MATE CENTER ROV COMPETITION -2019

THE AQUAHOLIC

TECHNICAL REPORT

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ROBO - TECH , ALEXANDRIA - EGYPT

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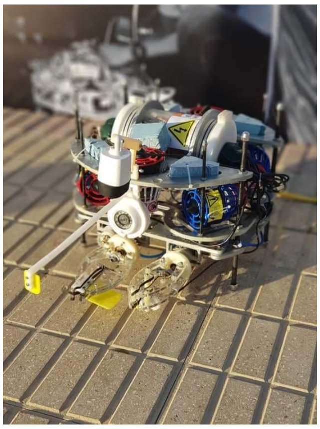
I. Abstract

In response to the request for a proposal released by Eastman Company for a Remotely-Operated Vehicle which can carry out numerous tasks in different conditions such as Ensuring public safety, maintaining healthy waterways, and preserving history Robo-Tech Company has decided to participate and design a Remotely-Operated Vehicle which is suitable for operating in confined and precarious circumstances. Robo-Tech is a marine company dedicated to the development and manufacturing of ROVs. The latest Remotely-Operated Vehicle from our company "The Aquaholic" was a difficult task to achieve as we split into four teams (Administrative, Electrical, Software, and Mechanical) to ensure our systematization, advancement, and fabrication of our product. The design was aimed at leaving free space to facilitate debugging and future improvements; moreover, the ROV's flexible design enables adding or removing any extra hardware or required software. We took into consideration the size and weight of the ROV to ease our mission. The software was developed and coded from scratch using C# and Arduino(IDE) allowing the user swift correction of any error. Electronics were assembled, modified, and tested extensively to ensure system stability. The safety for the environment and people is a priority, so we made sure that safety labels have been added, the thrusters have been shrouded, all sharp edges have been smoothed, and electronics housing all the wiring was as compact as possible also, electronics system is protected from any unexpected current surges by adding a safety fuse. This report will show the technical information about mechanical design, software, and electronics as well as safety considerations and future improvements.



(Fig. 1: fully assembled Aquaholic)

(Fig. 2: Robo-Tech Co. The Aquaholic members)
from right to left (bottom row): Abdelrahman Ayman, Abanoub Hani, Zeyad Ahmed, Retaj Tarek, Somaya Yasser (Mentor), Rowan Ashraf, Sherry Sadek, Mark Adel, Pola Qulta, Mohamed Bahaa and Karem Ibrahim (Mentor)

II. Design Rationale

A. Design Evolution

It is our third consecutive to participate in MATE ROV competition and to provide this golden chance to a larger number of people; we accept new engineers every year. Moreover, encouraging developments and getting the best out of our people has always been a part of our company's vision and thus we have gone over previous designs in order to identify strengths to build on and weaknesses to avoid.

(Fig. 3: Design evolution of ROVs built by Robo-Tech)

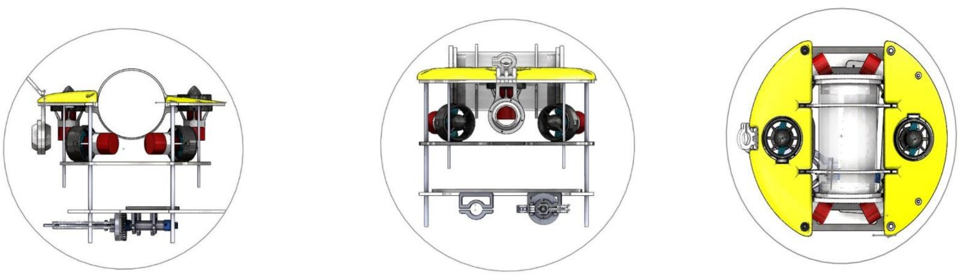
First, let's cover our first design, *The Golden Hind* and the problems that encountered us while developing it, we had two motors for up and down motion which were secured to the sides of the main frame, this made our ROV unable to perform useful maneuvering techniques. An Acrylic tube with a length of 25 cm was used as a control box that took too much space, as well as end caps that weighed in excess. The frame consisted of two vertical plates, which did not allow for adequate space to place the lateral motors within the confines of the frame and so those were offered no protection from collisions.

(Fig. 4: A free-hand sketch of Aquaholic during brainstorming)

Considering last year's ROV "*the Kraken*", the design of the lower plate wasn't sturdy enough and it had deformed after the competition, furthermore, the ROV's thrust capability and stability were compromised because of interference between the trajectory of the propelled water and the main plate.

The Aquaholic, however, has a Circular shape to use all the available space and to have a uniform plate, so that the thrusters maintain stability as well as help in stress distribution also, allow for water clearance. During our designing process, we were concerned about not exceeding 60 cm from all the projections and to make it weigh less than 15 kg in the air and to provide it with extra space for fixing the micro ROV.

(Fig. 5: Aquaholic fitting through 640 mm circles)



B. Frame

I. Design

We used Solidworks CAD to design our ROV, the design was aimed to let the motors work with the best efficiency and allow free space for propulsion, provide the pilot with full control, use the least parts, and have ample space for tools; in order to achieve that we designed a frame which is mainly composed of three plates: the upper plate is put horizontally, the up and down motors are secured to it vertically, and the control box is mounted in the middle to keep the ROV from flipping over by putting the center of buoyancy over the center of mass as it is our main source of flotation and it was fixed by crescent holders to have the ability to change and maintain the electronics easily. The lower and middle plates are secured horizontally by four vertical metallic bars. The four motors are attached to the middle plate, the arm is constrained on a slider to adjust its position. A moveable camera was constrained on the top to monitor the arm's movement while working on missions. Our ROV is 58 cm in height, 55 cm in width, 45cm in length, and 10 kg in the air

(Fig. 6: view of the frame)

II. Material Selection & Fabrication

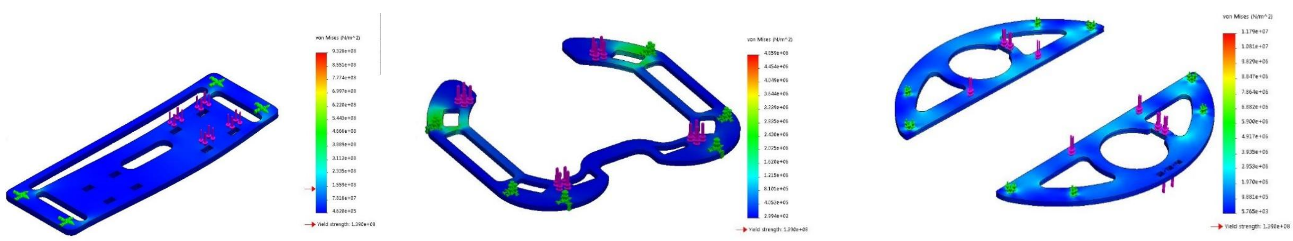
We have chosen Artilon (Polyethylene) in the frame due to its superior mechanical and physical properties, it is lightweight, durable, easily machined, and cut. We chose Acrylic for the arm because it is easily cut and shaped, fully transparent, lightweight, and strong, so it can be loaded with the missions, and carried weight. We took our designs to .the next stage using a CNC router, laser cutter, and a 3D printer

