two pieces of commercial float, it is easy to find and it is very cheap. It appears to settle the ROV in the water without using the thruster.

We had the chance to use our last ROV, but we decided to build and design a new one with new features.

Payload Tools

Considering the different missions the ROV must accomplish, we chose to use two different tools, a gripper to hold and manipulate objects, and rotation tool we designed to spin keys and knobs:

- The gripper consists of an acrylic body, a DC motor, aluminium brackets, connecting rod, and screw. The acrylic design was made in CAD and cut in the laser machine, while the aluminum pieces were manufactured using turning, milling and drilling processes. This year's gripper depends on only one DC engine that rotates the ¼" aluminum screw, manufactured with a threading processes. There are two brackets attached to the arms and to a manufactured piece inserted on the screw that opens and close both arms of the gripper. To control if the gripper opens or close, its power supply polarity can be inverted, this is possible thanks to our software and electronic configuration.
- The rotation tool was designed to use any kind of extension such as brushes, nets, wires or any manufactured parts to catch its target and spin it. It is a DC engine attached to an acrylic structure that can be adapted to fit any piece.

Both tools are screwed to the aluminum bar attached to the supports in the front part of the ROV, to have a better control we located the cameras above the tools.

Figure 4. Rotation tool and gripper

Figure 5. Payload Tools

B. Watertight enclosure for ROV (WER)

Balam's main electronics are housed in a 10.2 cm x 29.8 cm outside diameter acrylic tube sealed with an aluminum flange at each end. The flanges are fixed in place by a double O-ring seal. The housing's cylindrical shape allows the ROV an efficient move through water. Additionally, acrylic's transparency, concede supervision of components and status lights within the housing for safety inspection.

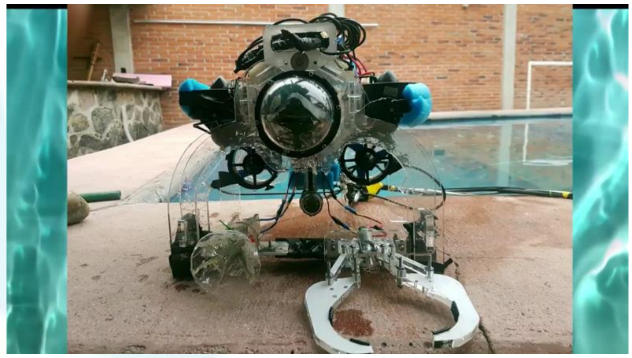

Figure 6. Completed ROV

The dome end-cap reduces drag on the ROV, and allows for extra room within the enclosure for two of our cameras. It has a wider field of view than a flat end cap. It's optically clear and doesn't warp or distort the footage. The flange is injection molded and has inner mounting holes as well as tabs for easy removal.

The other end-cap is made of aluminum and it has 10 x 10mm holes for connector penetrations coming from the tether, which allow for communication, power, thrusters, and accessories to connect to the internal electronics, also, an important component of the housing and part of the prelaunch safety checklist, is the vent, which allows trapped pressure to escape from an enclosure after it has been closed. It includes a threaded plug with double O-ring seal to open and close the vent. The main purpose of the housing is to keep the electronics dry, safe, and serviceable, the entire housing assembly is an integral component of Balam's frame as well as its source of buoyancy.

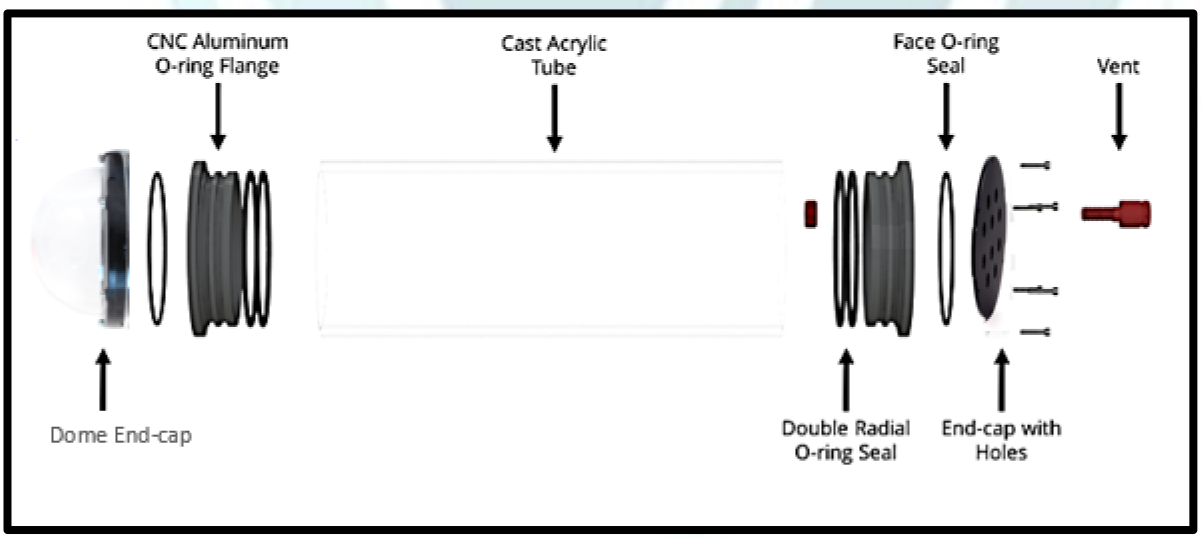

Figure 7. Components of the watertight enclosure

C. Electrical System

The electrical system is divided in 3 subsystems, the power module, the processing module and the peripherals.

