

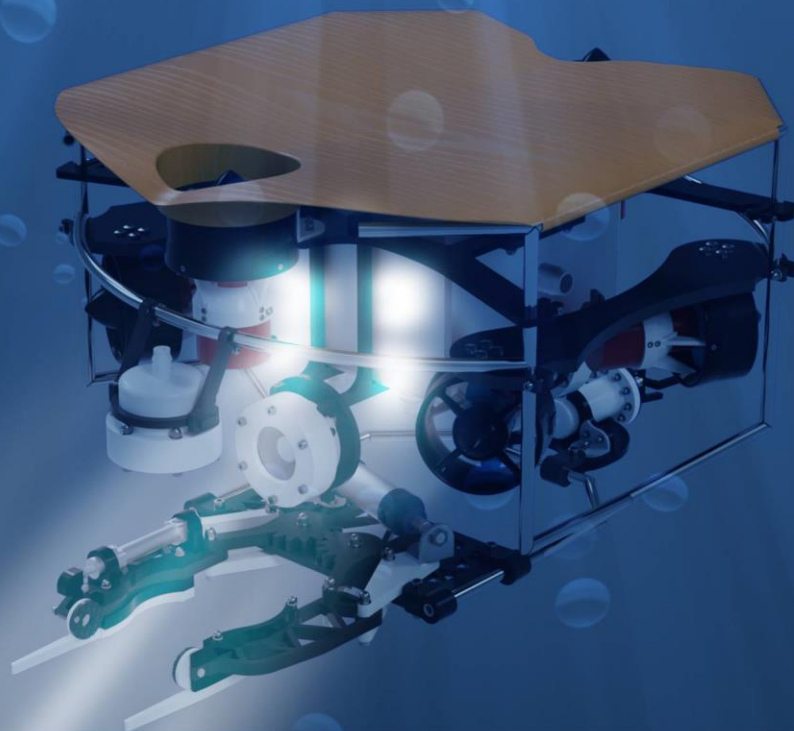


Alexandria University
Alexandria, Egypt



TORPEDO™
— ROV —

TORPEDO LATRO



Moustafa Zaky Sharaf	(CEO '18)	Mohab Said	(Mech.Team Leader '18)
Ahmed Ibrahim	(CFO '18)	Mostafa Walid	(CAD Design '17)
Mohamed Abusetta	(Elec.Team Leader' 17)	Abd-Elrahman Yousry	(CAD Design '19)
Karim Genina	(Surface team Coordinator' 17)	Ayman Hamed	(CAD Design&Tether Man'20)
Mohamed Yousry	(Communication Coordinator)	Mohamed Shaaban	(R&D'19)
Mohamed Gomaa	(Co-Pilot&GUI Spec.'19)	Ahmed El-Erian	(Fabrication - Diver'19)
Ahmed Kassem	(Software Developer'19)	Hadeer Sadik	(Mission Specialist'19)
Toka Abd-Elhakeem	(Camera Specialist'20)	Moataz Gamal	(R&D - Maintenance'19)
Mahmoud Beltagy	(Software Developer'19)		
Nevine Said	(Software Developer'20)	Company Mentors:	
Mohamed Karam	(PCB Designer'19)	Ehab AbdElrahman	(B.Sc Mech-Engineering '16)
Moatassem AbdElhaleem	(Pilot&Soff.Dev.'20)	Ahmed Hady	(B.Sc Mech-Engineering '16)
Mo'men Amin	(Electronics & Media'19)	Mohamed Attia	(B.Sc Mech-Engineering '16)
Ola Abd-Elwanees	(Elec.Fabrication'19)	Supervisor:	<i>Prof. Dr. Kamel Elshorbagy</i>
Ahmed El-Defrawy	(Elec.Fabrication'19)		

Abstract

Under-water missions require a high quality Remotely Operated Vehicle (ROV) specially designed for operating in confined and precarious conditions that are found in ports. For that purpose, our company spent days and nights in planning, research, analysis and development. Torpedo's engineers are specialized in various fields: electrical, mechanical, software and naval. All gathered with great ambition and tremendous effort to establish the state-of-the-art **Latro**.

Our company began with designing **Latro** using 3D Computer Aided Drawing software (Autodesk Inventor). The missions this year are very challenging and demand lots of research. Therefore, our R&D department developed different tools to assist in completing the tasks faultlessly. **Latro** is equipped with two grippers, giving it full functionality in mission solving. It has six thrusters mounted on it which have been developed to work efficiently and cost little. Bluetooth software was written to interface cargo boxes and our GUI processes all readings automatically. All ROV parts were mounted on this year's revolutionary frame design, weighing about 1 KG and costing under \$15.

One of the ROV's main assets this year is its compact and user-friendly surface control unit. Our company managed to make it more of a "plug and play" equipment so one can operate and use it effortlessly. Safety was always considered; shrouded thrusters, no sharp edges, and polarized connectors. Electronics housing wiring was as compact as possible. Exceptional team effort and time was put into work, with very little dependence on mentorship.

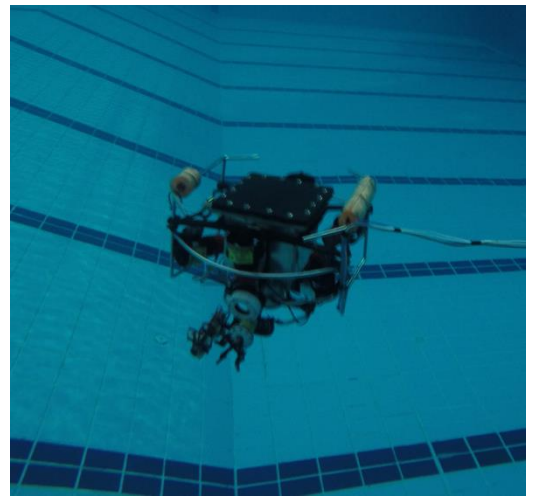
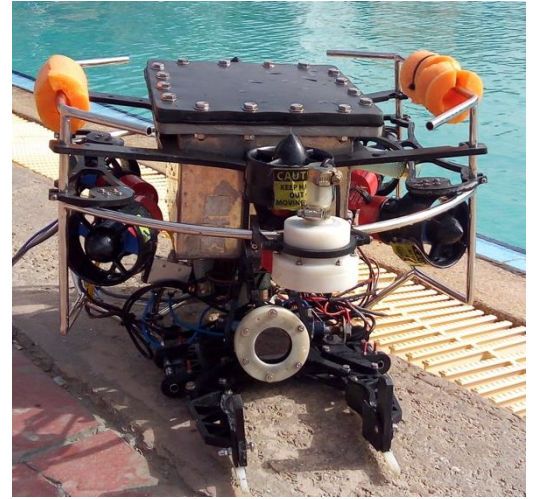


Figure 1. Real views of **Latro**.