III. Drag

Drag is the force acting opposite to the relative motion of an object moving with respect to a surrounding fluid. While designing our ROV we have tried our best to minimize the drag force on the Vehicle to increase its velocity, hence, according to skin friction drag, we have selected the Polyethylene material due to its smoother surface, diminished friction and minified exposed surface to the fluid "water" according to the foam drag following the equation **Fd = ½ P v^2 Cd.** There are many options to reduce the drag force, first by selecting the round shape for our ROV to reduce the drag coefficient so that the drag coefficient is 0.45 and as we have mentioned, by minifying the surface area

IV. Finite Element Analysis

We were thinking about how can we check if our design will be stable and safe in the water or if deformation would occur. We taught ourselves Solidworks simulation tools that were hard on us but we were able to overcome this difficulty. We did a stress analysis for each plate in our design to evaluate the structural integrity of our design



(Fig. 7: Stress analysis result for all ROV Plates)

V. Buoyancy

The buoyancy force is the upward force exerted by the fluid on the body that immersed in order to compensate for the weight of the frame, electronic components, and the other components. A buoyancy foam seen in (Fig. 8) was selected, cut to shape and mounted on the top, the Acrylic tube provided us with a high Buoyancy force as well. Accordingly, this leads to a slightly positive overall buoyancy

(Fig. 8: Buoyancy foam)

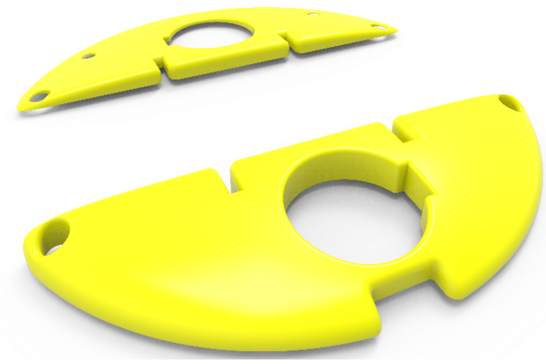
VI. Fiberglass

The main reasons why we made fiberglass:

1- To reduce skin friction drag by customizing the fiber to be very smooth and make the shape of the fiber as aerodynamic as possible

2- To make the shape of the aquaholic look better by covering the wires, electronics, and protecting the control tube. We also painted the fiberglass in yellow because it is easy to spot the Aquaholic in deep or unclean water

We used "NACA 0012 airfoil" as the profile for our fiber because we found it the lowest coefficient of drag possible.



(Fig. 9: Computer render showing Fiber Glass Design)

VII. Fabrication

For the fabrication of our mold, we used 2 pieces of MDF wood which were machined according to our requirements using a CNC router

VIII. Propulsion System

In our journey, this year to build a cheaper and a better ROV, after many comparisons between different motors we saw that the Blue Robotics T100 brushless motor thrusters seemed to be out of budget. So, we decided to hack a bilge pump with a 3D-printed part that was designed, tested, and printed by company members to use the T100 Kort Nozzle, This part is designed to make the flow smoother and streamlined through the Kort Nozzle. We used the modified bilge pumps from last year. The motors are constrained in a way to achieve all the possible motions and to preserve all the thrust and power, In order to achieve that the forward and backward thrusters are put in the 30° 60° angle configuration in the corners and the other two motors are put internally with an angle 180° for rotating.

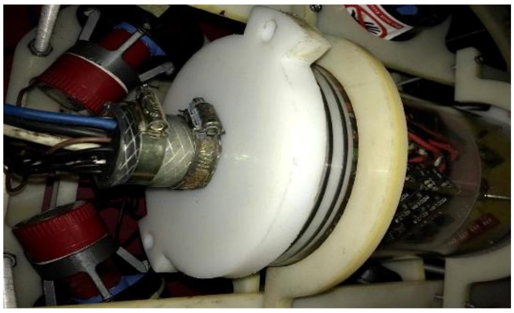
(Fig. 11: The modified bilge pump)

IX. Sealing

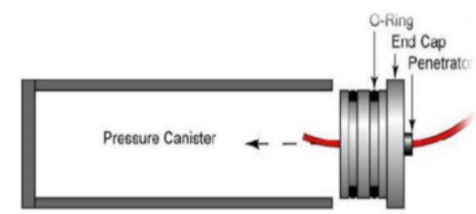
1.Acrylic Tube (Control Box Sealing)

We sealed the control box using 2 end caps each one of them has 2 O-rings, 1 of them is basic and the other is for safety. Both of them have only one hole to get all the wires in and out. We chose Polyethylene as the material for the caps as it is cheap, lightweight, and easy to machine.

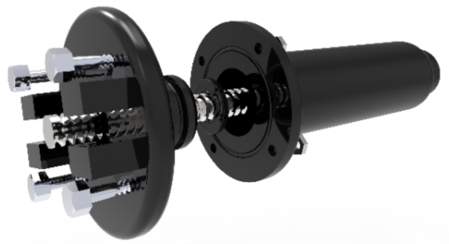
- Rubber O-rings
- Polyethylene for end caps
- Acrylic tube



(Fig. 12: Control box sealing)



(Fig. 13: Wires sealing)



(Fig. 14: Arm Housing sealing)

2.Arm Sealing

We seal the wire hole with an end cap. It is like a hose and inside it a perforated rubber, the wires get out from the holes in the rubber and we secure them with a hose clamp and behind the motor's shaft, we use an oil seal to prevent water from leaking inside

3.Cameras sealing

We bought pre-sealed cameras as they would save us time, effort, and money

(Fig. 15: Isolated Camera)

X. Vision System

In order to give our pilot, the best viewing angles for manipulators and surroundings we use three cameras, the first one is directed forward which helps the pilot in navigation. The other two cameras are directed to see the manipulators. These three cameras are connected to an amplifier seen in (Fig. 16) then to DVR to be displayed on the station's screen. We use Dahua DVR (Fig. 17) with the following specifications to get the output of the camera and show it on the screen and laptop.