Power module

For the power module the electric current flow is controlled by a circuit breaker connected to a power supply (provided by MATE). The flow can be controlled with both a manual and automatic shutdown in case of emergency. The manual shutdown is simply controlled with a switch. On the other hand, the automatic shutdown is activated by a 30A fuse, the maximum electrical current provided by MATE supply. The SID is shown in Figure 6. The output from the circuit breaker is plugged to a Murata Solutions DC/DC converter, that reduces the voltage from 48V (original supply) to 12V without change in amperage and with efficiency above 90%. As another security measure, a 30A fuse is connected before supplying all the other devices. The optimal size for the fuse is derived from the maximum expected consumption from the ROV, as shown in Figure 6. Peripherals like the thrusters, gripper, and cameras are directly connected to the 12V output. A secondary Step down DC/DC converter is used to step down the voltage from 12V to 5V and supply power to the processing module, and sensors.

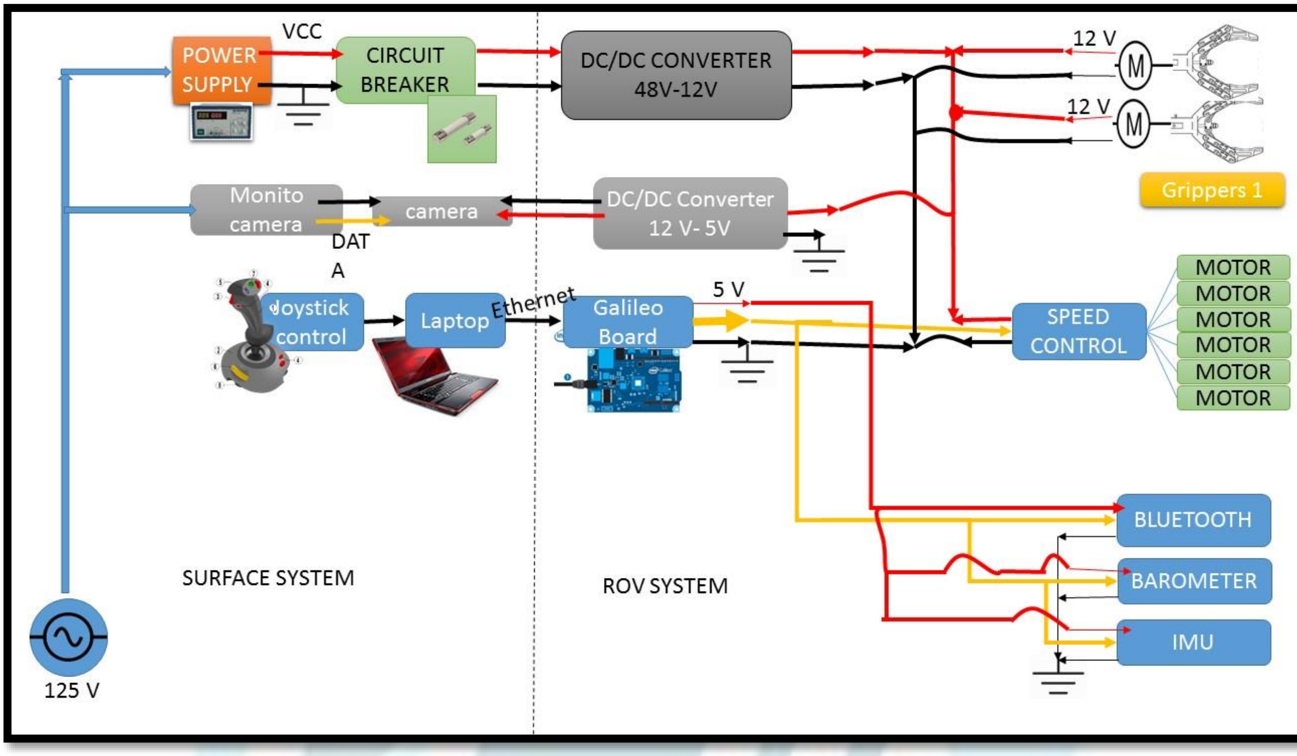

Figure 8. System Interconnection Diagram

In addition to the safe use of wiring, Balam uses a 16 AWG gauge wiring for the main tether for power supply, which can hold 41 Amperes maximun, and 12 AWG gauge wiring for the power supply for the ESC and Thrusters, which can hold 22 Ampers maximum.