Figure 2. Torpedo team members with their newest ROV, **Latro**.

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I. Design Rationale

1. Mechanical System

A. Design Evolution

Since 2015, Torpedo company built three ROVs, each with its unique features. **Bismarck** was built in 2015, **Triton** in 2016, and **Latro** is our latest. We mainly design our vehicles according to what's requested to perform in the product demonstration missions. Each year has new challenges, and therefore, modifications must be made. Modifications usually come at the cost of some main tradeoffs that are put into consideration, such as weight, speed, power budget, and cost. Our company strives for greater performance each year by correcting previous years' mistakes and experience gained from mission runs. Successful ideas are transferred to the next vehicles, like re-using **Triton's** pneumatic gripper and decreasing the size of **Bismarck's** rotating gripper that was later incorporated in **Latro**, as we found out they serve the needs of this year's missions and would save us the time of developing new products. Company members focused well on developing specific missions' tasks, such as Bluetooth pairing and agar sample collection, discussed later in this documentation. What helps the company continue evolving is passing experience from seniors to junior members, as the team currently has members participating for the 3rd year (Mohamed Abusetta '17 and Mohamed Yousry '17) and for the 2nd year (Karim Genina '17, Ahmed Ibrahim '18, and Mostafa Zaki '18).



 Bismarck 2015	 Triton 2016	 Latro 2017
Weight: 43.4 Kg Speed : 0.65 m/s Max Power: 432 W Net cost: \$2355	Weight: 16.9 Kg Speed : 1.3 m/s Max Power: 807 W Net cost: \$3668	Weight: 16.1 Kg Speed : 1.1 m/s Max Power: 636 W Net cost: \$3490

Figure 3. Design evolution of ROVs built by Torpedo and tradeoffs considered.

B. Design Process

Our company's main concern was to make **Latro** light-weighted, easy to maintain, compact in size, and solve missions' tasks efficiently following this year's restrictions. In order to begin the design process, we had brainstorming sessions with many creative ideas and solutions for previous obstacles. Team members introduced a piece of their mind on sketch for the design; each team member proposed creative ideas and the best ideas of each design were merged into one ROV, **Latro**. Typically, electrical and mechanical sub-team members communicate design possibilities and restrictions. In order to decide the size of electronics housing, electrical members acquire all needed data about electronics to be used, tests and simulations conducted on circuits and overall size is given to the mechanical department in order to begin designing. Housing material is decided, and then fabrication methods are discussed and executed. Next, mission tasks are discussed thoroughly and their specific tools are designed and integrated into the system, such as number of cameras and thrusters, manipulators and special equipment, such as agar sample collector. All of this is done while keeping in mind that **Latro** cannot exceed the maximum dimensions of 580mm in diameter. The decision was made not to go with the regular parallel-base design of **Triton** (2016), but to improve it for the sake of maintainability. The sketch was converted to a CAD model using Autodesk Inventor to make **Latro** a small prototype for the industrial ROVs.

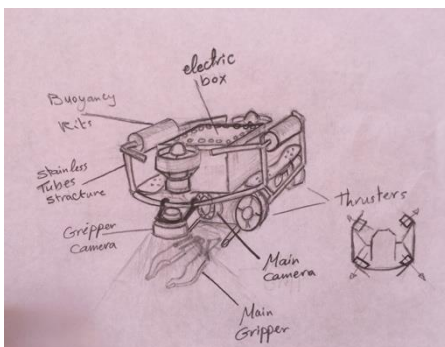


Figure 4. A free hand sketch of **Latro** during brainstorming.

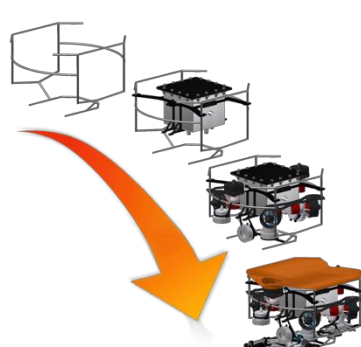


Figure 5. Step-by-step design approach of **Latro**.

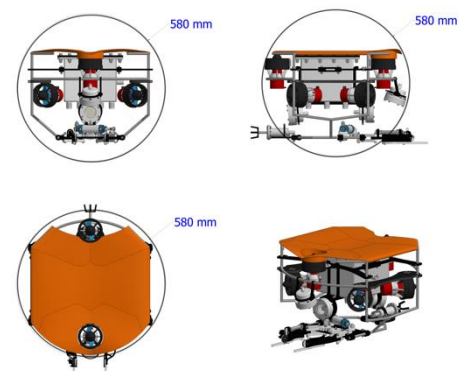


Figure 6. **Latro** fitting in a 580mm circle.

C. Frame and Stability

The frame's design was supposed to have a light weight and bear stresses. Therefore, using PVC or **high density polyethylene (HDPE)** was not recommended. PVC is vulnerable and HDPE cannot bear stresses and tends to have high deflection. The decision was between stainless-steel and aluminum. Aluminum weighs less than stainless steel. Yet, after conducting stress analysis, the decision was made to use stainless-steel tubes of 10 mm thickness. That is because the deflection in stainless steel when all components were fixed on it turned out to be approximately 6 mm and in aluminum 12 mm according to stress analysis conducted by company CAD designers.

