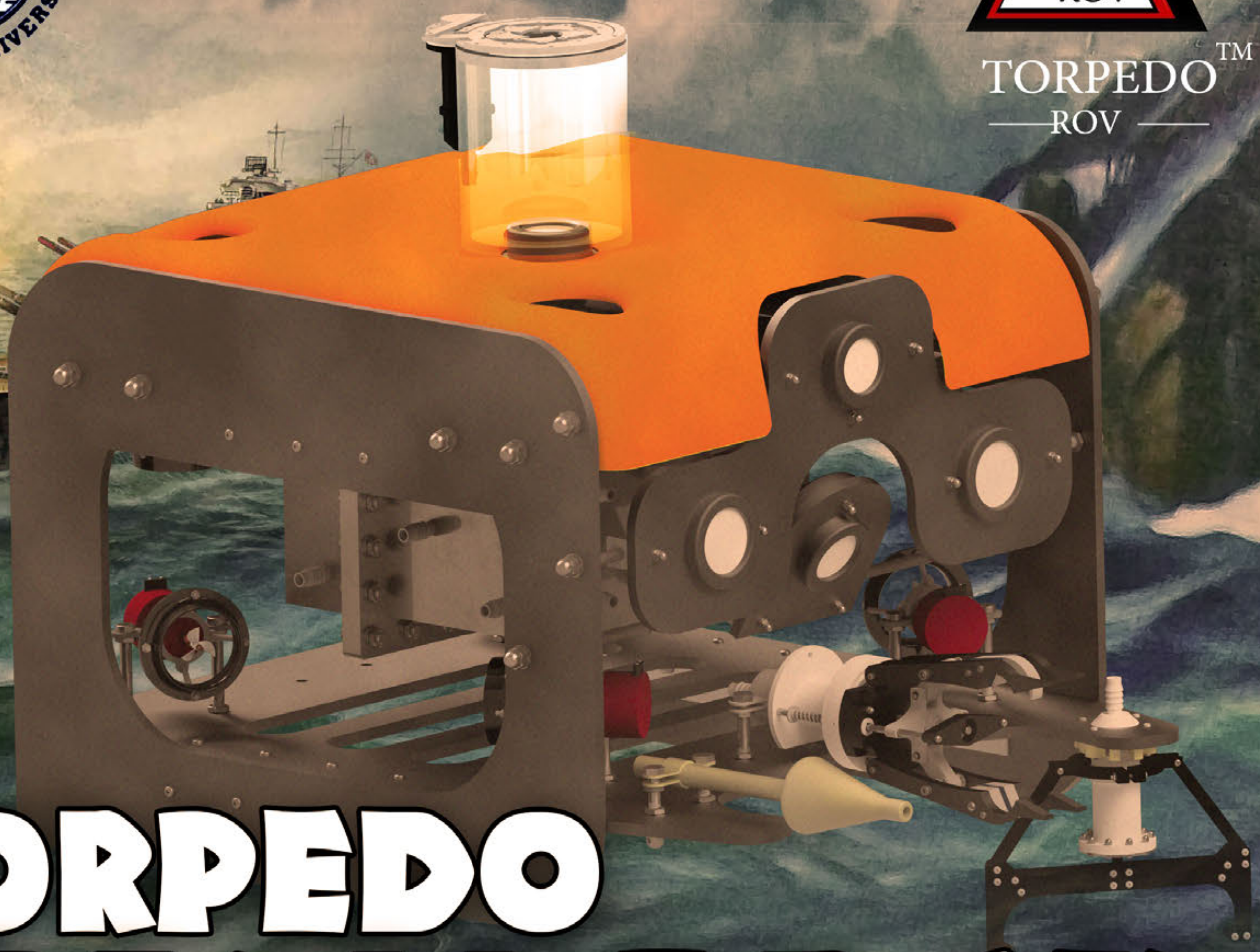
TORPEDO
ROV

TORPEDO™
ROV



TORPEDO BISMARCK

Company Members

Mohamed Mustafa Abusetta (CEO-'17)
Mohamed Yousry (CFO-'17)
Ahmed Hady (Mech. Team Leader-'16)
Saber Ashraf (Elec. Team Leader-'17)
Mahmoud Reda (Head of Manufacturing-'17)
Ahmed Mohamed Ibrahim (Pilot-'17)
Mahmoud Salah Salem (Pilot-'17)
Mohamed Moustafa Ahmed (Copilot-'17)
Mohamed Moubarak (Electronics-'17)
Mohamed Naser (Programmer-'17)
Ehab Abd ElRahman (CAD/Graphic Designer-'16)
Hamdy Dabos (CAD Designer-'16)
AbdulRahman Mohamed (Manufacturing-'17)

Superviser: Prof. / Kamel El Shorbagy
Mentor: Mahmoud G. Ali

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1.0 Abstract:

2014 Our company "**Torpedo**" has been established in order to contribute in the field of Robotics and mainly the industry improvement of marine vehicles (ROVs).

Although "**Torpedo**" is still a new comer to the field, all members are heavily experienced with previous robotics projects and solid mechatronics base. The company got wide variety of specializations as Mechanical, Electrical, Software, Naval and Industrial engineers in order to produce a reliable vehicle that can compete and perform the required tasks with high efficiency.

Concerning our Vehicle "**BISMARCK**"; its simple, modular design is the main advantage of our product that makes it able to be easily supervised & maintained. The vehicle is equipped with 8 Bilge 1100GPH to ensure efficient thrust and fast motion underwater. Also strong vision system makes the vehicle able to get a complete view over 3 faces (front, upward, downward) with the appropriate lighting system. All that in addition to different manipulation systems as well as payload tools that have been attached according to specific mission tasks.

"Teamwork" and "Responsibility taking" are the main aspects of our company members. Heavy Brainstorming took the major time in our schedule and after that came the design procedure. We used Solidworks as a 3D modelling and CAD tool. ANSYS FLUENT was our analysis & simulation tool to check for our design before machining process. The machining process was done using the latest techniques of Laser cutting, Routing & 3D printing to achieve the required design accurately.

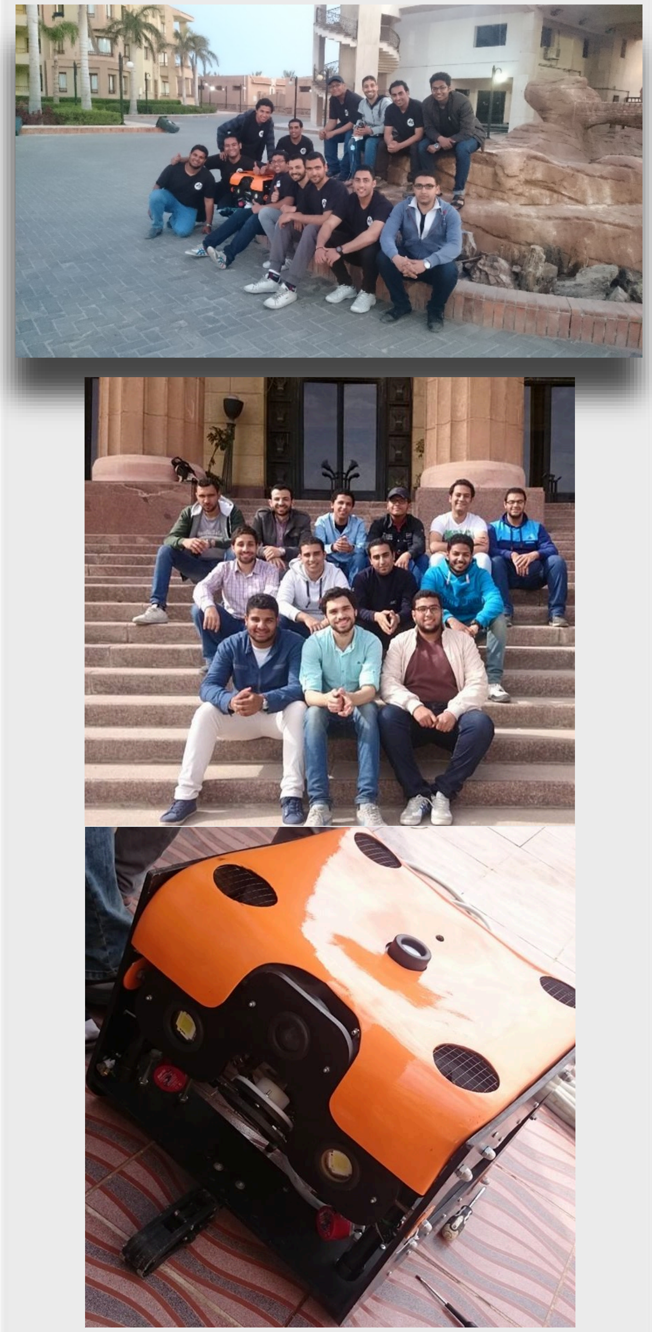


Figure [1] TORPEDO Company

2.0 Design Rational:

2.1 Frame

The frame is the basic structure that assembles all the vehicle components as electronics housing, cameras, lights, grippers…etc.