Processing module

For the processing module an Intel Galileo was used. An Intel Galileo is a microcontroller based on Intel Quark SoC X1000 Application Processor, a 32-bit Intel Pentium-class. Using this microcontroller has many advantage over conventional microcontroller such as Arduino Uno like processing power in which Galileo has 25 times more clock speed or 256 times more RAM. It also has many of the capabilities of the Raspberry pi, like the ability to run a Linux image, with low power consumption. The main advantage over these microcontroller is the modular design. The Galileo has the same headers as Arduino, making it possible to adapt to a huge variety of shield and hardware, it also has one Ethernet port, three serial ports and PCI Express slot. Making it able to evolutionate to more advance and resource consuming tasks like image processing.

The ability to run a Linux image and also being able to be programed in an Arduino IDE is a huge advantage. When the Arduino C language is not powerful enough, we can change to Python, C, Java etc. or even try Linux multitasking abilities. Making it a versatile yet simple and ready to play.

Peripherals

The peripherals used are:

- Six Electronic Speed controllers (ESC) for the thrusters.
- Gripper
- Vale spinner
- Bluetooth
- IMU
- Barometric sensor
- LED lights
- 2 FPV Cameras with wide angle
- 1 Aqua-vu waterproof camera

All the modules are connected by custom Printed Circuit Board (PCB) and security micro molex connectors that prevents and eliminates any short circuit or communication loss.

ESC

One innovative aspect of the Electronic systems is that the design was planned to have the ESCs outside of the WER. The objective is to have a simple wiring design inside the WER enclosure, to dissipate in a more efficient way the heat produced by the ESC, preventing any air expansion inside the WER, and finally reducing the quantity of connectors to the WER, minimising leak risks .

To achieve this the company designed 3D printed enclosures for each esc. The enclosure was later filled with epoxy resin shown in figure 7. Power cables and I2c bus cable got out of the ESC enclosure and later are connected to a power/I2C hub which unifies the I2C and the power cables. This power cables and the bus are connected to the WER by Blue robotics penetrators. With this configuration the quantity of connectors used in the WER to control the thrusters was reduced from to 6 to only 2 connectors. This allowed us to use a small WER and reduce the size of the ROV. The implemented design can be seen in figure 10.

Figure 9. Electronic Speed Controller sealed with the 3D printed case filled with epoxy resin.

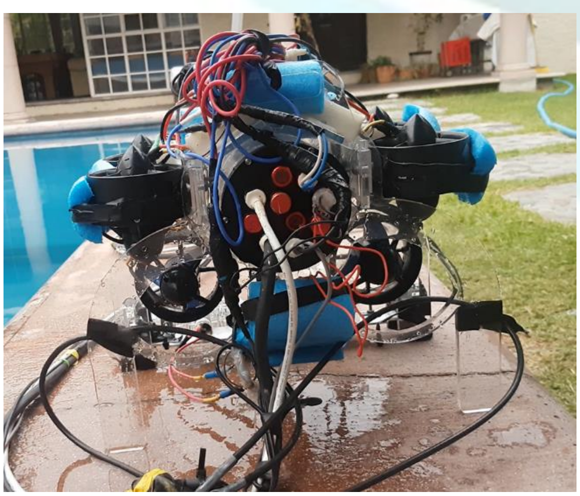

Figure 10. Rear part of the ROV.

I2C
A huge advantage this ROV has over last year's model, is the implementation of I2C protocol to control the ESC. I2C means inter-Integrated system, this protocol allows with one bus with two cables: Data, and clock, connect up to 128 different devices, assigning each devices an specific address. This protocol allowed us to implement the design of the ESC previously mentioned, and to have available PWM pins for any later upgrade. In total we have 8 devices that use this protocol, one inertial measurement unit, one barometric sensor and six ESC.

PCB
The company designed 3 PCBs one for the power module, one custom shield for the Galileo and one power/bus Hub to unite all ESC signal and power. The electronic cad designs are in figures 11 and 12.