To make **Latro** even more light-weighted, we used stainless steel tubes instead of solid rods. This gave us more variety and flexibility in designing the shape, as these light tubes can be easily manufactured and welded in any shape. The frame shape is octagonal to get enough space, so that arranging and removing components can be easily done. Following our company's design, the frame weight is reduced to more than half in comparison to last year's ROV. The weight of the frame is 1.016 kg. Last year frame's weight is 2.7 kg and was made of **HDPE**.

In addition to the stainless-steel frame, there are HDPE layers: one to carry the electric housing and the 2 vertical thrusters, the other consists of two small plates to carry the four horizontal thrusters. This allows us to control the center of thrust force, ensuring the center of drag and center of thrust are on the same line of action to prevent pitch moment. The layers are moveable on the stainless-steel frame to control the center of gravity, center of buoyancy and line of action of drag, giving advanced control of vehicle stability. The bottom tubes of the frame allow convenient mounting of payload tools.

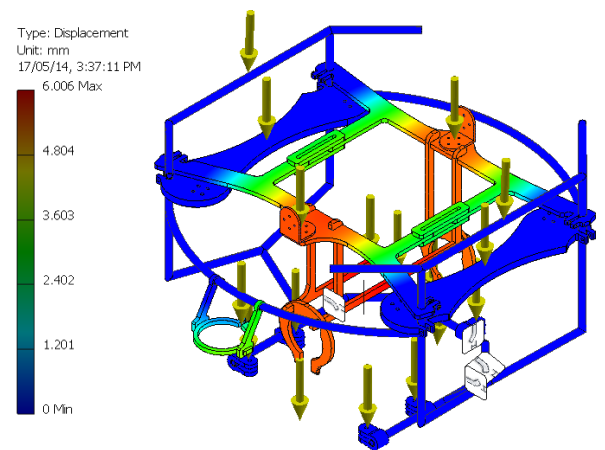


Figure 7. Stress analysis conducted on Latro.



Figure 8. CAD of frame on the left and real frame on the right.

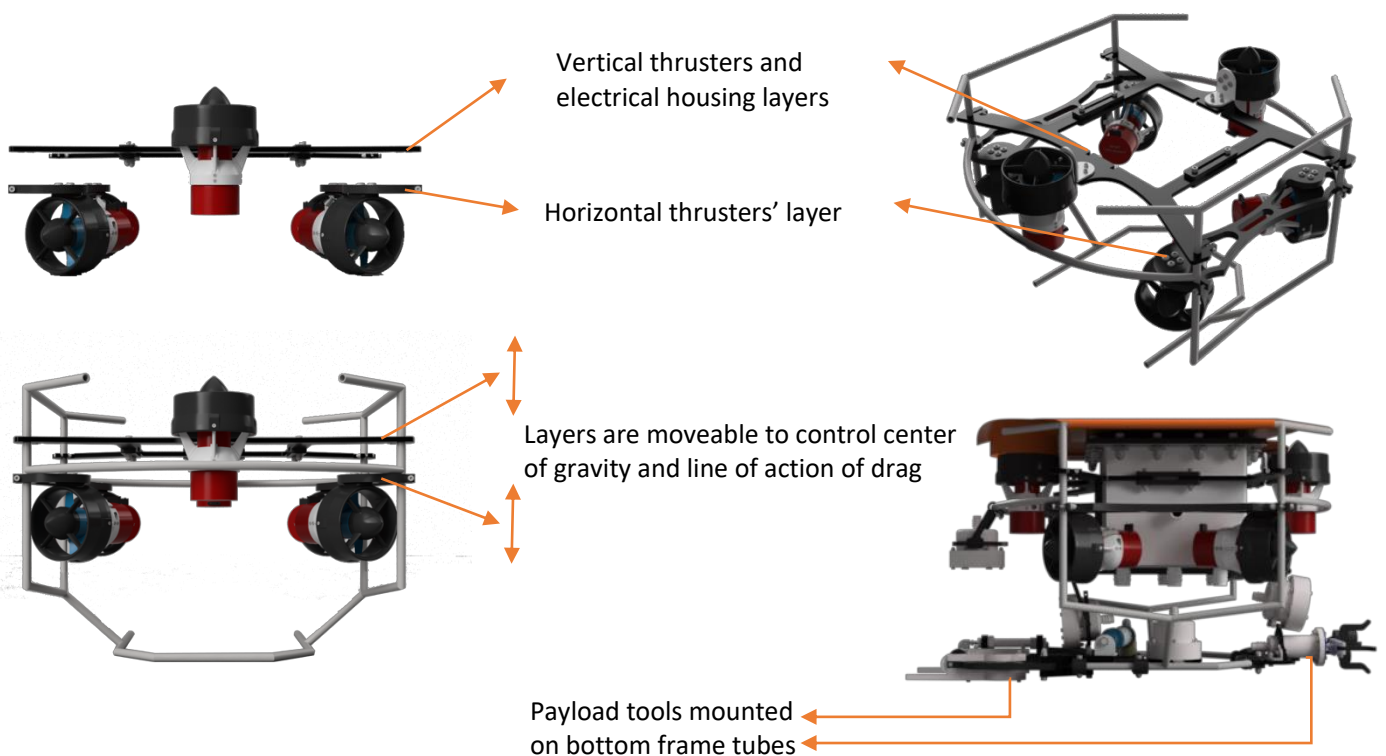


Figure 9. Different properties and special features of **Latro's** frame.

D. Thrusters

Continuing our yearly trend, which is building a much cheaper ROV than previous years, we accomplished a major challenge concerning the thrusters. The Blue robotics T100 brushless motor thrusters seemed to be very expensive for us, therefore, many discussions were held within the company and we decided to make a modified RULE's bilge pump, due to its low cost and convenient thrust force.

The R&D team presented two ideas. The first was using the bilge pump with a propeller designed by us connected to the motor with a coupling and a newly-designed kort nozzle for the propeller. However, the propellers available in the market were less than 53 mm in diameter and we needed larger ones because force is proportional to propeller diameter and RPM. Therefore, we excluded this concept.