- Type: HDCVR.
- Resolution: 720p.
- Video input: 4 channels.
- USB port: 2 ports.
- Power supply: 12v/1.5A.
- 1 HDMI

(Fig. 16: Amplifier)

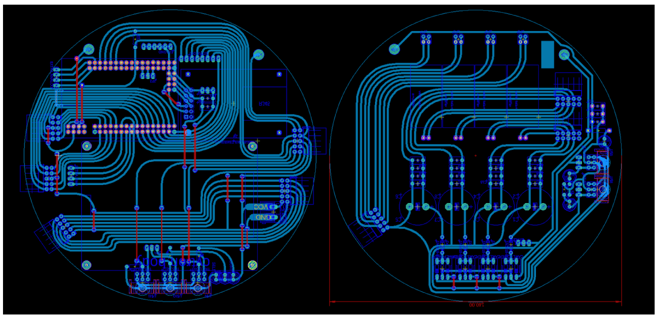
(Fig. 17: DVR)

XI. Electronics and Control

1. Motherboard (Onboard Circuit)

A) Circuit Layout

As we broaden our aim every year the amounts of tasks depending on the electrical side increases in return. This year our electrical team sustained two major problems one of them was the insufficient space that has forced us to create and design not one but two electric circuits which provide full control over the ROV's power distribution, display, and communication systems. Containing the following items as the main components:



(Fig. 18: The motherboard circuit via Eagle)

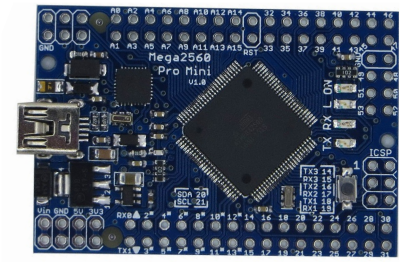
- An Arduino mega-mini development board
- 4 Cytron 10Amp DC Motor Drivers
- Power regulation system providing 5 and 9 volts
- Three N-channel Mosfet transistors
- SPI module for communication
- 4 Video balun amplifiers

All located on a relatively small footprint divided into 2 boards that are connected together using bolts, nuts, and spacers with a diameter of 140 mm. We used an Arduino mega-mini development board for not only its small size but also for its capabilities providing more digital and analog pins. The connectors are suited in one direction and fetched in parallel to simplify the overall flow of current. Extra analog and digital pins are supplied from the Arduino board to try and test new ideas and concepts. The tracks are adjusted to a specific width according to the rate of current flowing. Extra ground pin headers are used in urgent supply cases. Extra 5V and 9V pin headers are outputted from the two regulators as well, we used Eagle CAD in order to design our PCB.

Board Components:

- Arduino board

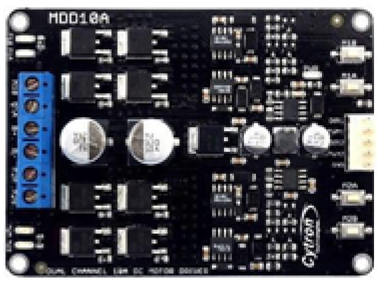
Our Mega-Mini board seen in (Fig. 19) is the Control Unit of the circuit as it overtakes several tasks. It is supplied by a 9 Voltage supply from the 9V regulator. It receives the pilot's signal as a concatenated string of data from the GUI software using the SPI protocol. It gathers the overall data and sends it back to the GUI software as a concatenated string of data with all the sensor readings and overall changes in the system.



(Fig. 19: Arduino Mega-Mini)

- DC Motor Drivers

The Cytron 10 Amps motor drivers control the motor's direction according to the received signals and controls the motor's speed according to the received PWM signal from the Arduino board seen in (Fig. 20). There are 4 motor drivers in total in the ROV controlling 6 Bilge pump motors and one DC motor.



(Fig. 20: The Cytron motor driver)

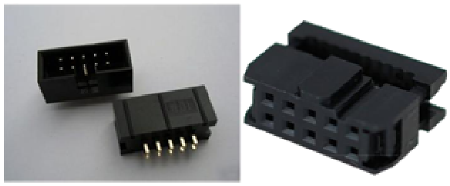
- ENC28j60 SPI Module

The ENC28j60 Ethernet Module seen in (Fig. 21) is a board that contains an Ethernet port and converts Ethernet input into SPI or (Serial Peripheral Interface). The board is based in on microchip’s ENC28j60 integrated circuit and it can be used to provide internet connectivity to microcontroller systems like Arduino boards over Ethernet. Since the board is small in size and it supports SPI interfacing protocol with very fast response to commands sent to the ROV and data received from the sensors.

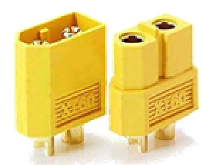
(Fig. 21: SPI Module)

- Pin Headers & Connectors

We used a pin header for all the external connections to the circuit due to their cheap price, efficiency, and durability. We use a variety of pin headers including double row male, female headers, and also IDC10 connector as seen in (Fig. 22). We also use XT60 connectors for delivering power to the circuit seen in (Fig. 23).



(Fig. 22: IDC-10 connector)



(Fig. 23: XT-60 Connector)

2. Tether

The tether consists of three main sections:

A) Pneumatic Hose

The Pneumatic Hose connects the compressor to the solenoid for transporting the pressurised air to the pneumatic arm.

B) Ethernet Cable

It was chosen to contain the camera's signal and the wires that transport signals between the onboard microcontroller and the main laptop on the station.

C) Power Cable (2 wires)

There are 2 x 6 mm copper wires that go along the length of the tether with different colors to eliminate confusion and protect from short circuits.

(Fig. 24: The Tether)

3. Station

We bought a Pro’s Kit case that fitted our required dimensions for the screen, DVR, a network switch, Power supply in which we arranged and put everything in place and secured everything with double sided tape and hot glue. Then we added our connectors and switches to ensure safety and to ease setting up our station for the trials

4. Power distribution

(Fig. 25: Voltage Regulator)

Our vehicle is powered by an external 12VDC power supply. The 12V output of the power supply is connected to the cameras, solenoids, and power pins of the motor drivers. As for the rest of our circuit, we used two linear voltage regulators. A 9V regulator was used to power the Arduino and a 5V one was used to power the sensors and spin module. The presence of those regulators ensures that the regulator on the Arduino board does not heat up significantly.