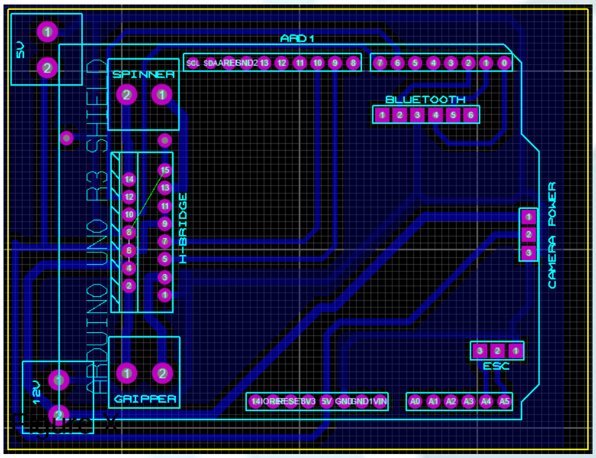

Figure 11. PCB custom shield for Galileo

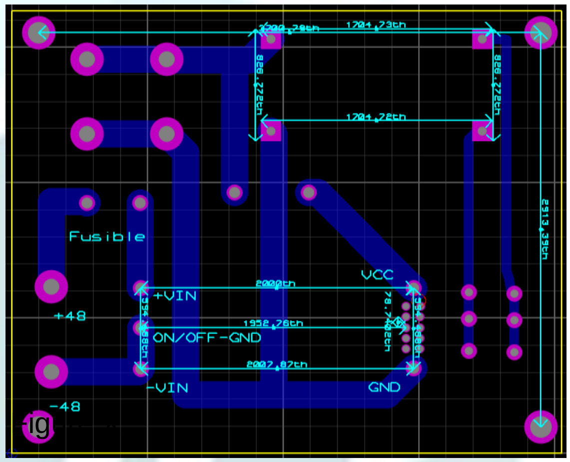

Figure 12. PCB for power module

Control
To control the ROV, we use a Thrustmaster T-Flight Hotas X Flight that has high precision and provides an efficient way to control the ROV.
Tether
The tether is composed by 1 Ethernet cable, one power cable and one data cable for the cameras. This cables were united by plastic strips, and every meter a floating device was implemented.

D. Software

Overall:
The system used to control the ROV was developed with a client-server architecture. So we can divide the ROV system into two parts. The server would be inside the ROV. And the

client which will be on the laptop, running a custom application to control the ROV. For software flowcharts, see Appendix A

Server:
The server is on the Intel Galileo Board that runs a Linux Operating System inside the ROV. The server system is a multiprocess program developed in C, which consists of three processes:

- **Communication:** This is the main process, here the server initialized and it will wait for the client to establish a connection. Once the client is connected to the server, it waits to receive a JavaScript Object Notation (JSON) string, which contains the values of the thrusters. Then it send it to the control process, and waits for the data acquisition process to send back information to the client.
- **Control:** This process receive the values of the thruster from the client and uses a PID controller in order to make smoother movements with the ROV.
- **Data acquisition**: this process read the information from the sensors inside the ROV including a barometric pressure sensor and an Inertial Measurement Unit (IMU 10-DOF) which includes a magnetometer, accelerometer a gyroscope. Then it send the data to the communication process.

Client:
We established the connection with the server using a web socket. By using a Joystick we receive the information needed in order to command the ROV what to do. The system is able to control the speed by getting the information of how far is the joystick being pushed. The client is also responsible of the management of the cameras, by pressing a button the pilot can switch views of the different cameras.

The client have this main functions:

- Get movement information from the joystick and send it to the server.
- Receive sensor data from the server and display it in the GUI.

Unity receives the data from the joystick and interprets it using a vector control algorithm. This algorithm is able to take the data and transform it into the necessary information to signal each motor what to do. The ROV counts with two driving modes: normal mode and exponential mode. The exponential mode is useful when the pilot needs to maneuver in closed spaces or make soft movements.

The ROV is capable of making a variety of movements depending in what direction the joystick is pushed.

Figure 13 shows the movements according each color.

RED: Forward and backward
BLUE: Turns on its axis.
BLACK: Wide turns.

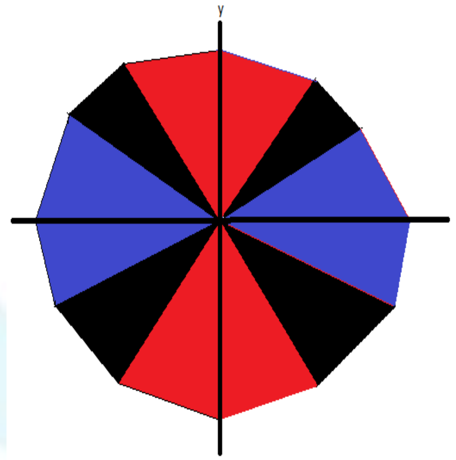

Figure 13. Color indicators for each movement of the ROV.

Figure 14. Joystick buttons

Figure 15. Joystick buttons

III. Safety

A. Company Safety Philosophy

For TecXotic, safety is a core value and it is an intrinsic belief that dictates our actions in any circumstance. Our focus is not only prevent accidents, but to improve the process under which we operate. We believe that an active and effective accident prevention and safety program is an integral part of the construction process providing not only a safe work environment for employees but a safe environment to flora and fauna surrounding the ROV.

B. Job Safety Analysis

The Figures 16, 17 and 18, show the job safety analysis forms of the experience launching the ROV, laser cutting, and the ROV maintenance respectively.