The second concept was to **re-use** the propeller with its kort nozzle of last year's malfunctioned T100 thrusters which was more than 70mm in diameter. Eventually, we created a suitable coupling with the bilge pump motor and the T100 propeller to eliminate the separation and eddies. Moreover, 3D-printed bases and pillars were designed and fabricated by company members and were used to hold and support the kort nozzle. These pillars are designed to make the flow smoother and streamlined through kort nozzle. Consequently, second concept was our choice. Considering finance, this new design is 74% cheaper than last year.



Figure 10. Torpedo's newly developed ROV thrusters(TP100) in CAD (left) and real view (right).

After several discussions regarding the number and configuration of thrusters to use. We settled to use 6 thrusters. For horizontal control, four bilges are arranged with an angle of 30°-60° in the corners to make use of the greater force component in the forward/reverse direction (y-axis). These four thrusters are for surge, sway, and yaw. The other two thrusters are for the vertical and pitching moves. This arrangement provides **Latro** with five degrees of freedom: Heave, surge, sway, yaw and pitch. These degrees of freedom ease the maneuvering for the product demonstrations, as many objects need to be deployed with a certain angle.

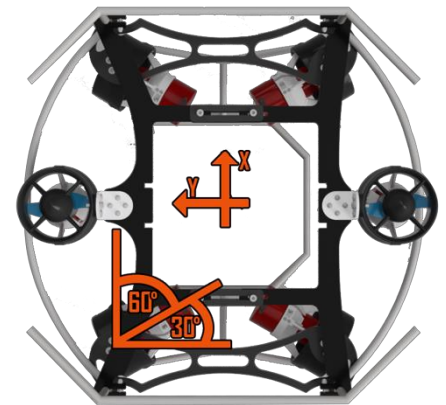


Figure 11. Arrangement of thrusters on frame.

E. Computational Fluid Dynamics

Computational Fluid Dynamics (CFD) was used to predict and verify flow effects on **Latro's** movement, such as drag and lift force values and distribution. Simulations performed assisted us to understand water flow upon our vehicle, reducing the need for costly prototypes, eliminating rework and delays, and saving time and development costs. As thrust force is known, the maximum velocity of our vehicle could be determined. CFD was conducted using ANSYS Fluent and validated experimentally. CFD results allowed us to accurately relate our motor signals to the actual speed.

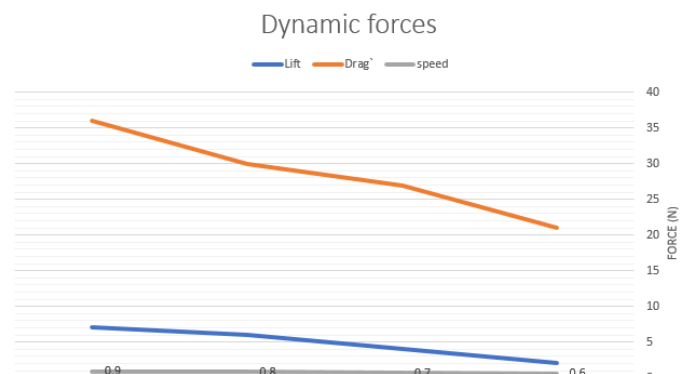


Figure 12. Relationship between drag, lift and ROV speed.

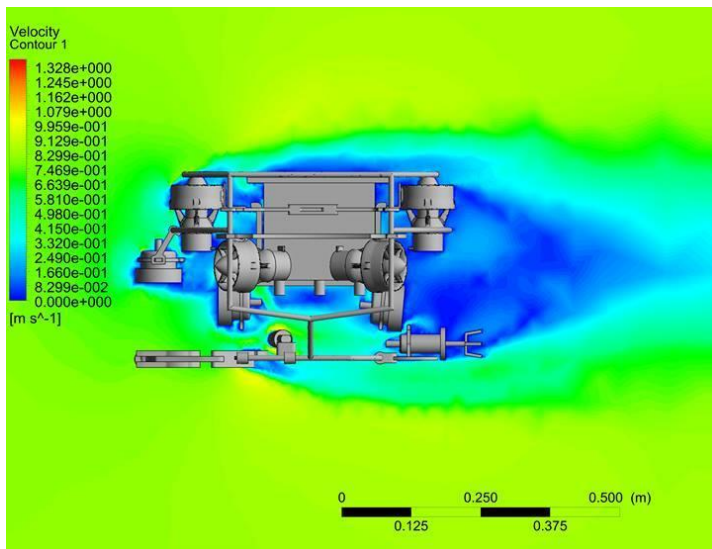


Figure 13. Velocity distribution along *Latro*.

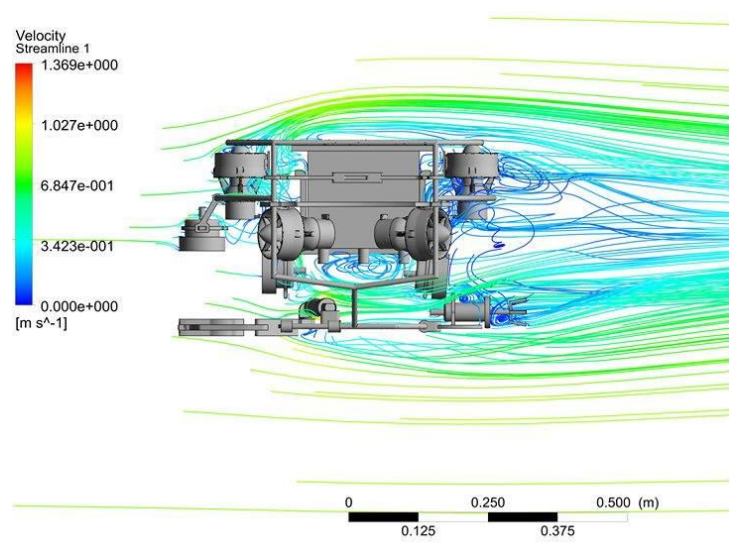


Figure 14. Velocity streamlines along *Latro* that we used to predict the eddies' regions.

F. Fabrication and Sealing

Frame

During the manufacturing process, we used a 2D model for the rods utilizing wood plates cut by computer numerical control (CNC) to guide the operator for the operation to be smooth and precise. This way was more effective than using a drawing sheet and gave us accurate dimensions.



Figure 15. Wooden 2D model on the left and a frame welded joint on the right.