It provides the vehicle with the proper mechanical strength and durability. The projected frontal area is designed as minimum in order to ensure minimum drag with respect to its size .The hollow frame to make it light and easily carried. Also relatively large width allows better stability, more space for fixation and parts installment.

Figure [2] frame CAD design

It is necessary to note that a 3D CAD model for the entire vehicle has been designed using ***Solidworks***. Later on, we were strictly guided by the model in the manufacturing & fabrication process.

The bottom half of the frame is clear to enable unimpeded visibility for the pilot through downward looking cameras during the mission. All attachments are positioned on the lower frame for functionality and easy access for serviceability.

The machining process of the frame was done using computerized numerical control (CNC) Routing \ Milling machine.

Figure [3] Machined Frame parts

Material Selection

The main four sheets (2 sides, floor, and roof), are made of PA 6 polyamide (Artelon) allowing high degree of toughness, wear-resistance, low density and easy machining process.

- **Material properties:**
  - Modulus of Elasticity= 2620 MPa.
  - Yield Strength = 103 MPa (brittle).
  - Elongation at break = 2.5% / 5%.
  - Density = 1126 Kg/m³.

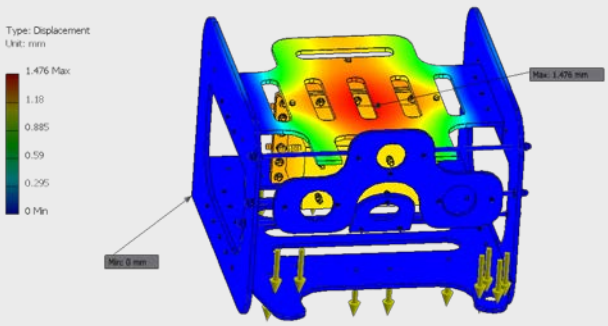


Figure [4]. Displacement of the frame when applying electronics housing weight as a maximum allowable force.

2.2 Thrusters

Eight in-house designed thrusters make up the propulsion system. There are 4 thrusters that provide motion in the horizontal plane and another 4 to provide the vertical motion.

- **Selection**

Amongst various thruster types, 8 Bilge pumps 1100GPH (12V – 60W) were used; providing good performance under high pressure, without consuming too much power.

We had the option of sealing motor manually which could offer a wider variety of technical features when purchasing the motor, in addition to the relatively lower cost. However, the main advantage for using bilge pumps is the already sealed-motors alongside the reasonable cost which would definitely reduce the time and effort needed for sealing as well as eliminating the probability of fabrication issues and leakage occurrence.

Figure [5] Bilge pump 1100 GPH

Propellers specs

3-blade Nylon propeller
Size: 40x55
Φ3/16" (4.8mm)

- **Arrangement**

In the horizontal plane, the 4 thrusters are arranged with an angle ***30-60*** degree in order to make advantage of the greater force component in the forward\reverse direction.

This arrangement of the 8 thrusters, allows the vehicle to maneuver in all directions.

Figure [6] Side view of Bismarck

- **Shrouding**

Thrusters have been shrouded using a kort nozzle with outer diameter 100mm & length 35mm.

After simulating the thrust using initial trials for different diameters and length, we observed that this design results in 6% additional axial thrust more than without shrouding. This design was set to be the final optimum design.

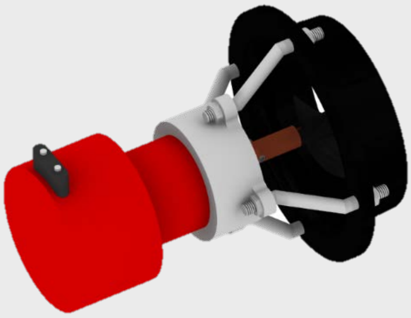


Figure [7] Propeller shrouding

2.3 Tether

Figure [8] Tether connection with electronics housing

Silicone hose with O.D 19.05mm (3/4 in.) is used as the tether to connect the vehicle with surface. Selection of tether material and size meets our requirements set for high elasticity and drag reduction, without hindering the vehicle's motion.

As to the connection of tether with the electronics housing, using stainless steel nozzle as a built-in *nipple* to connect with hose end resulted in no leakage. Further tightening the hose with a *worm-drive hose clamps,* ensured proper sealing with no leakage to the inside electronic components and hardware circuits.

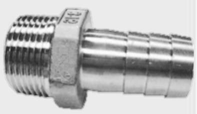


Figure [9] Worm-drive hose clamp & S.S Nipple

- **Cables**

Power cable

Electrical power cable (2*2 mm) for feeding our ROV with the required power

Size: 12 AWG • *Material: copper*

Length: 20 m • *Voltage drop: 4.17 V*

Communication

Category 6 Ethernet cable (Cat6 - figure) that provides lower crosstalk, a higher signal-to-noise ratio (SNR), was selected interact with the vehicle by sending and receiving signals.

Size: 24 AWG • Material: copper

Length: 20 m • Voltage drop: 0.84 V

Equation: $U_{\text{loss}} = 2 * \frac{(L * p * I)}{s}$, where

L = *length of cable*, p = *electrical resistivity of copper*, I = *current*, s = *a single core cross section area*.

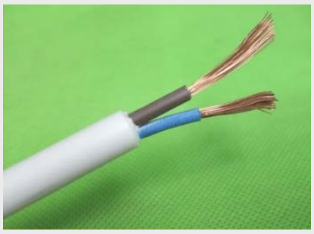


Figure [10] Power cable

Figure [11] Cat- 6 cable

- **Wire sealing**

For sealing the other end of wires to ensure no leakage, a creative rubber sealing was designed and used to only make the wires pass through very small holes and thus prevent any possible leakage to complete its path through the hose. We have to say the two rubber sealing have been used in each single hose connection.

2.4 Buoyancy & Balancing

With its wide shape, Bismarck got a very good stability performance underwater. Based on hydrostatic stability principles; placing floats above all the vehicle components in order to ensure that center of buoyancy remains above center of gravity. And as a result of both gravitational and buoyant forces, a restoring moment will be generated; allowing the vehicle to return back to its initial position. Thus providing better stability against any potential underwater disturbance.

- **<u>BISMARCK is slightly positive</u>**

In case of any hardware failure or the inability to communicate with the vehicle due to tether cutting, the vehicle will slightly rise upwards until reaching the surface.

By calculating the total dry weight of the vehicle and its volume, we were able to get the required volume for the floating material - Rigid polyurethane foam was selected – in order to make the buoyant force ranges 5 -10 % more than the actual weight.