TECXOTIC	Job Safety Analysis Form	
Safety information for TecXotic -Monterrey Institute of Technology and Higher Education- Morelos, Mexico	**Task:**	LAUNCH/RETRIEVE ROV
	Name of Department:	Safety Office/Pilot Team
	Analyzed by:	Kim Marilú Yáñez Pérez
	Date:	05/20/2017

Required Personal Protective Equipment:	
1. Two or more operators 2. Life jacket	3. Non-slip, closed shoes 4. Sun protection (when necessary)

Required/Recommended Trainings:
Experience launching/ retrieving the ROV.

TASK	HAZARDS	CONTROLS
Pre-launch	Falling	Wear the required non-slip footwear. Inspect pool area for hazards before launching the ROV. One of the operators must always have a hand on the tether.
	Electric shock	1. Verify all power in Control Unit is off 2. Verify electronic box is sealed 3. Ensure all tools are appropriately guarded an electrical appliances are protected by means 4. Ensure all extension cords are in a safe condition with plugs and connections properly wired.
	Back strain	1. Kneel down. 2. Stay low and near to pool edge 3. Avoid sharp twisting movements and do not over reach for ROV.
Launch and Retrieval	Finger Damage	Make sure thrusters are disabled and/or power is shut off to the vehicle before putting hands and fingers near thrusters.
	Drowning	Never launch alone. Ensure all personnel wears a life jacket near pool.
	Sunburn	Sunhat / sunglasses / sunscreen / protective clothing
	Electric shock	If leak is detected, immediately cut power to TCU.

Figure 16. JSA of the launch/retrieve of the ROV

TECXOTIC	Job Safety Analysis Form		
Safety information for TecXotic -Monterrey Institute of Technology and Higher Education- Morelos, Mexico	Task:	OPERATE ACRYLIC LASER CUTTER	
	Name of Department:	Safety Office	
	Analyzed by:	Kim Marilú Yáñez Pérez	
	Date:	05/20/2017	
Required Personal Protective Equipment:			
1. Protective glasses, ocular protection is mandatory 2. Gloves (if available).	3. Extinguisher		
Required/Recommended Trainings:			
Tutorial on laser cutting. Tutorial might be imparted by other members and/or experienced operators.			

TASK	HAZARDS	CONTROLS
Carrying acrylic items	Dropping	a) Do not overload b) Carry every acrylic item one at a time c) Operate with a co-worker
Cutting	Airborne particles	Do not inhale particles generated as a result of laser applications. May cause irritation to the respiratory track.
	Flammability	Operate device ONLY within controlled and supervised environment. Extinguisher must be kept accessible.
	Electrical	1. Verify all electrical components. 2. Ensure all tools are appropriately guarded and electrical appliances are protected.
	Beam Emissions	Do not look directly to beam.

Figure 17. JSA for operating the acrylic laser cutter

TECXOTIC	Job Safety Analysis Form	
Safety information for TecXotic -Monterrey Institute of Technology and Higher Education- Morelos, Mexico	Task:	ROV MAINTENANCE
	Name of Department:	Safety Office
	Analyzed by:	Kim Marilú Yáñez Pérez
	Date:	05/20/2017
Required Personal Protective Equipment:		
1. Antistatic wristband		
Required/Recommended Trainings:		
Operator must be part of, or be supervised by, a member of the Electronics Department or the Manufacturing Department.		

TASK	HAZARDS	CONTROLS
Maintenance	Electric shock	1. Verify all power in Control Unit is off 2. Verify electronic box is dry. If not, proceed to dry it before unsealing it 3. Ensure all tools are appropriately guarded and electrical appliances are protected 4. Ensure all extension cords are in a safe condition with plugs and connections properly wired
	Finger Damage	Make sure thrusters are disabled and/or power is shut off to the vehicle before putting hands and fingers near thrusters Operator must wear protective gloves if thruster testing is needed

Figure 18. JSA for ROV maintenance

C. Vehicle's safety

The vehicle has a fuse box that goes from the power source to the robot. Before the energy reaches the robot, it will pass through this fuse box. This means that if power surges or if there is a short circuit, the fuse will be released to protect the entire system of the ROV, preventing it from being totally damaged and thereby saving the robot and a lot of money for repair costs.

In addition, the vehicle's safety features are not only focused on the ROV, but on the environment too. Balam's propellers are covered by a frame that protects marine flora and fauna from being harmed when they spin. Also, the ROV does not have any sharp edges and the material with which it is made-up is not toxic nor for the sea or for the personnel with direct contact with the ROV. Finally, Balam's fulfils all the basic safety features that the competition demands.

Furthermore, it is important to highlight that TecXotic's ROV is almost completely constructed with reused material, and advanced technological tools such as 3D printers.