Camera Housing

Using Low Density Poly Ethylene (LDPE) was the optimum choice because of its low density ($0.91g/cm^3$), weight and price. It was fabricated by lathe and 3mm Acrylic was used for the lens and fabricated by CNC laser. **O-Rings** were installed between the male and the female and a gasket between the 3mm Acrylic. The number of bolts was decided by the formula in figure.

Optimum Number of Bolts

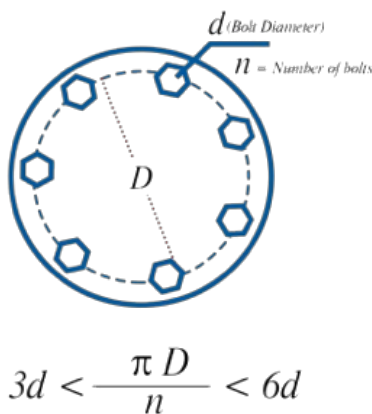


Figure 16. Formula used to determine number of bolts to use.

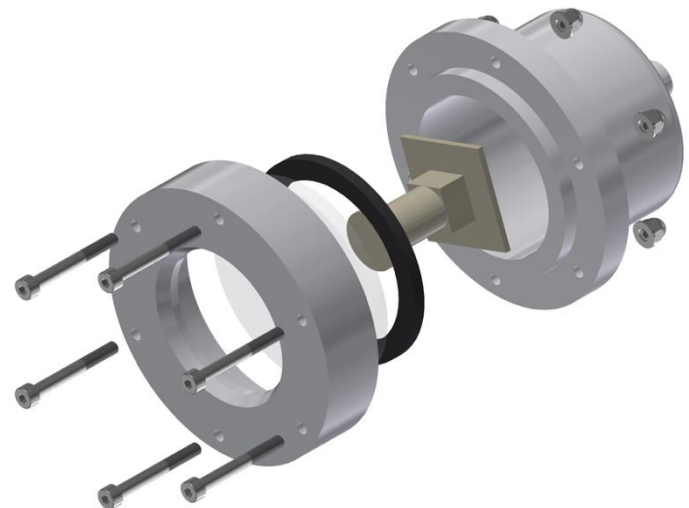


Figure 17. Exploded view of camera's housing.

Wire Sealing

For wire sealing, our company used nozzles installed in each wire entering or leaving the insulation boxes, connected to a hose and rubber rings inside. To ensure zero leakage, two levels of rubber sealing are used, and hoses were bind from each side by jubilee clips.



Figure 18. Wire sealing technique.

Electric Box

It was designed as a cuboid, which allows plenty of space for the electrical components. A comparison between stainless-steel and aluminum was made, resulting in using aluminum for its low density (2.70 g/cm^3 compared to 7.8 g/cm^3 stainless-steel) and mass. Therefore, a 3mm aluminum sheet was cut by company members. Cuboid net was printed on a drawing sheet and glued to the aluminum sheet, then it was manually cut by a jigsaw inside the workshop. Next, it was bent by a press brake machine and welded using Metal Inert Gas method (MIG). The 10mm flange was casted, shaped and welded with the box. The cap was meant to be light, so 10mm HPDE was used (density 0.952 g/cm^3). A **rubber gasket** was used for sealing between the flange and the cap and pressurized by bolts. An HPDE base was used as the electric box fixation. A test was made by putting the box in water and applying 1 bar inner pressure (equivalent to 10m), resulting in no leakage.



Figure 19. Different CAD and real models of Latro's electric box.

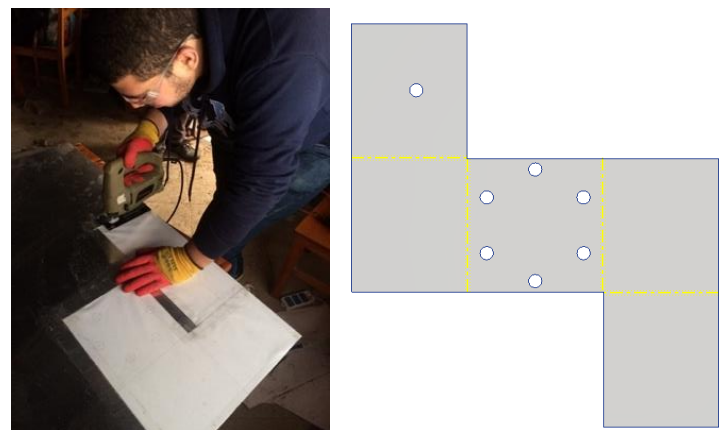


Figure 20. Cuboid net sheet of electrical housing glued to a 3mm aluminum sheet and cut out by Mostafa Zaki using a jigsaw.

DC Motor Sealing

Our R&D team used an applicable way to seal the DC-motor to get high torque as standard dynamic sealing decreases the motor's torque. The DC-motor was sealed by putting it in a case. This case and the flange have two **O-Rings** to prevent leakage. To seal the shaft and its coupling, an oil seal was used. To overcome the disadvantages of the oil seal which decreases the motor torque, we used **hard chrome** as the material of the coupling because of its excellent surface finish and low surface roughness, so that it has low friction with the oil seal. This method's advantages are low weight and small volume. Because of its low density (0.91 g/cm^3), weight and price, using HDPE was the optimum choice and was fabricated by lathe.

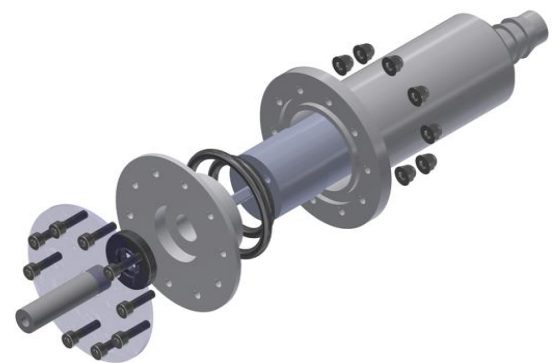


Figure 21. Exploded view of motor casing.