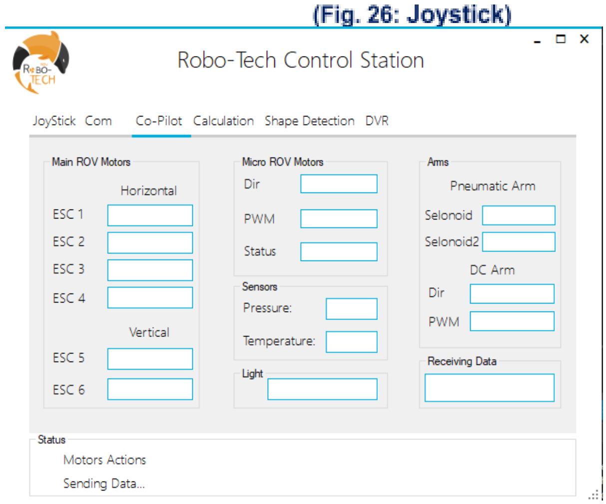
5. Control and Communication

(Fig. 26: Joystick)

Our ROV is controlled by The Extreme 3D Pro Joystick seen in (Fig. 26) which communicates to a C# application. The C# application maps the pilot movement of the joystick to numbers represent directions, speeds of motors, and other orders, then the C# program concatenates all data in a String and sends it to the motherboard controller (Arduino Mini Mega) using User Datagram Protocol (UDP) via Ethernet cable. UDP is then translated to SPI using the SPI module. The SPI module translates the UDP to the SPI that Arduino can understand. After the microcontroller receives data it starts to parse this data into values and write them on the motor drivers, lights, and pneumatic arm. We made the ROV controlling as simple and as straightforward as possible to make it easy to receive or send data and to ensure that the pilot would be able to drive efficiently.

6. Graphical User Interface

We have designed a user-friendly GUI written in C#, it provides full control and monitoring of our vehicle it has six tabs; each has a purpose. The GUI is one of the ways of viewing feedback from the ROV, it provides the stick position, the slider position, buttons conditions (Clicked or not), live monitoring of motors, communication success which is essential for the Co-pilot to help the pilot have good insight.

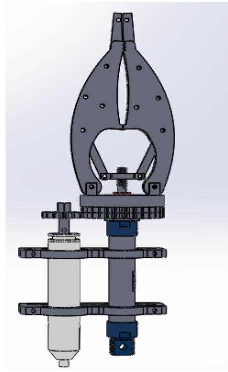


(Fig. 27: The Aquaholic's GUI)

XII. Mission Tools

After Brainstorming and lots of meetings we have come up with different ideas to match our needs. However, we were really concerned to make it as simple as we can. We started to design and test our ideas using CAD so we can start fabricating the most suitable ones.

1. Multifunctional Pneumatic Gripper



(Fig. 28: Pneumatic gripper)

Aquaholic is supplied with a multifunctional pneumatically driven claw rotated with a DC motor to provide it with an extra degree of freedom, help our pilot, ease the missions, and limit the usage of extensions. Its piston is controlled by 5/2 Solenoid to control the position of the stroke in both directions easily So in order to make it the most suitable, we have chosen:

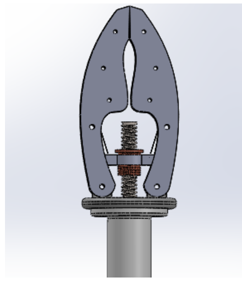
-Polyethylene for designing the base for its reliability, Strength, and as it is easily cut

-Acrylic for designing the end effectors to provide the pilot with a clear view.

- Our gripper mechanism was meant to have both angular and parallel opening and to open up to 17 cm wide to provide enough space for the pilot to pick up the mission objects easily. Thus, we have designed the end-effector to be extended as a link to control its movement directly with slots connected to the pneumatic piston through a laser cut part. It was deliberate to be three layers maximizing contact with the gripped object to 1.8 mm.

The middle layer in one side is premeditated so the door of the grout's mechanism can be attached to it. The end effector is designed to have two curves with different diameters in order to be able to complete most of the tasks and hold everything tightly

2. DC Gripper



(Fig. 29: DC Gripper)

We added a DC gripper to be in control of its opening speed and to save time as it will assist us on performing different tasks at the same time and provide us with the capability of adding extensions to it, so we can hold the fish in the second mission and to be capable of attaching the lift bag to lift the degraded tire and the canon.

3. Lift Bag

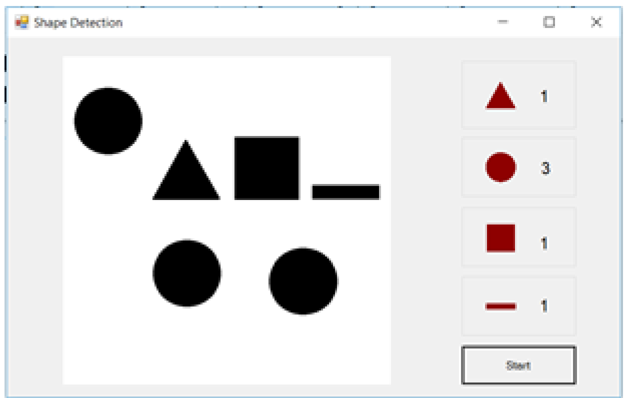
(Fig. 30: The Hook part)

The Mechanical Department designed a part that looks like a hook, The hook is secured to the lift bag using rope so that the pilot can easily attach the lift bag mechanism to the Canon. We also use a pneumatic system controlled by a 2/2 Solenoid valve for pumping the lift bag.

4. The Image Processing Algorithm

The Company's Software department developed its shape detection algorithm by implementing OpenCV (with the use of Emgu.CV-a.net wrapper- as to integrate it with our C# code). The code takes an input image from the DVR and using repeated Gaussian Pyramid decomposition and median blur unnecessary detail is removed, a Canny Edge detection algorithm is then applied to that image. Circles and lines are then scanned for using Hough Transform Functions. Following that, contours are scanned for and by using the ApproxPolyDP function on those contours, triangles, and squares are detected by counting the number of vertices of the function's output either 3 or 4, respectively. The count of each shape is then displayed in a simple GUI fig. (31)

So that it can be interpreted at a glance.



(Fig. 31: Computer program (Image Processing Algorithm)

5. Micro ROV

(Fig. 32: Computer render showing micro ROV design)

We thought of the most effective way to navigate through the 6-inch core pipe considering the appropriate specifications for it. Our company decided to use only one motor (T100 bilge) as for its effectiveness and to save as much space as possible while using rollers for smooth movement inside of the pipe. We also used twined Artelon and shaped it as desired to seal the camera and flashlight. The Artelon is closed from one end and sealed with gasket sealer from the other end using acrylic to provide a clear image.

XIII. Safety

From day one and the rule "Safety First" is held in our minds, we have been thinking day after the other in our company how to make our work environment safe and make sure that no accident whatever may happen of course that seems to be un-imaginable but when you develop your safety protocols it may occur one day.