IV. Logistics

A. Project costing

RE-USED MATERIALS FROM 2015 & 2016			
Qty	Description	USD	
15	3 wire hard use cable 12 AWG	$	31.23
4	Blue RoboticsT200 Thruster Preinstalled BlueESC	$	946.20
4	Blue RoboticsT100 Thruster Preinstalled BlueESC	$	756.20
1	Arduino Uno - R3	$	24.98
1	Intel® Galileo Gen 2	$	74.95
1	Laptop Alienware 15 r2 - core i5 6300hq / 2.3 ghz	$	2,924.48
1	Easy cap video capture	$	17.85
3	5MP Sensor Arducam Mini Camera Shield JPEG output for Arduino Mega256	$	215.23
1	Underwater camera Aqua-Vu AV 760CZi	$	299.99
15	UTP Wire (m)	$	13.38
15	RCA yelow cable	$	8.92
		$	**5,313.41**

Figure 19. Cost of the reused materials of the ROV

Qty	NEW MATERIALS FOR 2017 Description	USD
3	Afro 30A Race Sec Mini ESC (OPTO)	$ 61.39
1	Bar30 High-Resolution 300m Depth/Pressure	$ 112.77
1	SparkFun Logic Level Converter - Bi-Directional	$ 20.46
5	Turnigy Pure-Silicone Wire 16AWG 1m (Blue)	$ 89.49
5	Turnigy Pure-Silicone Wire 16AWG 1m (Orange)	$ 89.49
1	Blue Robotics Cast Acrylic Tube - 11.75", 298mm (4" Series)	$ 93.96
2	Blue Robotics O-Ring Flange (4" Series)	$ 100.92
1	Blue Robotics Dome End Cap (4" Series)	$ 102.66
1	Blue Robotics End Cap with 10 Holes (4" Series)	$ 41.76
1	Blue Robotics Enclosure Vent and Plug	$ 13.92
1	Blue Robotics Penetrator Wrench	$ 13.92
10	Blue RoboticsCable Penetrator for 6mm Cable	$ 139.20
2	Blue RoboticsCable Penetrator Blank (No Hole)	$ 27.84
4	Blue Robotics Cable Penetrator for 8mm Cable	$ 55.68
2	Blue Robotics O-Ring Set for Cable Penetrators	$ 10.15
3	Blue Robotics M200 Brushless Motor	$ 492.15
2	Blue Robotics Tether Cable Thimble	$ 20.41
1	Blue Robotics Vaccum Plug	$ 15.33
1	Blue Robotics Potting Kitt	$ 17.90
8	Afro Electronic Speed Controler (ESC) 30 AMP	$ 204.64
1	HotasX Thrustmaster Thrustmaster T.Flight Hotas X Joystick	$ 92.26
9	400 x 800 x 9 mm uncolored acrylic sheet	$ 155.26
9	400 x 800 x 6 mm uncolored acrylic sheet	$ 339.97
3	Loctite 0.85 fl. oz. Marine Epoxy	$ 17.85
4	HC-05 master-slave Bluetooth Module	$ 28.72
1	Digikey Isolated DC/DC Converter 500W 38-75Vin 12Vout N Log	$ 208.21
1	2017 MATE International ROV Competition - TEAMS - EXPLORER	$ 250.00
1	Aluminum bar 2 x 1/8 x 3.66	$ 17.67
1	Liter Epoxy resine with catalizer	$ 29.74
		$ 2,863.72

Qty	NEW MATERIALS FOR 2017 Description	USD
1	Shipping and aditional taxes	$ 150.00
	TOTAL AMOUNT	$ 8,327.13

Figure 20. Cost of the new materials for 2017 and total amount of the project.

B. Resource Administration and Management

In order to develop a proper activity plan for the whole team it was necessary to first talk it through with the leaders of each area. First we had to figure out how to solve last year problems, so that was the main task to work on. During this process the other areas of the project needed to advance as well, so the team met at the beginnings of August and discussed the main points for the making of ROV, this was also because most of the team members were not participating in previous competitions. Once everyone understood what is necessary to make an ROV in general, the team roles were assigned and the first tasks as well.

The whole project is planned to be done with the resources that the school provides, so it is very important that the team members learn how to use special equipment like a 3D printer, Laser cutting machine, Mill, PCB printer, among other. A effective way to achieve this was to use the experience of the team members that were in previous competitions or in advanced semesters and teach to the rest of the team how to use the main resources for the ROV making.

Once the main aspects were defined, and the competition brief was realised, the team work through on adapt the ROV into the competition needs, and solve the problems that were presenting during the project.

V. Conclusions

A. Description of challenges

Several problems were detected at the time of analysing the requirements for this year competition. First of all, the team had to figure out how to solve the problems that the last year ROV had, so the team analysed what the vehicle was lacking of and work with those aspects at the beginning of the design process.

The areas that needed improvement the most were the use of the ESC, the tools that the ROV were focused on the competition requirements and the user interface. Taking those aspects as starting points, working on them with the required time and work distribution and an accurate work plan, the team was able to go through the design process with the certainty that those areas work always in accordance as they were designed.

Solve the ESC problem was not easy, because in last year competence the ESC that were used tended to fail continuously, and despite of implement several methods to solve the problems like change the firmware or even chance the microcontroller, this components didn't work as they supposed to, so the team decided to change of components and implement instead of the typical kind of communication for the ESC that is pwm, the team decided to use I^2C communication.