- **<u>Technical specs.</u>**

- *Vehicle dry weight: 43.4 Kg*
- *Foam type: Rigid polyurethane*
- *Foam Density: 36 Kg/m^3*
- *Vehicle's Volume: 0.01853 cubic meters*
- *Required Foam Volume = 0.02715 cubic meters*

Figure [12] rigid polyurethane foam

- *Foam characteristics: environmental friendly, non-toxic, water and shock proof, good resistance against chemical corrosion, thermal insulation and antistatic.*

- **<u>Balancing the vehicle</u>**

The required volume of the foam sheet was applied above the top frame to achieve the slightly positive buoyancy. In order to compensate the non-symmetric arrangement of the vehicle components, a ballast system was applied in the four corners of the vehicle's frame for getting the center of gravity always in the middle.

N.B\ We achieved slightly positive buoyancy according to Archimedes principle between the total weight and the buoyancy force acting on our ROV (Weight slightly lower than acting buoyant force by 5%-10%).

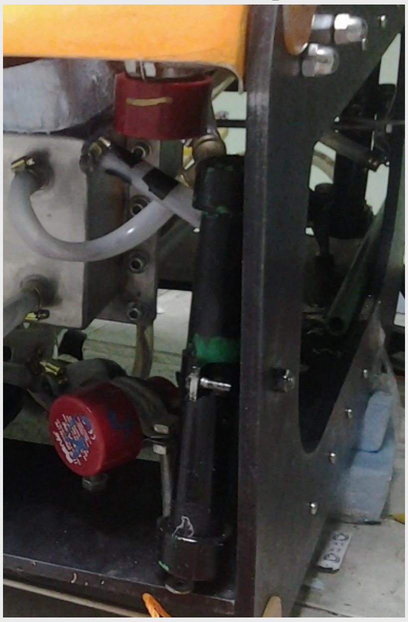


Figure [13] Creating Balancing system by adding ballasts to the vehicle corners

- **Fiberglass**

After installing the foam sheet, a layer of fiber glass was applied for giving more strength and pleasant shape.

Figure [14] Fiberglass CAD model

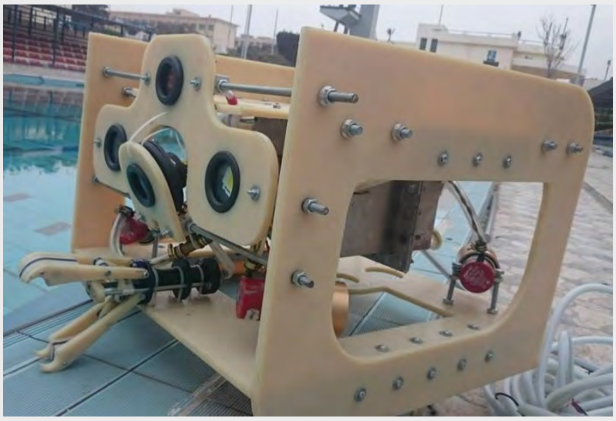


Figure [15] Initial assembly - Before applying Foam & Fiberglass

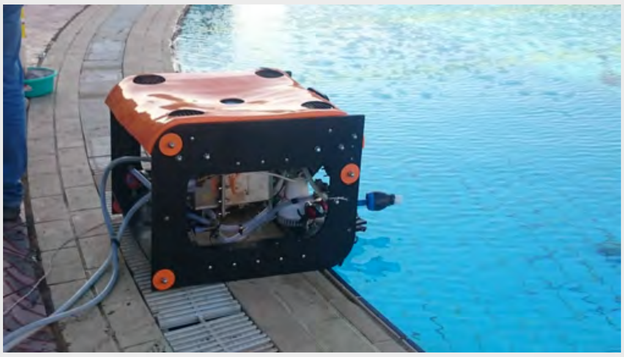


Figure [16] Final assembly - After applying Foam & Fiberglass

2.5 Electronics & Hardware

- **Power distribution**

At the beginning of work, we faced the fact that almost all the available electrical components and actuators that we -commercially- need will run under 12V Direct Current. And so with the available power supply that would be provided (48V Direct Current – 40Ampere fuse as a protection against maximum load), we set our priority on choosing a reliable converter that can withstand the vehicle's load allowing appropriate tolerance as well. After making a marketing survey and taking costing factor into our consideration, "SD-500L-12" *Mean Well* was selected as to be the reliable DC-DC Converter that meets the criteria set. It will be placed inside the electronics housing.

Figure [17] mean well converter

Specifications

INPUT:

- Voltage range 19~72V
- Efficiency 86%
- Current 12A/48VDC

OUTPUT:

- DC voltage 12V
- Current range 0~40A
- Rated power 480W
- Voltage adjust 11~15V

PROTECTION Methods:

- ***Over load*** **(105 ~ 125% rated output power):** Constant current limiting, shut down o/p voltage after about 5 sec., re-power on to recover
- ***Over voltage*** **(16 ~ 19V):** Shut down o/p voltage, re-power on to recover
- ***Over temperature*****:** Shut down o/p voltage, recovers automatically after temperature goes down

Current load table

Component	Max Current
12V thruster	**7A**
20W 12V LED	**1.67A**
12V camera	**1A**
Gripper motor	**1.5 A**
Arduino mega	**0.8A**

Maximum Load
Maximum Load results when using 4 thrusters, 2 lights, Arduino mega and 4 cams. Maximum current load consumed would be: 36.14A.

- **Mother board**

Our circuits are designed to simulate motherboards and RAM in computers in order to create more reliable electrical system rather than using the ordinary wiring method and suffering from the issues of high voltage drop, wire chucking in addition to bulky shape.

The board is divided into two symmetric parts with two terminal connectors to feed the circuit with power and act as a protection from high current.

An "Arduino mega" has been attached on the motherboard in order to control all the drivers & switches as well as sending feedbacks. Moreover, 10 motor drivers and 6 simple switches have been attached on the board to both control the vehicle motors, and switch on-off the pumps & lights respectively.

Figure [18] mother board

- **<u>Controller Board</u>**

The controller board is the brain of any robotic application. Concerning our vehicle, we preferred using the open source programmable micro-controller boards “ARDUINO” that demonstrated high efficiency with robotics applications. “Arduino mega 2560 kit” was selected as it has 54 digital input/output pins of which 15 can be used as PWM outputs, 16 analog inputs.

It receives orders from auxiliary control box and after that it controls all motor drivers through the mother board. It also receives signals from thruster driver boards as a feedback for motor status then sends this feedback signals to the auxiliary control box.

Figure [19] Arduino mega

- **<u>Motor drivers</u>**

Following the concept of simplicity and avoiding troubleshooting in noise and control, the motor drivers were designed as simple as possible. At first we used on-off motor drivers later on we improved them to speed control drivers.

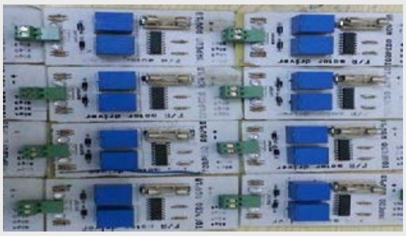


Figure [20] motor driver boards

The electronic components for the motor drivers are:
- *Two relays* to control motor rotation direction.
- *Uln2003* Integrated Circuit.
- *3 Pins*; two of them to control motor direction and the third one is Pulse Width Modulation to control the speed.
- "*TIP 142*" power transistor to create PWM for speed control.
- *Fuse 10A* to limit the current.

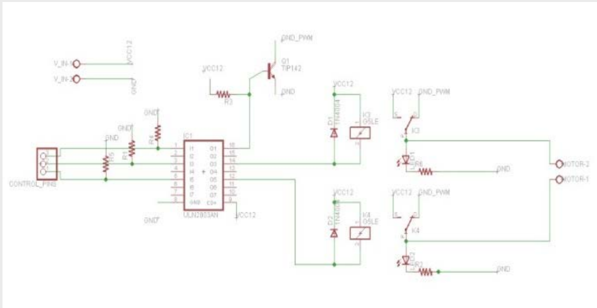


Figure [21] motor driver schematic design

- **<u>Electronics housing</u>**

Two rectangular cross-section halves are bolted together to act as the housing for all the electronic components and hardware circuits that controls the vehicle.