G. Buoyancy

We decided to go with slightly positive buoyancy (2-5%). In case of any hardware failure or the inability to communicate with the vehicle due to system failure, the vehicle will slightly rise upwards until it reaches the surface. By equalizing the buoyancy force produced by the immersed total volume of **Latro** (0.014 m^3) to the dry weight of the vehicle. We decided to use rigid polyurethane foam (Density: 36 Kg/m^3). Another important part is the fiberglass cover of the ROV, designed to be streamlined and optimizes the dynamic water flow. Fabrication was completely done by company members. Fabrication includes: preparing the form, placing fiber glass cloth on the form, adding resin and hardener. Next, we applied paste to fill the imperfections and coated the fiber with a filler material. Finally, the cover was painted orange as it is **Torpedo's** official color.



Figure 22. Steps and sequence used to build **Latro's** fiber glass cover in **Torpedo's** workshop.

2. Electrical System

A. Tether Control Unit

Our tether control unit is a mobile surface station of **Latro**, putting together precise control aspects, power control, safety handling above and below the surface, video distribution and lastly, voltage and current measurement for system feedback to our co-pilot in case of any emergency situation. A control box was designed to manage the wiring in the station and connect the ROV.

One of the main TCU features is minimizing setup time to 25 seconds only. That is to ensure a trouble-free setup procedure. In order to achieve this short time, we made sure that no laptop is necessary to get the ROV launched, by using a USB shield directly between the microcontroller and joystick. A laptop is connected afterwards for the sake of starting our GUI, which is independent of ROV operation. In addition, fast and polarized connectors play an important role in the setup. For the power connection, we used an XT-60 polarized power connector to avoid any miss-wiring by members. For communication, we used a polarized 8-pin connector for our terminal, which proved to make extremely firm, easy and stable connection of our tether.



Figure 23. **Latro's** Tether Control Unit (TCU).

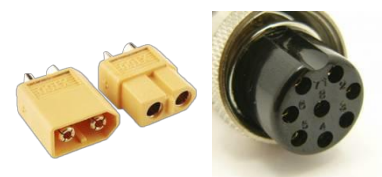


Figure 24. Polarized connectors.

Safety is of a great concern, therefore, our company preferred using a 25A DC circuit breaker to protect **Latro** from overload and short circuit hazards. Also, unlike the fuse, used as a fast ON/OFF switch. For real time monitoring of voltage and current drawn from MATE's power supply, our engineers built an electric board containing current and voltage sensors and a 20x4 character LCD. We relied on a digital sensor over permanent magnet moving coil (PMMC) for the sake of space and more system integration. Our video feed is distributed using a Digital Video Recorder (DVR) and viewed through a 21" LCD monitor. TCU design has proven to be durable, easy to ship, and allows the team to quickly mobilize and demobilize during product demonstrations.

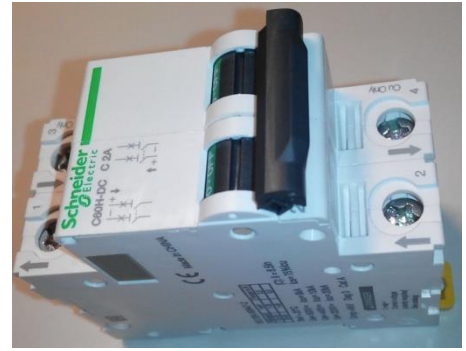


Figure 25. 25A DC circuit breaker in TCU.

B. Tether

We incorporated an Ethernet CAT6 cable for the communication tether. We preferred the CAT6 type over CAT5e because of the greater transmission performance and better immunity from external noise. CAT6 is also more robust in terms of malleability and can handle harsh conditions. As for power tether, in order to stand for the current drawn, minimize voltage drop to an acceptable rate, have the optimum weight and also the minimum cross sectional area in order to minimize the drag force. Considering derating factors of water thermal resistivity (1.17), ambient water temperature of 25°C (1.22), max current drawn from the source (20A), We were easily able to choose our tether in order to have the optimum gauge number of our cable, so we chose to use a 13 AWG stranded cable, considering a factor of safety of 1.5.

C. Joystick

This year, we used Logitech 3D pro joystick. We interface the joystick using a USB host shield connected to our TCU's microcontroller, which is an Arduino Mega. Our software engineers wrote a C++ program to interface both the Logitech joystick and a USB keyboard to be used as a spare controller if the joystick failed unexpectedly. We built an additional electrical board placed on top of the TCU containing a toggle switch to select between the controllers, either the Logitech joystick or the keyboard. The microcontroller reads joystick's readings, applies vector algorithm and then sends the thrusters' direction and speed to the ROV.

D. Electronics

Power Conversion

We use four main DC-DC converters to step down 48V to 12V with maximum current 20A for powering our thrusters, motors, microcontroller and lights. With these converters, we solve 2 problems facing us from previous years: high cost and heavy weight. These are lower in cost and Lighter in weight.

Voltage Drop Calculator

Result

Voltage drop: **6.57**
 Voltage drop percentage: **13.69%**
 Voltage at the end: **41.43**

Wire Material	Copper
Wire Size	13 AWG (5.18 kcmil)
Voltage	48
Phase	DC
Number of conductors	single set of conductors
Distance*	25 meters
Load current	20 Amps
Calculate	

Figure 26. Voltage drop percentage at full load.



Figure 27. Logitech 3D Pro joystick.



Figure 28. Four DC-DC converters tied together on one of the electric box plates.

Electronics Box

Our company ensures its dependency of self PCB manufacturing. As every year we design custom boards with a goal in mind, we find it cheaper and more reliable to manufacture our own boards by equipment already present in our workshops, like CNC routing machine. We followed a mother board approach in our design to collect all components and microcontroller and decrease wiring as much as possible. After our electrical circuits pass fabrication phases, we perform tin plating to protect the copper from oxidation and increase the longevity of the boards.