As we believe that safety starts from yourself, we started our training for the new members by putting some safety values that must be put in consideration during our project or else firm decisions are taken against those who broke any of these rules.

A. Safety Features

1. Self-Safety features

(Fig. 33: Mark Adel following Safety precautions While using a grinding wheel.)

As mentioned before, each member has to start by himself to make sure that there will exist no accidents aiming to make a safe environment of work. Safety protocols are the main value in our work so during work which are:

- During welding or using drillers you must wear glasses
- Using dry hands and tools and to stand on a dry surface while using electrical equipment.
- Company members must wear non-electrical conducting gloves, toed shoes, and safety glasses.
- Wearing special masks and gloves during dealing with chemical substances.
- First aid kit presents always.

2. Vehicle's safety features

After months of working on our project, we cannot let our achievement pass with any issue so our Mechanical and Electrical teams made sure that the safety conditions are applied to our project. We smoothed all sharp edges, covered the propellers with Kort Nozzles, put safety signs covers all over the ROV, pressure release valve, and regulators exist in the pneumatic system and finally capped nuts to exist at any end on any bolt.

Also, the Electrical team did his role, fuses are used all over the ROV and the tether to protect it from overcurrent also heat shrinks are used on the welded wire.

B. Testing protocol

Our company has a safety checklist to ensure that everything is done correctly before testing the ROV and we start with a dry test for the thrusters and all the ROV electrical and mechanical process to be sure that everything is working correctly before trying it underwater we have priority of checking we start with the power supply then the pressure of the compressor to be sure that all the members of the company are safe.

C. Safety Checklist

Tether connected to the ROV.	√
Check if the cables are securely fastened to the frame.	√
All electrical components are properly sealed.	√
Check the 12v from the power supply with a multimeter	√
Check fuse.	√
Ensure the pressure release valve is closed tightly and the protection cap is secured.	√
Check camera’s positions	√
Check current.	√
Thrusters and propellers are properly attached.	√
Service, transport or handling of ROV must be performed by at least 2 company members.	√
No exposed wires.	√
Thrusters operating smoothly with no latency in response	√
Check the buoyancy.	√
Check for any signs of leakage (Bubbles, loose fittings or broken parts)	√

D. Operational Checklist

BEFORE MISSION RUN

- **Set station box and run the ROV system. Drag the arm slider and Fix it.**
- **Check for exposed wires or damage. Check sealing.**
- **Set compressor output 275 kPa. Check power supply output 12v. Check fuse.**
- **Test thrusters and cameras. Check pneumatic air lien.**
- **THE AQUAHOLIC READY FOR LAUNCH.**

LAUNCHING

- **Adjust the position of the Gripper camera and fix the Camera.**
- **Put the ROV in the water.**

END OF MISSION

- **Bring up ROV.**
- **Power off the ROV, Control box, and compressor. Stow tether securely.**

XIV. Conclusion

A. Build Vs. Buy

Our company has a lot of brilliant minds and creative thinkers that could make a solution literally pop out of the sky. For example, a T-100 thruster costs $120, which approximately is 2,124 L.E. As a result, we purchased the T-100's propeller and Kort Nozzle separately and installed on a bilge pump motor using a 3D-printed extension designed by our mechanical team. Moreover, we manufacture our own PCBs. Not only this but also, several components were still in a perfect condition such as a tether, motors, and motor driver. Further, certain components needed to be purchased ready-made as the hand-made version will not be efficient.

B. New Vs. Reused

We are working hard every year to save money by using parts from our last ROV and that does not mean that we are not eager to innovate and develop more effective and efficient systems for both the mechanical and electrical parts of our ROV, we did not disassemble our last ROV because we are using it for teaching others. The parts we used from our last ROVs are our Bilge pumps, T100 Nozzles, Propellers, DVR, Cat6 Cable, Motor drivers, and Cameras as they are lightly used and still maintain the same quality. we made a new Station Box with high efficiency it has a monitor screen that receives its signal from the Cameras that are connected to DVR, we also made it easy to connect/remove the connections and cables.

C. Budget

	Item	QTY	Amount	Total
Income	**Members' dues**	**9**	**165$**	**1,485$**
	Sponsorship	**---**	**1,156$**	**1,156$**
		Total Income		**2,641$**

	Item	Amount
Operation Expenses	**ROV Components**	**871$**
	T-Shirt	**62$**
	CNC	**115$**
	Pool Rent	**462$**
	Local Registration Fees	**150$**
	Regional Registration Fees	**300$**
	Total Expenses	**1,960$**

Category	Expense	New\re-use	Source/Note	Unit Price	QTY	Total
Mechanical	Acrylic tube	Re-use	Putting every electronic component Inside it	$22	1	$22
	Sheet Polyethylene	New	Used for making the vehicle frame	**86$**	----	86$
	Frame cutting	-------	(CNC) laser cutter	**115$**	----	115$
	T100 nozzle	Re-use	Used as a guard for safety precautions	$17	6	$102
	propellers	Re-use	Used for vehicle movement	$2	6	$16
	O-Ring	New	Used for sealing	$0.5	10	$5
	Acrylic tube sealing	Re-use	Sealing electronic components by two caps	$26	2	$52
	Balance system	New	Used: foam and weights	$3	2	$6
	Bolts and nuts	New	Used for holding the arm and frame	$0.5	40	$20
	Station box	New	Used to control the ROV	$173	1	$173
	5/2 solenoid valve	New	Used for control the pneumatic gripper	$8	1	$8
	2/2 solenoid valve	Re-use	Used to control the lift bag air	$8	1	$8
	double acting cylinder	New	Used for the pneumatic arm	$13	1	$13
	Fiberglass	New	USD to reduce drag	$86	1	$86
			Mechanics total		$712	
Electrical	Motherboard	New	Used for handling the ROV's system	$8	1	$8
	6mm Power	Re-use	Used for tether cable	0.5$	30m	15$
	CAT6 Cable	Re-use	Used for tether cable	0.5$	14m	7$
	Anderson Plugs	New		5$	1	5$
	Motor drivers	Re-use	Used for controlling motors	11$	6	66$
	Arduino Mega	Re-use	Used to control the electrical system	15$	1	15$
	Bilge pump	Re-use	Responsible for the thrusters Energy	9$	6	54$
	Dc motor	Re-use	Responsible for the Gripper movement	12$	1	12$
	Joystick	Re-use	Responsible for the ROV movement	45$	1	45$
	DVR	Re-use	Used to display cameras vision	15$	1	15$
	Dahua camera	Re-use	Responsible for the Visual view	10$	1	10$
	Dahua camera	New		11$	2	22$
			Electric total		274$	
			ROV total cost		986$	

XV. Training

Every year, our company announces training courses for people of all ages to increase their knowledge and acquire various skills including technical and non-technical skills as well as leadership skills. Our company's training course is lectured by our team members who are eager to help others in the pursuit of a better future. Participants are introduced to fundamental safety protocols in the presence of experienced members. New team members are chosen from the course according to their efforts to accomplish given tasks which are originated from previous lectures. Many different challenges are introduced in the training to see how attendees perform under pressure and how they face hardships. Also, presentation skills are introduced and practiced to ensure that new team members meet demanded qualifications.