Figure [22] Electronics housing

We preferred this box-shaped design to allow unimpeded access to the electronics inside.

Also the components tend to be in a cuboidal form, allowing them being densely packed into a cuboid enclosure than using a typical cylindrical enclosure, minimizing the size of the housing.

Concerning water resistance, drag force can be neglected considering the relatively low vehicle's thrust.

Material Selection

Stainless steel sheets with 3mm thickness was selected to be the housing material. Providing high strength and corrosion resistance and above all the high thermal conductivity allowing better heat transfer for cooling the internal hardware circuits and the 500W converter.

Using finite element analysis to obtain a satisfactory result of 1.6 safety factor under the maximum depth of 9m and also maximum deflection of 0.6 mm.

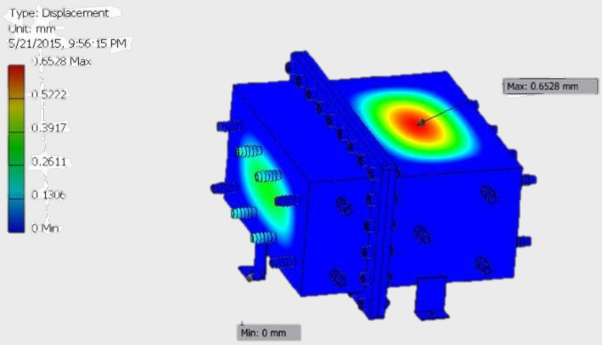


Figure [23] Safety factor under 9m depth

Assembly procedure and bolts arrangement was done following Shigley's standard for pressurized vessel. Eighteen M8 bolts were used and thus no leakage appeared under high deep water pressure.

Sealing

Sealing method was done using two layers of square gaskets; one inner layer added before the bolts and another layer added on the outer diameter in order to ensure better sealing. The result was no leakage at all.

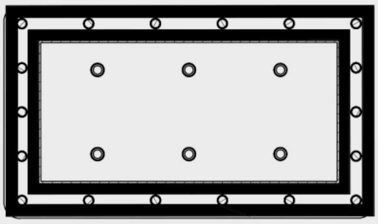


Figure [24] Inner & Outer Gaskets for proper sealing

2.6 Vision & Lighting system

- <u>**Cameras**</u>

Cameras are the main environmental interaction sensors that provide the vehicle with the ability to see the surroundings. Thus cameras should allow a complete surveillance underwater with a clear view for all the manipulators and payload tools to help the pilot better control of the vehicle.

Figure [25] CCTV camera

Four cameras were used; attaching them as one on the top surface (overhead camera), one on the bottom surface (bottom camera) and two on the front surface (forward camera and main gripper camera)

Selection

When selecting camera type we were governed by the following: *photo sensibility*, *viewing angle* and *size*. We have selected 4 different types which are CCTV "1/3"," SHARP 600TVL" (Sharp 2365 & Sharp 36B15).The fourth camera is a wide angle one to serve as the gripper's camera; providing a wide view for the pilot to better control the manipulators.

Manually designed housing for the cameras have replaced the original housing only for sealing purpose. We have to note also that the built-in night vision have been disabled as to the powerful lighting offered better performance in dark deep water.

Figure [26] Camera Housing

DVR

220V DVR 4 channels was used to connect the 4 cameras and show a complete view for with all of them together. The DVR provided the co-pilot with the ability to use a separate monitor for analyzing the data transmitted and processing the images received.

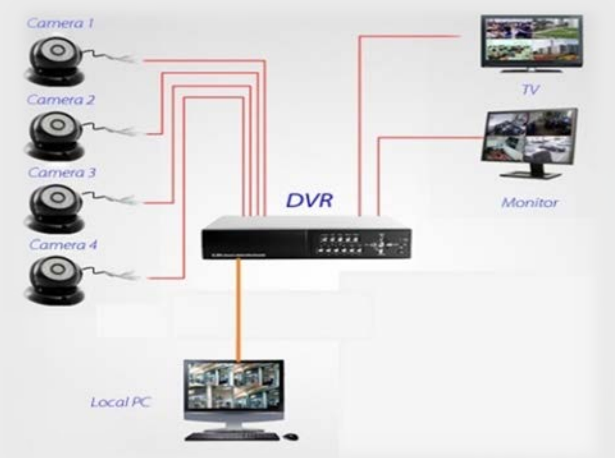


Figure [27] DVR connection

- **Lighting**

High power LED with 3000lm controlled by on-off driver, to be sure that the shortage of light, won't be a problem.

Our Lights have a 20Watt nominal power, use 12V input, so they use the source directly from the Meanwell DC-DC converter.

As to the relatively high power consumption, a heat sink has been used for heat transfer and in order to avoid reaching over-heating.

Figure [28] Lighting CAD and real housing

2.7 Main Gripper

Manipulation systems differ according to their required functions and design mechanisms. Bismarck got a powerful manipulation system acting as the vehicle's main gripper. Its modular design enables the maintenance team to manually fix the gripper with 90º rotation to flip between a horizontal or vertical end-effector according to the specified mission.

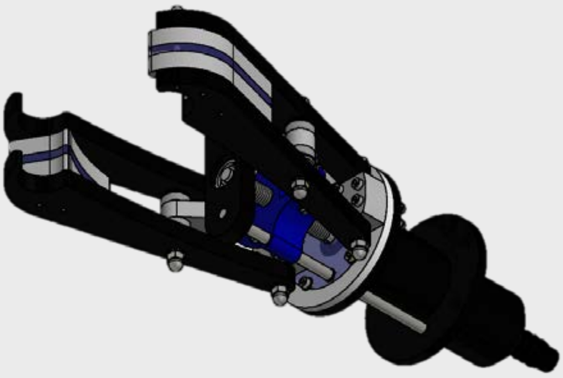


Figure [29] Main Gripper CAD model

This main gripper is supposed to be the vehicle's hand underwater, allowing the vehicle to easily handle tools; deploying sensors, attaching objects, collecting samples or even installing and removing components.

Based on power screw mechanism, simple motor rotation could totally open or close the hooky-shaped end effector. Providing better tightness with high torque during gripper's closure.

As to the design procedure, we preferred a simple 1 degree-of-freedom design that can perform the required main tasks efficiently, rather than using a complicated higher DOF gripper that consumes more time during maintenance.

For any additional tasks that seem difficult to be achieved, another special manipulators has been attached especially for performing these tasks.

- **Manufacturing**

Among materials diversity, polymer was the main used for the motor housing and end effector components; providing high strength to weight ratio. The machining process was done using milling, laser cutting & 3D printing.