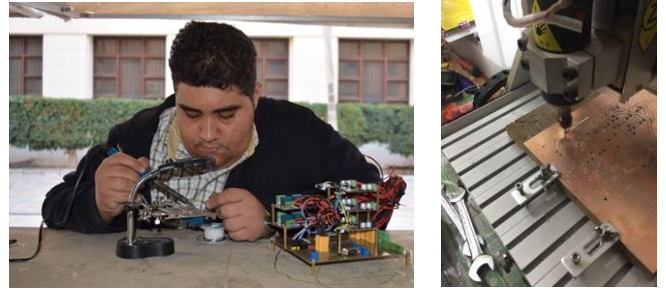


Figure 29. Ahmed Ibrahim soldering electronics and operating CNC machine for PCB manufacturing.

For thrusters' operation, we decided to use Cytron motor drivers (MD13s) with maximum current (13A) to control the internal brushed DC motors. We chose to buy it over making our own for many reasons, small size, fully NMOS H-Bridge for better efficiency, no heat sink is required and it has current protection. In addition, it has been used in previous robotics projects which made it the optimum and most appealing choice to us.



Figure 30. Cytron 13A motor driver.

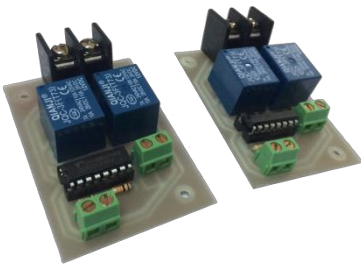


Figure 31. Custom made two-channel relay modules.

For lights, rotating valve DC motor and agar collecting DC motor, team members designed and fabricated 2 relay modules (2 channels each). Each channel controls one direction, such as lights on/off. One module was used for the rotating valve motor that rotates in both directions, while the other module runs lights and agar collecting motor that rotates in one direction only.

When it comes to plugging the electric and electronic components into our main board, we connected the DC-DC converter to our main board by using XT60 connectors. Also, we used D09 serial connector to connect the communication tether entering the electric box to the main board. Our communication tether consists of 4 pairs, 2 pairs for camera signals, 1 pair for RS232 bus, and others are for ground and rest is left empty for future purposes or improvements. The heart of our board is an Arduino Mega based on AVR Atmega2560.



Figure 32. Bottom side of main board.

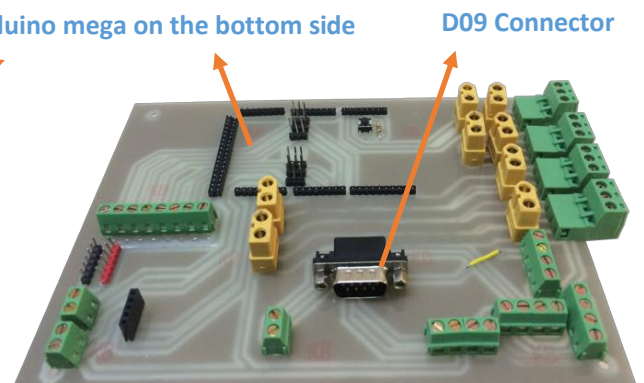


Figure 33. Custom main board fabricated by company members.

E. Communication

Communication between the TCU and ROVs plays a vital role in ROV performance. Members surveyed several candidate protocols to use. Last year's I2C protocol resulted in several problems due to limited tether length allowed protocol standards to be stable. We decided to use UART with RS232 which is a very robust system for being used in the industry and tried out in other robotics projects by *Torpedo* members. Its code is also much easier to debug and implement. It is inherently full-duplex. Company members designed and fabricated RS-232 modules themselves to reduce cost.

Communication and control properties are:

- **Baud Rate: 115200 bits/second**
- **Surface control code Arduino full loop time: 3 ms**
- **Bottom control code Arduino full loop time: 2 ms**



Figure 34. A pair of RS-232 modules after fabrication.

F. Control Software and Algorithms

Our company has developed more than an algorithm in C and C++ in order to provide our pilot intuitive maneuvering, overcoming water current issues, adjusting pitch angle, allow maneuvering in reverse mode, speed adjustment, and finally, a backup plan in case if joystick malfunctions. *Latro's* front motion is not absolute. It can be adjusted so that its front control faces its main gripper (pneumatic) or in other cases its back-rotating gripper, giving the pilot more control over the ROV by eliminating the need to operate the ROV using backward moves. This option is possible due to the presence of two cameras on the same axis, giving full view of the two grippers' surroundings.

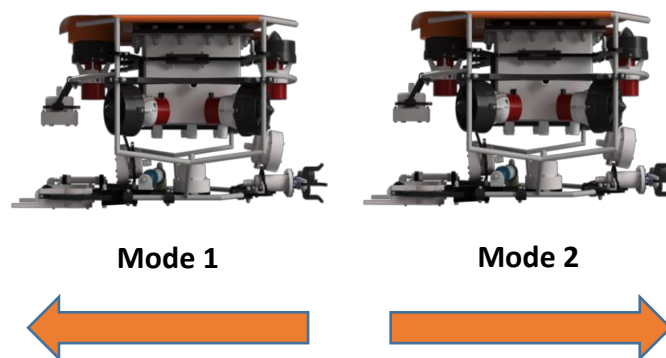


Figure 35. Illustration of default moving directions according to mode selected by joystick.

Pilot Friendly Features

A slider on the joystick is used as a scale factor for the speed, to speed up and slow down the ROV to get an even greater movement precision whenever desired. The algorithm supports a backwards mode that reverses the forwards and backwards directions to allow the pilot to be as precise working with either gripper on either the front or back end of the ROV. Moreover, the same algorithm was applied on the vertical motors to allow pitching in both directions with the desired angle, while the ROV rests in the same position in space, or even when going upwards or downwards with any desired speed. This allows the pilot to retrieve objects much faster to the surface as pitching allows grippers to face upwards, allowing the pilot to adjust the pitch of the ROV back to normal when carrying heavy objects, and most importantly, unlocks a combination of movements that would not have been possible without the algorithm.

Thrust Vector Algorithm

We designed a digital keyboard algorithm that moves the ROV with full thrust in the main directions (forwards, backwards, rotation, up, full thrust pitch, etc.). This was not enough for the precision needed to fulfill our vision. Therefore, we used this as our spare algorithm in case the joystick malfunctions, using a toggle switch to switch between algorithms. For our main plan, we developed an analog algorithm that maps our joystick's X and Y axes, and moment inputs as resultant forces to the four motors in the horizontal plane of the ROV. We then calculate the thrust needed from each motor to provide that resultant force and moment. Consequently, we map the forces such that the maximum movement of the joystick in any direction moves the ROV with full thrust in that direction. This allows the pilot to perform any complex movement with maximum precision, such as rotating while moving in a certain angle (for example, 25° with respect to forward); which only makes the ROV an extension to the pilot's hands.