B. Lessons learned and skills gained

The learning experience through the project was amazing a unique for each member of the team. Due to the variety of grades and majors of the team members, we were able to learn from each other not only technical skills and knowledge, but also how to deal with different personalities and working styles, and for this year competition the team consulted more about project managing and inner communication so everyone could know what each area was doing and how it was done, so the whole team could learn about each aspect of the ROV.

Change the microcontroller was a completely new experience, because most of the team member were used to deal only with Arduino microcontrollers, so learn the differences between the Arduino and the Intel Galileo microcontrollers was crucial if we wanted to use that the Intel Galileo has over the Arduino. In order to accomplish that the team had to investigate in different information sources and learn how to identify in an effective way the useful information to be later applied for the required needs.

C. Discussion of future improvements

At the time of making the first tests of the ROV in the water the team detected that the stability of the vehicle was not good. After analyse what was happening we went back to the first steps that were taken for the mechanical design of the ROV, and the team realized that the stability was not worked as an important aspect for the mechanical design, this was mainly because the team considered more important how the material was going to be used and how was going to be the distribution of the components that were going to be outside the waterproof enclosure.

So for future improvements the stability of the ROV is going to be a major aspect to work through, also because the team has the knowledge and the tools needed to design a stable structure that can allow the ROV to move easily across the water. Using software like Solid Works it is possible also to analyse the structure to find out where are located the main stress points so the ROV can be robust enough to deal with all the charges that can be applied in the competition.

D. Reflections on the experience

The MATE competition has been a great inspiration for all the TecXotic team members. To work in such a great project is a completely different experience compared to the work that is done in normal school projects. This overpases every other thing that is worked with the school purposes, because it is amazing to see gather a group of students from different careers working together with a single objective, to participate in an international competition where all their work can be used in a practical way.

From the beginning of the project to the end, the main thing that has been in our minds is to learn form each member of the team not only technical skills that can be useful for our professional development, but also through the way, we have built more than an ROV, the friendship that has been made between the team members can last more than any robot.

“This will be my second year participating in the MATE international competition, and i can surely say that is a experience that can’t be compared with nothing else I have known. What is like to start the ROV from scratch, till it has complete the first mission is something unbelievable to see. All those hours of hard work, and nights that we didn’t sleep got to a point in which you can breath and say we did it is one of the things that I will always of this project.

Now as CEO of this project I can say that the experience is completely different, because I feel more responsibility on this project. I have dedicated the mot of my time working in the

ROV, and even though there were some moments in which I felt like I was going down because of all the pressure, and lack of time for my other personal activities, now almost about to go to the international competition, I can say that everything was worth it.

My view in my career now is focused on doing more projects like this, so I will be able to learn more technical and social skill that I'm sure will be very helpful for everything that is going to come for the future" - Miguel Figueroa

VI. Acknowledgments

TecXotic ROV Team, would like to extend our sincerest gratitude to the following benefactors:

- Marine Advanced Technology Education Center
- Tecnológico de Monterrey Campus Cuernavaca and Director Ph. D. José Carlos Miranda - For being our alma mater, funding the ROV components, materials and all the support given to the team through all these months.
- Ing. David Garcáa Suarez - For being our mentor, for all the time he dedicated to being with us, his unconditional support to the team, energy, long nights working, knowledge and patience.
- Ph.D. Mónica Larre, Director of the Professional Division - For authorizing this project, allocate budget for the ROV costs, and her unconditional support
- 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.