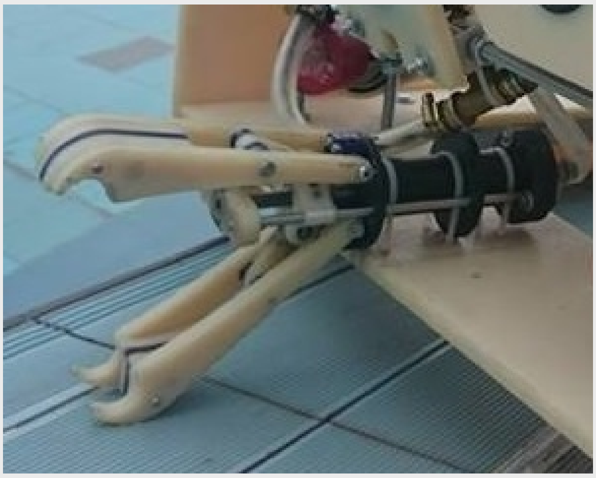


Figure [30] Main Gripper

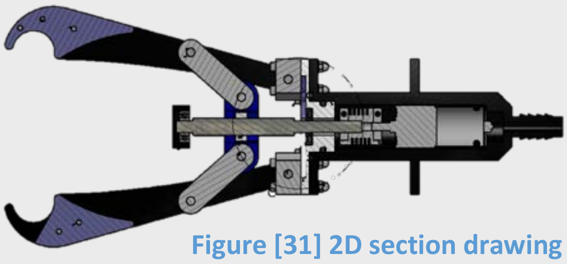


Figure [31] 2D section drawing

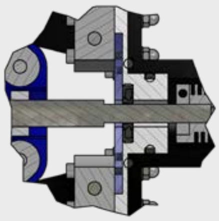
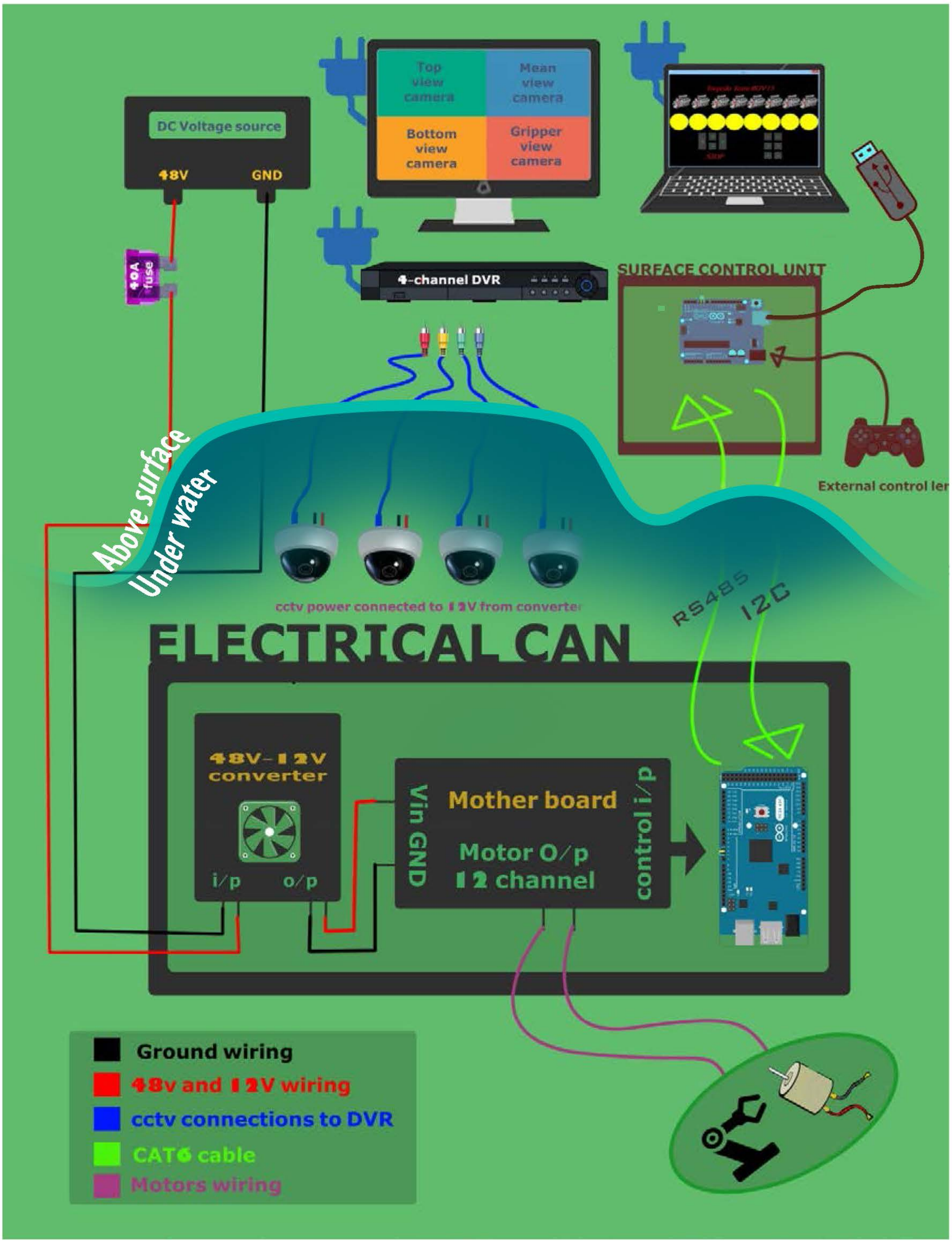


Figure [32] Closer look to sealing technique

3.0 System Interconnection Diagram (SID):



4.0 Software & Algorithm:

Bismarck is mainly controlled using laptop in which we preferred to use rather than using joysticks. This enabled us to overcome lack of buttons and limited functions that might occur in joysticks, in addition to the easiness of a laptop to be replaced in case of malfunction, using the laptop already available from any other member of the company. And thus reducing spare components and allowing better financial management.

Regarding software selection, we preferred using JAVA to be our professional open source coding tool. The company programmers set themselves to start building the company's own GUI; taking online courses and MOOCs as their guiding material.

The GUI program was used to control all the vehicle's actuators as well as switching on-off the lights. Moreover, we used a feedback signal to supervise the status of each motor and ensure that all actuators are typically in service.

Two Arduino KITs are used from which one is Arduino Mega inside the electronics box, and the other is Arduino Uno inside the auxiliary box above surface. For the used protocols, I2C & RS-485 were used as the communication protocols with programming the Arduino. They are specified as the following:

I2C: The two KITs are programmed to communicate with each other in a Master Reader/ Slave sender configuration; Via the I2C synchronous serial protocol.

The Master one is the *Arduino Uno* which is programmed to request, and then read, 6 bytes sent data from the uniquely addressed Slave *Arduino Mega*.

RS-485: a physical connection standard for Serial data transfer. RS485 uses a pair of wires in a differential configuration which allows long distance communication and very high speed. As a result, we used it between the two Arduino KITs as a Half-Duplex. This means it is able to send or receive within the same wires and only one direction at a time.