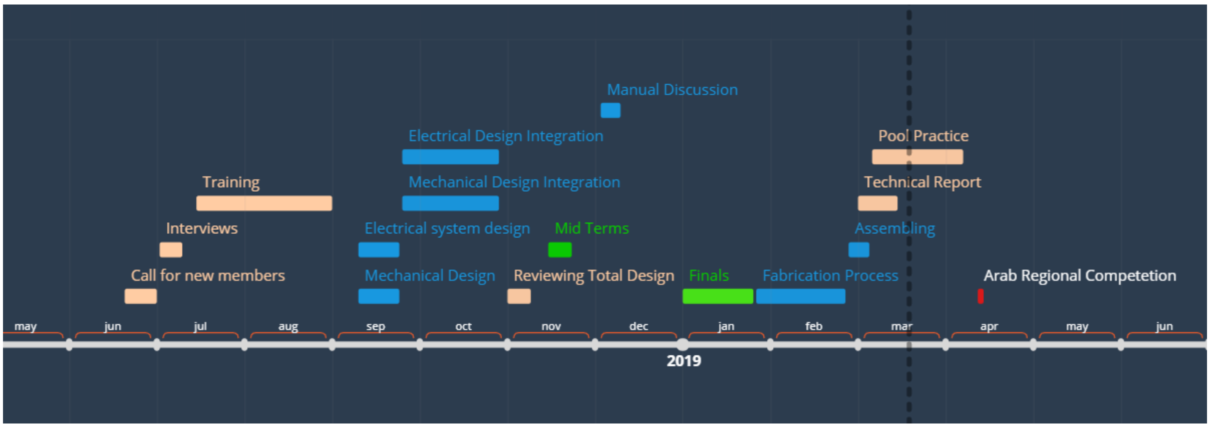
(Fig. 34: During Training Session)

XVI. Project Management

We have started working on Aquaholic we had put a well-planned timeline in order to accomplish the best possible outcome one month before the regional competition so that we would have enough time for testing, debugging, and modifying. Since the first day, the company rules were applied, the company CEO divided us into groups and each group has a leader as the CEO gives the tasks to groups and they distribute the tasks among them in a way which enhances each member's abilities to accomplish required tasks on time and to finish tasks faster and in a more effective way. We have followed a "Team Scoring Rules" to evaluate each member's work. Our CEO has set up two general meetings per week to assign weekly production goals, duties, and to discuss our working progress throughout the week. We had had our first meeting at the 13th of August 2018 to start the training for the new members and to strengthen our knowledge to take our company to a whole new level and We have finished our camp on the 10th of October 2018. Since then we put on our mind that we must all cooperate to finish our Initial and basic work before the start of January so we began meeting to put the baseline of things needed to make the design (e.g. Control box, Frame, etc...).

(Fig. 35: Job Assuagements)

Our To-Do list was shared with everyone to ensure that everyone would be productive and no tasks would be repeated. We planned to fabricate our design, motherboard, gripper, station, and tether in January, to work on missions' extensions and Technical documentation on February and finally to rehearse for the regional competition missions on March.



(Fig. 36: Timeline)

XVII. Troubleshooting Techniques

To ensure that we have a good technique to handle mistakes and errors in mechanical, electrical, and software departments whether from human non intended errors or technical ones in our very first meeting we have made a troubleshooting agreement to help us trace and take action to correct them. When a problem appears, we determine the affected or malfunctioned components of the ROV so we will be able to reach the exact cause of the error then we Identify the problem by testing and determining every possible thing the error can appear from then we try several things to solve the problem and take notes about the tried solutions and what was the best one.

We follow the following steps in solving problems:

-If we are having trouble with a specific piece of ROV hardware, such as motor doesn't work or any other component, an easy first step is to check all related cables to make sure they're properly connected.

-Follow the system checklist: in order to make sure that there is nothing missed.

-Define an action plan.

-Reboot and check if everything is working fine.

XVIII. Challenges

1.Technical Challenges

This year we encountered and overcame multiple technical challenges, which improved our skills and experiences. This year it was decided that we create a new frame. After weeks of designing, we have faced lots of problems in our initial design so we started all over again and made a different one. However, we thought of making it circular as this frame took advantage of the circular size Second challenge was in the design of the Gripper as we were trying to make the most possible missions with the gripper so We have made three grippers before settling on using this one as it is multifunctional, the Third challenge was in code this year as we are using a new communication protocol - SPI instead of Serial communication - between the station and the Arduino, the Fourth challenge we have faced is the Micro ROV and its docking as We have made many designs and settled a lot of meetings to solve all the possible issues and make it flexible, small, and good enough.

2.Non-Technical Challenges

A Major challenge We have faced was managing our time between Studying, Courses, and Working on ROV. Thus, We have been put under great pressure, However, We have managed this by putting a well-planned timeline and a daily schedule to ensure that We are managing our time perfectly and It was also hard for us to find fixed days to work across the week as everyone had his own duties and this affected negatively our Company but We have fixed Sunday and Thursday as General meetings to follow up on our working progress.

Lack of existence of some components in Egypt and the necessity of buying them abroad was really challenging as it takes a long time to deliver so, we have decided to order all the required components just as We started the new members Training so we have mostly handled this challenge this year.

XIX. Lessons Learned

1. Technical Lessons

Since most of our components were built from scratch, members had to deal with different materials, use different tools, and methods in fabrication and as there is only one chance in making lots of things as we have to be careful with our budget. The company has learned to be critical thinkers to expect every possible mistake before making anything and to check it with other members to get to know different points of view therefore along this line, company members have learned to be near with their overall work. Since the first day, we started our project and worked hard to get the best out of us by doing technical researches, applying laws of physics, developing our soft skills, and overcoming challenges. As a result, we have improved upon a variety of skills in mechanics, engineering, electronics, and programming as well as teamwork. It provides invaluable experience that in no way could be taught in school. Electrical Engineering; Arduino Programming, C# GUI Programming, and Circuits PCB Design. Mechanical Engineering; Solidworks, Manipulators Mechanics, and Pneumatic System.