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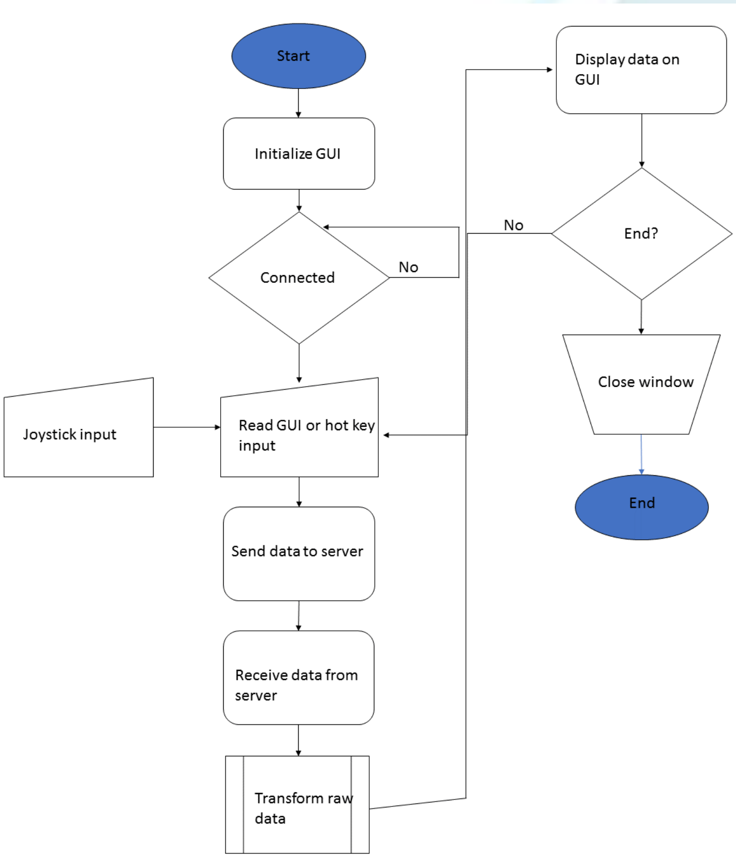
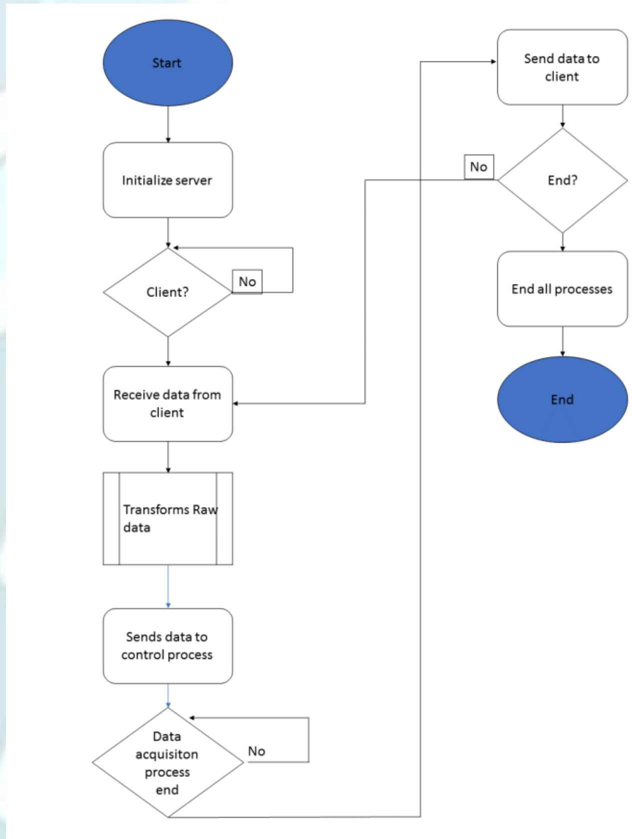
VIII. Appendices

A. Software Flowcharts

Client Flowchart



Communication



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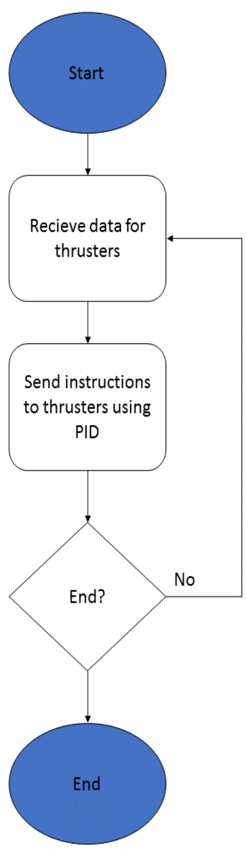

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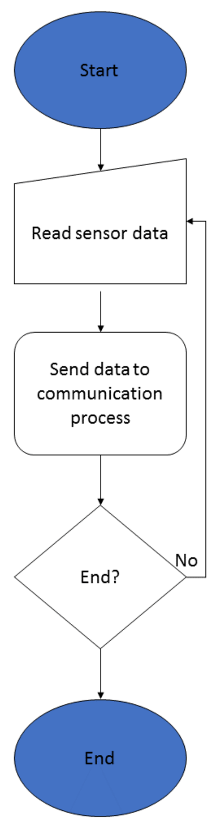

B. Operational and Safety Checklists

Pre-launch

- ❑ Area clear/safe (no tripping hazards, items in the way)
- ❑ Verify power switches and circuit breakers on TCU are off
- ❑ Tether flaked out on deck
- ❑ Tether connected and secured to ROV
- ❑ Tether strain relief connected to ROV
- ❑ Electronics WER sealed
- ❑ Visual inspection of electronics for damaged wires, loose connection
- ❑ Nuts tight on electronics WER
- ❑ Thrusters free from obstructions
- ❑ Power source connected to the 30 amp. fuse box

Power Up

- ❑ Power supplying 48 Volts nominal
- ❑ Control computers up and running
- ❑ Verify thrusters are working properly (joystick movements correspond with thruster activity)
- ❑ Verify video feeds

Launch

- ❑ Call “launch”
- ❑ Launch ROV, maintain hand hold
- ❑ Wait for release order

In Water

- ❑ Release air bubbles from buoyancy materials
- ❑ Visually inspect for water leaks
- ❑ If there are large bubbles, pull to surface immediately
- ❑ Engage thrusters and begin mission

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
- ❑ Washdown thrusters with deionized water