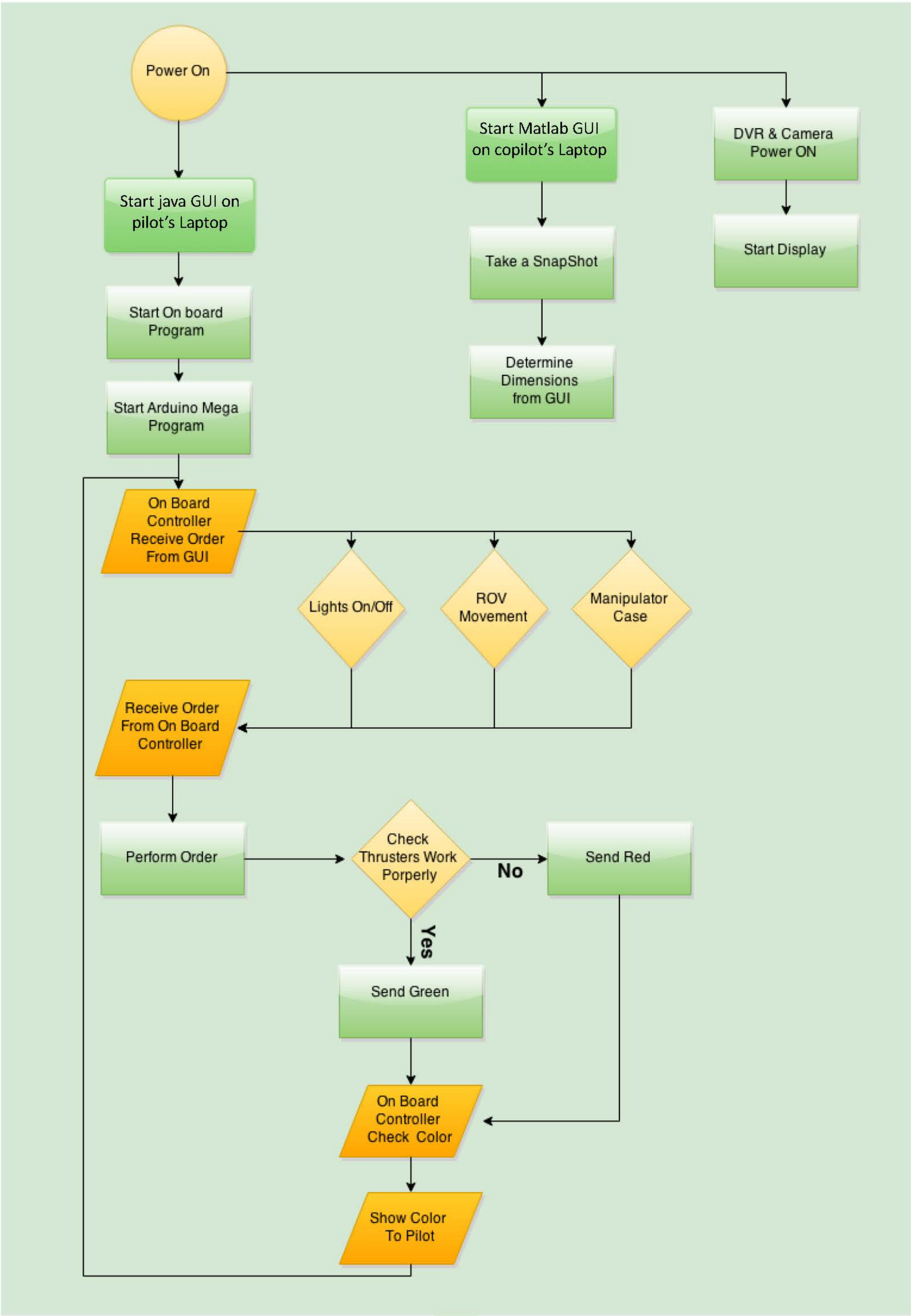
- **Auxiliary control box on surface**

It consists of:

-*Arduino Uno board* which receives signals from laptop/pc through serial port, and then sends it to Arduino mega using **I2C** communication protocol. It receives the feedback signal from mega using **RS-485 protocol** then it sends back to laptop/pc for status supervision on the GUI.

- *Switch* to control light (on and off).
-*Wires* from vision system (Underwater cameras) to laptops and TV monitors.

- **Software Flow Chart**



5.0 Special Features:

5.1 Image Processing

Image processing was selected to be our measuring technique underwater.

Preselected object has been fixed with a pre-known dimension to act as the measuring reference.

By analyzing the image pixels captured from the front main camera, and then using a MATLAB graphical user-interface (GUI) program to scale the captured image with the predefined distance between parallel pointers, and thus we were able to get the accurate dimensions for any components underwater.

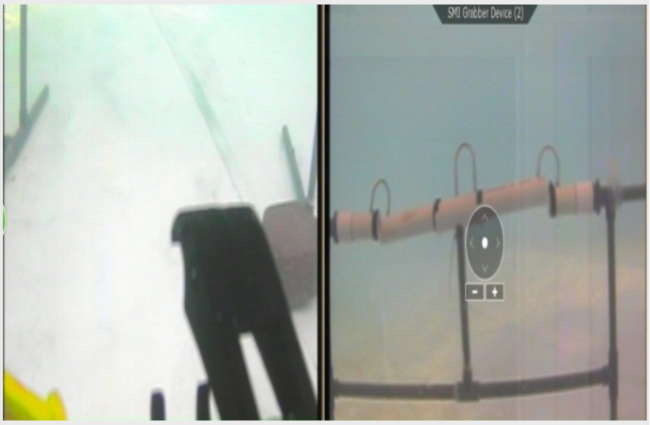


Figure [33] real view of two cameras

5.2 Sample Catcher

When it seems difficult for the main gripper to just pick up samples due to its shape (round samples or oblique curvatures) or due to its position (samples stick beneath solid surfaces), so this unique design will offer the pilot to just centers the hole with the required sample then close the gate and you will keep the required sample inside.

Figure [34]. Sample Catcher 3D CAD model

This unique design was an inspiration from the working mechanism of how digital cameras open and close its lens.

Regarding material selected, the motor housing was made of polyamide thermoplastic material. The sample housing is made of transparent Acrylic. We have to note that Sample Catcher has been fixed directly above the vehicle's top camera; in order to achieve better control for samples collection.

Figure [35]. Sample Catcher fixed above the top camera

5.3 Revolver

Another special tool designed mainly for dealing with rotational applications underwater. This mechanism proved highly efficient way in controlling fluid flow through pipeline system. By engaging the revolver with the specified valve and controlling the rotation to quickly open or close the valve in order to ensure that fluid will flow in the specified path.

Main material used was thermoplastic polyamide for providing high strength to weight ratio besides chemical & corrosion resistance as well as easy machining process.

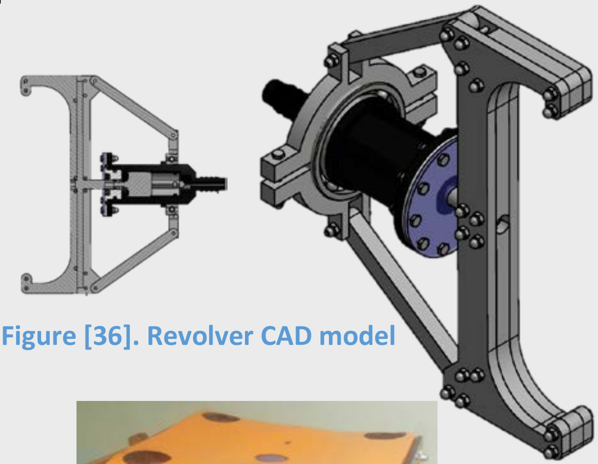


Figure [36]. Revolver CAD model

Figure [37]. Revolver attached – preparing for M3 testing

5.4 Payload tools

- **Lift Line**

For any large load that could be difficult for the main gripper to deal with, we have attached some tools to tightly hold the required object, and then it can be easily detached and pulled from the vehicle to the surface.

1st Design

This design can be generally used for any object that contains a hole that enables the lift line to be hooked with the object and hold it tightly. The lift line has been attached to the vehicle by flexible hose to be easily detached when pulling it using rope from the surface.

Figure [38] Lift Line

2nd Design

This Clip-like design is used when it is required to grip and deal with round cross-sectional objects (e.g.: Pipes), the clip can be attached with the main gripper to open its jaws and after holding the pipes tightly, it can be easily detached and pulled through a rope to the surface.

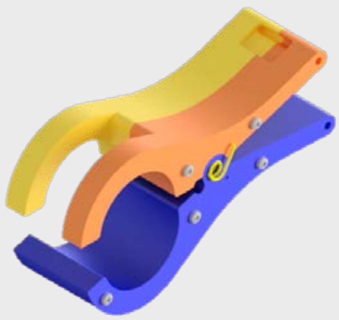


Figure [39] Clip

5.5 Flow Rate Sensor


Figure [40]. Flow Rate sensor

For measuring the water current, a flow sensor has been attached with the vehicle in order to be deployed and settled on floor. As to achieve accurate reading, the flow sensor must be positioned so as the flow direction should be set normal to the sensor's input surface area.

For the previous purpose, a special modification has been made to achieve accurate reading of the current. This fixed Sail-like shape ensures that whatever the initial position is, the flow sensor will self-rotate until the fluid flow is totally normal to the input surface area.

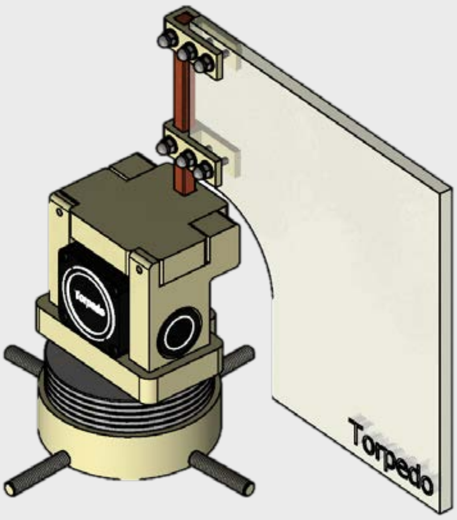


Figure [41]. Flow Rate sensor after modification

5.6 Voltage measurement

For measuring the grounding of anodes, our company have developed some techniques to perform this task.