2. Interpersonal Lessons

We have enhanced lots of non-technical skills throughout this year that would definitely help us in our lives, and our future plans, Such as our :

-Project Management Skills as putting a suitable schedule, and timeline. Handling different situations, and overcoming challenges have helped all the members to have a better mindset

- Communication Skills including (Presentation and Writing Skills), team working to make sure of reaching the company goal by cooperation, and being good listeners

- Critical Thinking and Crisis Management as handling challenges, and solving different issues has helped us to be more responsible, more efficient, and enhanced our critical thinking.

-Time Management and Self-Learning as we have self-learned lots of things. We were patient and persistent in our working progress to have a perfect output.

XX. Future Improvements

1. In the Electrical Section:

The company has always tried to minimize the whole ROV and a very big part of that is the control tube that houses all the electronics so that is a goal we aim to achieve, which forces us to use better and newer technology like a better microcontroller that would also enable more key features in the future like a PID or less latency or even onboard image processing which would save us a hustle.

A very important improvement is using different motors, smaller ones which would dramatically decrease the size, and weight of our overall product. It's preferable to use better cameras in order to enhance our vision underwater with better viewing angles and night vision.

2. In the Mechanical Section:

We want to use a dome instead of a tube to minimize the drag, make the overall look more professional, and also shrink the air volume inside the control unit. Also, we want to change the material of the body of the ROV to be Aluminum instead of Artelon because Aluminum is stronger.

Better manufacturing techniques are a goal we aim to achieve to give us more control over what we have which in return would benefit us greatly.

XXI. Reflections

"Participating in MATE competition for the third consecutive year has enabled me to grow significantly because of the countless challenges and obstacles that arose. However, I was able to gain ample technical skills, such as troubleshooting. As a result, the non-technical accomplishments that I gained this year were the most valuable thing I learned." **-Mark Adel, CEO.**

"My participation in Robo-Tech Company has provided lessons of leadership and cooperation, as well as the knowledge that will be of great benefit to my career. I have gained technical skills and experience in mechanical design, CAD software, and manufacturing. As well as non-technical skills including team working and presentation skills. Working experimentally, testing material, and choosing which to use based on the mission requirements have been very fruitful and exciting. **" -Abdelrahman Ayman, Mechanical Department Leader.**

"Being a part of Robo-Tech company as a Mechanical engineer for the second year has been an experience that I will always treasure. With a year of experience backing me up, I reflected on last year's problems and I focused on avoiding them this year.
Day by day my Technical and non-technical skills have been getting better. " - **Retag Tarek, Mechanical Engineer, CFO.**

XXII. Acknowledgment

We would like to express our very great appreciation to the following benefactors:

Eng. Youssef Abdelfattah: for his assistance and supporting us with technical/non-technical knowledge

MATE Center: for providing us with this golden opportunity which allowed us to expand our knowledge and apply it

AAST: for allowing using the academy pool

We are all grateful for **our parents** without the inspiration and support they gave to us we wouldn't be what we are today

Track Co-Working Space: for providing us with a suitable atmosphere to work in

XXIII. References

• **Books:**

-The Art of Electronics by Paul Horowitz, Winfield Hill
-Learning OpenCV: Computer Vision with the OpenCV Library
-Underwater Robotics Science, Design, and Fabrication by MATE
-Arduino Cookbook by Michael Margolis. / Head First C# by Andrew Stellman. / Modelling and control of Robot Manipulators by Lorenzo Sciavicco, Bruno Siciliano

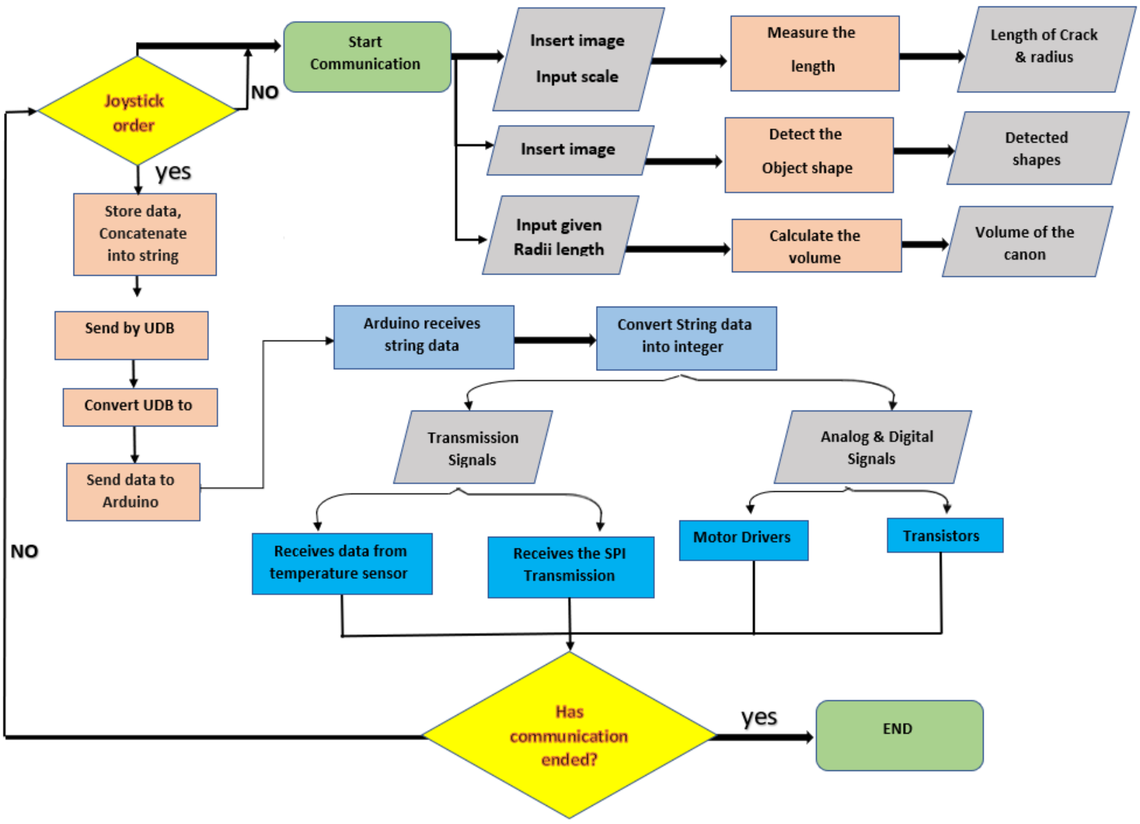
. **Online Courses**

Youtube | Solidworks Complete Learning Tutorials
Youtube | Arduino Lessons
Youtube | Tutorial Series for CadSoft Eagle
Youtube | C# Visual Studio Tutorials
OpenCV GitHub Wiki