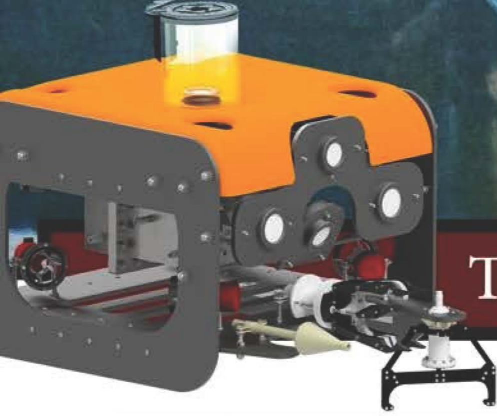
Using simple methods to solve problems that can save time & effort, we designed a simple circuit with LED and resistor in which the two terminals of the circuit are connected to a long wire connection.

Regarding the first wire, it was connected to the cathode of the LED and its end was connected to a magnet.

The second wire was connected to LED anode and its end was attached to metal terminal.

To perform this practically, we have attached the magnet to the main gripper and the metal terminal to the ROV base.

After that we attached the magnet to the GND and check the other points by the metal end. If there is any voltage between the GND and the other point the LED will turn on.



6.0 Project Costing:

		Unit	Material	State	Quantity	Unit Price	Total
Net ROV Cost	Electrical System	DC to DC Converter	N/A	Cash Donated *	1	180.00	180.00
		PCB Circuits	N/A	Cash Donated *		150.00	150.00
		Tether	Copper	Purchased New		100.00	100.00
		CCTV Cam	N/A	Purchased New	4	35.00	140.00
		LCD Screen 24"	N/A	Purchased Used		110.00	110.00
		DVR	N/A	Cash Donated *	1	60.00	60.00
		Electric CAN	Stainless Steel		1	100.00	100.00
		Arduino Mega	N/A	Purchased New	1	50.00	50.00
		Arduino UNO	N/A	Purchased New	1	20.00	20.00
		Lights	N/A	Purchased New	2	3.00	6.00
		Camera Cable	N/A	Purchased New	2	.15$/m	12.00
		CAT6 Cable	N/A	Purchased New	1	.25$/m	20.00
		Current Sensor	N/A	Purchased New	1	6.00	6.00
		Water Flow Sensor	N/A	Purchased New	1	10.00	10.00
		IMU Sensor	N/A	Purchased New	1	10.00	10.00
	Mechanical System	Thrusters	N/A	Cash Donated *	10	55.00	550.00
		Frame	Polyamide	Cash Donated *		176.00	176.00
		Frame Cutting	CNC Router			55.00	55.00
		Fiber Glass (GFRP)	N/A	Cash Donated *		100.00	100.00
		Manipulators Fabrication	N/A	Cash Donated *		135.00	135.00
		Studs	Stainless Steel			5$/m	20.00
		Camera & Light Housing	Polyamide	Cash Donated *	6	15.00	90.00
		Thether Hoses	Silicon 3/4 inch			.75$/m	37.50
		Propellers	Nylon	Purchased New	10	5.00	50.00
		Manipulator Motors	N/A	Purchased Used	3	5.00	15.00
		Bolts & Nuts	Stainless Steel			45.00	45.00
		Water Flow Sensor Housing	Polyamide			20.00	20.00
		Pump	N/A	Cash Donated *		73.00	73.00
		Balance System	Foam Sheets			15.00	15.00
	Spare Parts	PCB Circuits	N/A			50.00	50.00
		DC to DC Converter	N/A	Cash Donated *	1	180.00	180.00
		Arduino Mega	N/A	Purchased New	2	50.00	100.00
		Arduino UNO	N/A	Purchased New	1	20.00	20.00
		Lights	N/A	Purchased New	2	3.00	6.00
		Thruster	N/A	Purchased New	3	55.00	165.00
		Manipulator Motors	N/A	Purchased Used	2	5.00	10.00
		Propellers	Nylon	Purchased New	5	5.00	25.00
	Other Expenses	Power Supply	N/A	Cash Donated *	2	30.00	60.00
		Wasted Materials & Prototypes	N/A			500.00	500.00
		Tools	N/A			300.00	300.00
		Registration				70.00	70.00
		Local & Regional Travel		Donated **		100.00	100.00
		T-Shirts & Jackets			13	20.00	260.00
		Poster				10.00	10.00
		Visa			13	160.00	2,080.00
		Flight Tickets			13	1,100.00	14,300.00
		ROV Shipping		Donated *	1	2,700.00	2,700.00
		Canada Transportations				500.00	500.00
		Accommodation			7	480/Day	3,360.00
					ROV Net Cost		$ 2,355.50
					Total Cost		$ 27,151.50

*	Mansour Foundation For Development Donated
**	Alexandria University Donated

We would like to thank all our sponsors and crowd funding backers for their contribution. We really appreciate their helpful support

7.0 Safety:

"Better safe than sorry" ***proverb***

As safety is the main priority to our company, some procedures were set to ensure total safety for all the company personnel.

- All personnel wear personal protective equipment (PPE) when existing in the workshop during manufacturing.
- Cords are kept out of aisles and walkways to keep the area neat and prevent tripping
- All electrical equipment are shut-off after their usage, thanks to the reminding placards placed in workshops and working facilities.

In addition to the previous, safety features have been applied to our vehicle as well

- All electrical equipment have been enclosed in a sealed housing with padded insulating material.
- All hardware circuits are connected to fuses according to the maximum load.
- All propellers are shrouded with kort nozzles and the upper thrusters are covered with wire grid.
- All bolts and screws have been trimmed and connected with a cap at its end to eliminate sharp edges. Frame has been filleted for the same purpose.
- Warning stickers have been placed in front of any probable source of danger
- Feedback system for motors have been applied to the GUI for supervision

8.0 Challenges:

8.1 Technical challenges

- When we designed the ROV we wanted to reduce the wiring as we can, so that we designed a motherboard that contains all motor drivers and the Arduino on it without wiring at all.
- ***Buoyancy Problem:*** During the first launch of the ROV, we discovered that it has negative buoyancy and also the center of gravity is not well-centered, meaning that our initial calculations were not accurate enough. As a result, we decided to create a balancing system depending on ballasts on the bottom of the ROV to resolve the problem and move the CG back to center. After that the vehicle showed good stability and maneuverability.

8.2 Non-technical challenges

- At first when we decided to create a team to compete effectively. The point was that we have no senior mates, no funding, and no previous experience in ROVs. We didn't want to participate in teams having already senior members to give us the experience on a golden plate. So we started from scratch and contact with each other and our team established in that great form.
- The second main non-technical issue of the project was funding. Due to issues of Bureaucracy and red-tapes, it was very difficult to obtain a start-up funding without previous experience or well-reputation. We depended on self-funding to get our project start.

9.0 Lessons learned:

9.1 Technical

- The more arranging you are, the more success you achieve. One of our most important things we care about is our progress with respect to timeline.

- All our tasks should be previously planned, sketched, calculated or designed before starting to perform the practical part.

- We have learnt how to work quickly and efficiently with CAE & CAD such as SolidWorks, AutoCAD, ANSYS, Altium Designer, etc.

Also with programing languages such as java and c.

9.2 Interpersonal

- The most difficult and important part of creating a good team is picking the right members. Since the team incorporated a more thorough review of candidates before choosing members, the team was able to select members that worked well with each other.

- Establishing a functional cooperation between students with different academic backgrounds as Electrical and Mechanical disciplines can be a challenging task. Deep understanding of how things should be managed, and what is the top priority with respect to time lead to conflict elimination.

- "we fail to rise again'' those words we applied it well, as we had lots of failures during our initial trials.

10.0 Future improvement

This year we designed our control board to be a mother board that contains Arduino in it to reduce wiring as we can. Also we programed a GUI that control motors and resend a feedback of its situation.

The next year we aim to develop our GUI to be a *complete supervisory system* so as to be helpful for the pilot to deal with the vehicle components as well as environmental surroundings.

Also we want to develop our vehicle to be *auto-balanced* against any hydrodynamic disturbance.

11.0 Reflections on experience

- Mohamed Mostafa Abusetta - CEO

When I have been selected as a team leader, I felt responsible for the success of the team. I have learnt how to defer between main priority and secondary needs. Also I had a challenge to make a good timeline that serve us to distribute our efforts between the project and the academic study.

- Mohamed Nasser - Programmer

I have learnt a lot of technical and non-technical skills; the technical skills are how to build a system from scratch, improving my programming skills and also get a good overview. For the non-technical skills, I understood how to create reliable ideas not only creative, how to simplify things as possible so I can distribute my efforts between different tasks.

12.0 Acknowledgement

Apart from the efforts of ourselves, the success of any project depends largely on the encouragement and guidelines of many others. We would like to express our special thanks of gratitude to our

- **Competition organizers**: MATE, HADATH & AASTMT for their efforts to organize the event.

- **Alexandria University & Dean of engineering**: for providing us with a place to work. Special thanks to "Youth Care" and their financial & logistics support

- **Professional corporations**: "Aquila CNC" for their technical & financial support.

- **Mansour Foundation** for their huge care and financial support for our project improvement and shipment.

- **Faculty staff and team seniors**: For sharing technical experience with us

- **Torpedo backers** and their contribution for the crowd funding campaign

- **All companies that supported us with flight tickets**

- And last but not least; **our deep thanks to our families** for their moral support and encouragement.

This is impressive to say, that without those efforts this project would have been a lot different.

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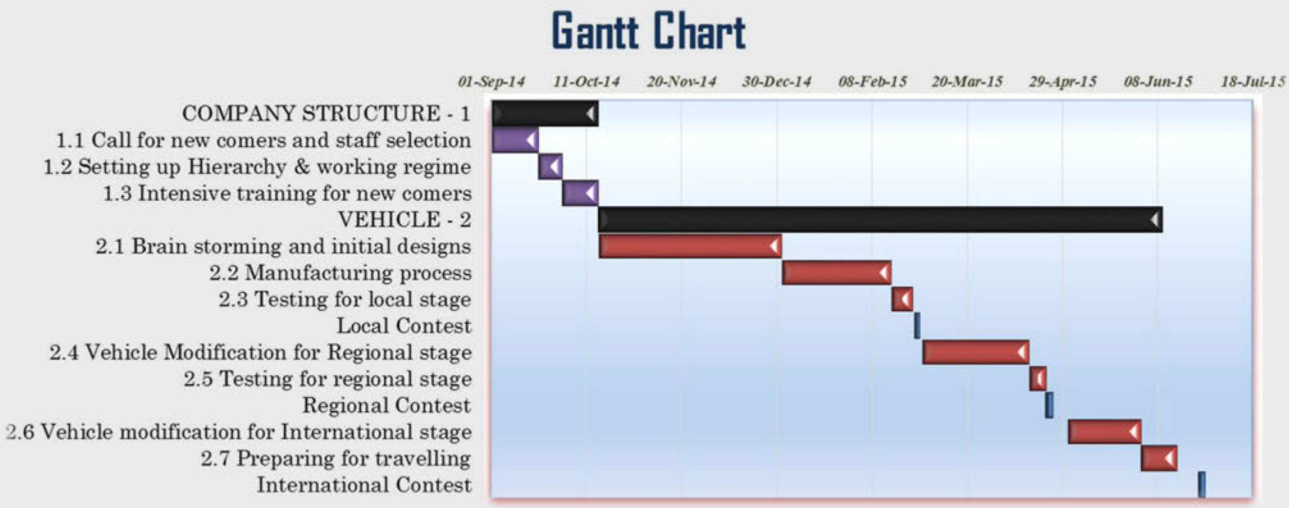
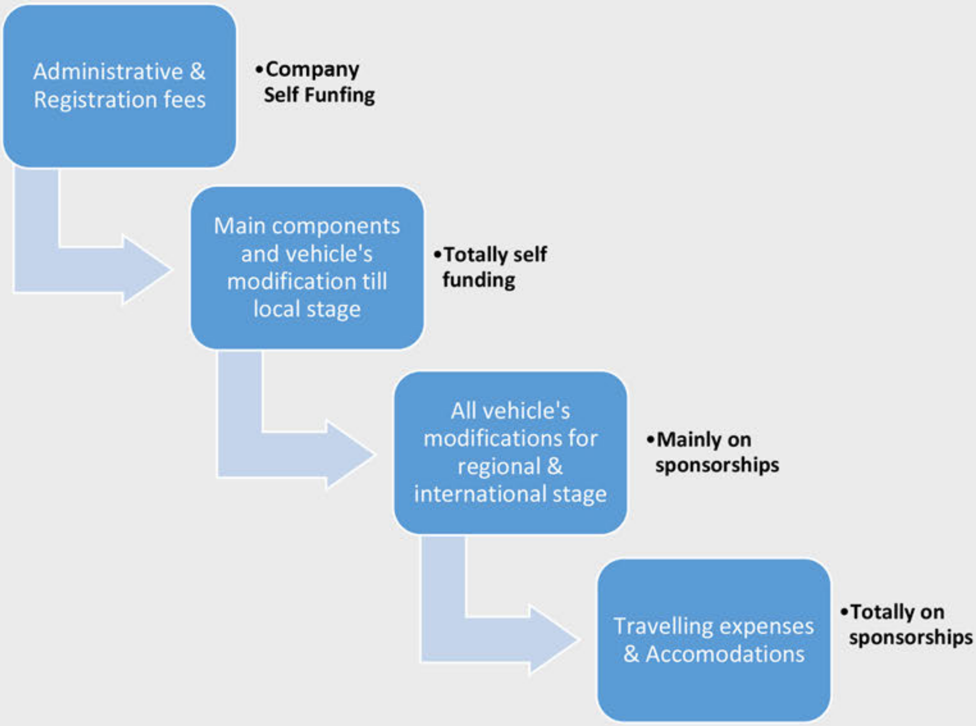
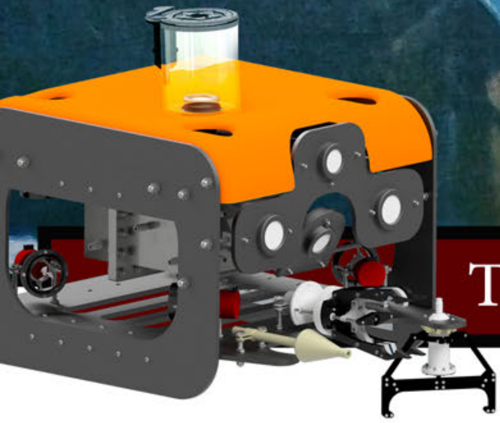
Appendix A.

Project Management



Budget Planning





Appendix B.
Safety checklist

dry test	√
Check fuse	☐
Check all connectors and cables	☐
Check if all cables are securely fastened to the frame	☐
Check current and voltage	☐
Check if the ROV control station is properly grounded.	☐
Check if all thrusters have their protective gratings installed.	☐
Make sure that manipulator is not in one of extreme positions, which can cause jamming.	☐
Check cameras	☐
Check for housings proper sealing	☐
during test	☐
Check for bubbles	☐
Monitoring current and voltage	☐
Monitoring motors feedback	☐
after test	☐
Check for probable mechanical damage	☐
Check all connectors and cables	☐
Check the structural integrity of thrusters and propellers	☐