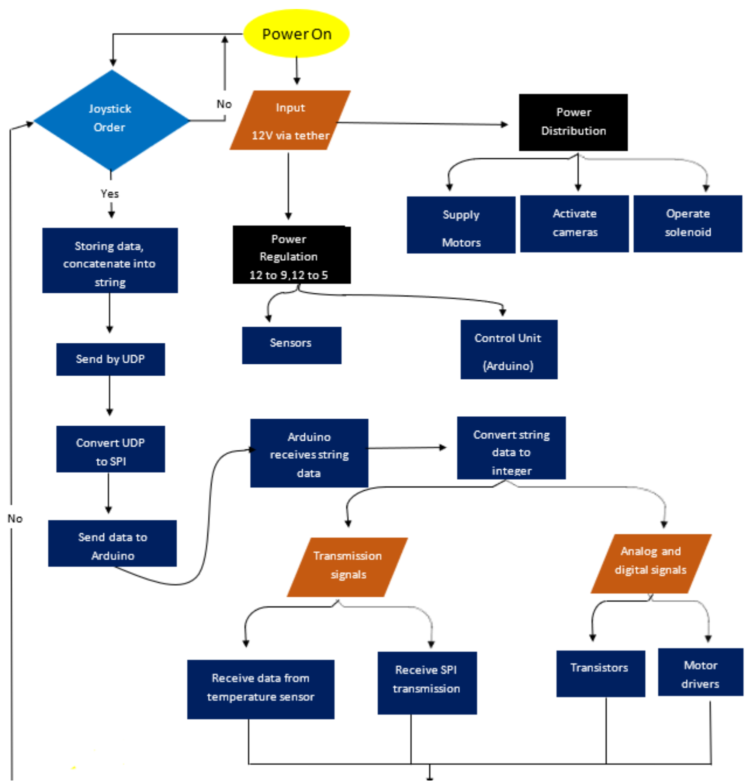
XVI. Appendices

A. Flowchart

1. Software Flowchart

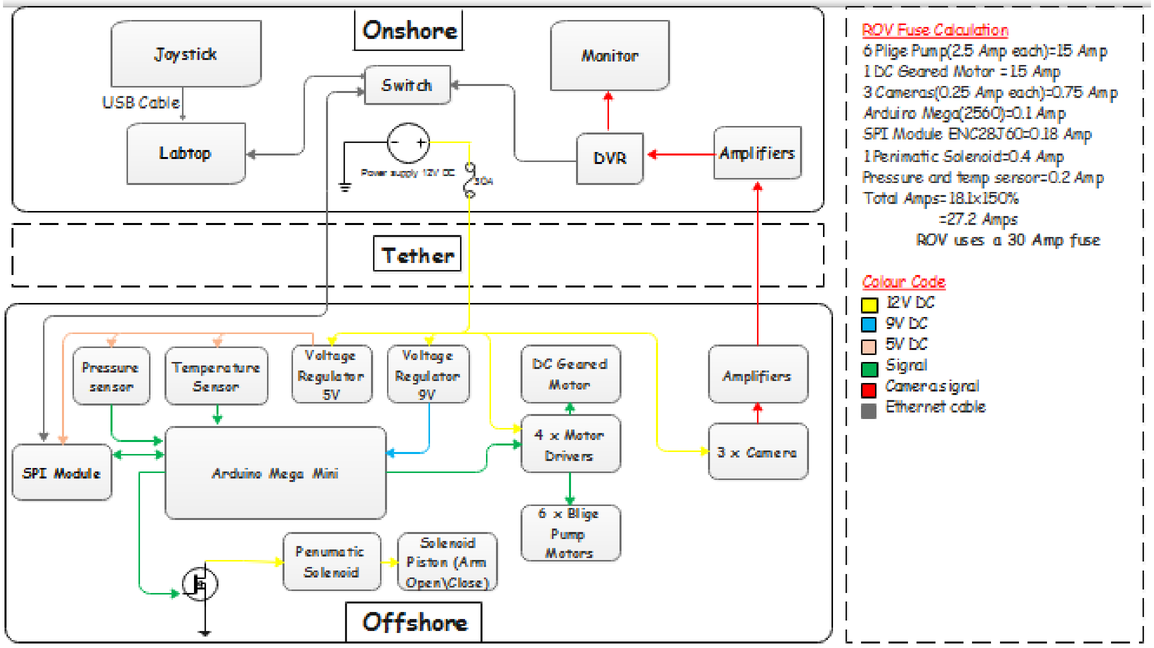


2. System Flowchart



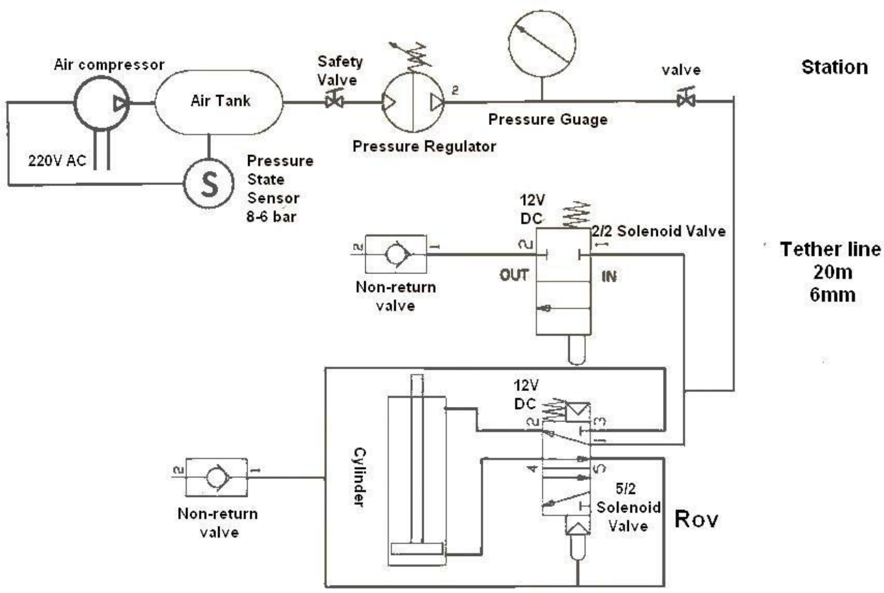
B. System Interconnection Diagram

1. Electrical System SID



C.

2. Pneumatic System SID



Pneumatic System Interconnection Diagram (SID)