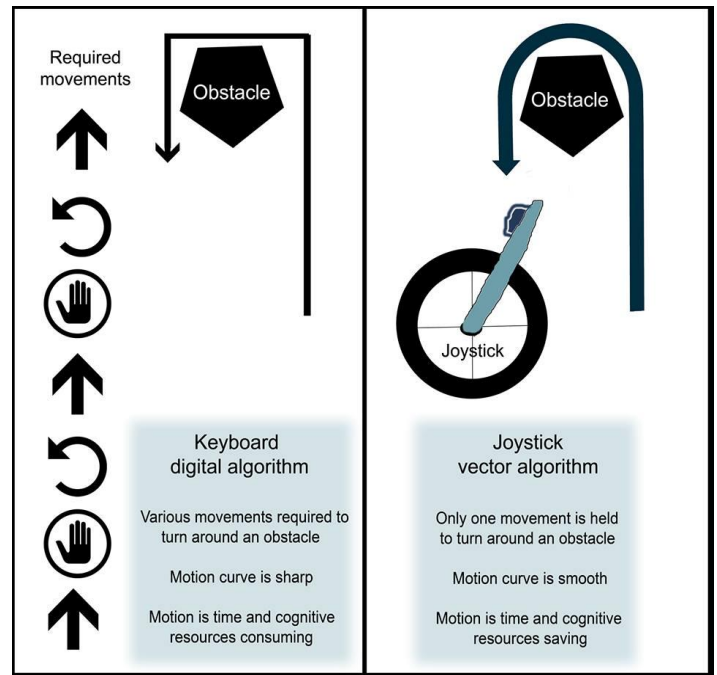


Figure 36. Demonstration of the working of vector algorithm of Keyboard on the left and Logitech joystick on the right.

G. Graphical User Interface and Vision

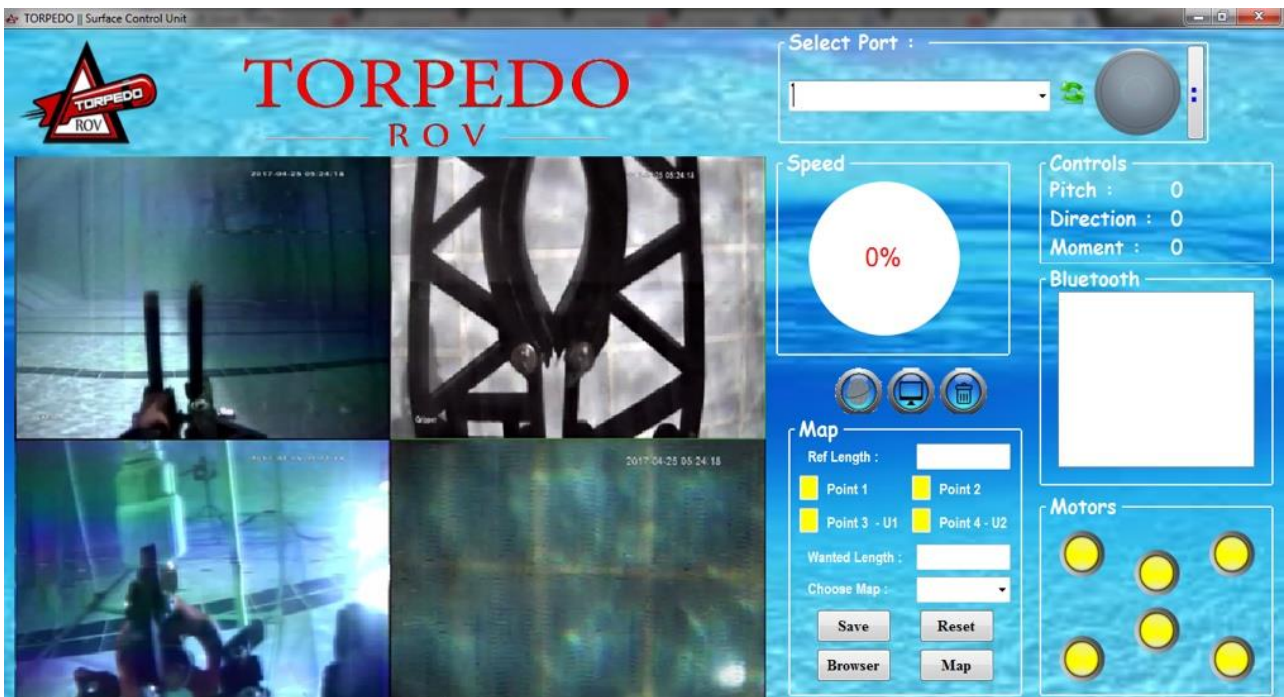


Figure 37. *Latro's* GUI, video streams and feedback from ROV.

A graphical user interface is one of the ways of viewing feedback from the ROV, providing a high-level interface for the pilot and co-pilot. We designed a windows application, written in C#. It is designed to view sensors readings and send/receive commands to/from *Latro*. It also shows progress in mission, which conserves the time of the Co-pilot for better use. In order to improve environmental interaction, our company paid attention to cameras selection, so, we relied on 3 CCTV 720p wide angle cameras and a true scale camera for mapping in product demonstrations.

3. Mission specific tools

A. Multi-tasking Manipulator

We used last year's pneumatic manipulator for its stability and precision. It is a light weight manipulator that could tackle most product demonstration tasks. As high holding force was needed, pneumatic power was used, and based on a pneumatic cylinder, we built up our manipulator. A Four-bar mechanism was used to perform the parallel motion in the x-direction with only 20 mm in y-direction which gives high accuracy and intuitive control to our pilot. End effector consists of a vertical groove to hold cylindrical elements (flanges) with a maximum diameter of 140 mm. Also, 2 small plates are assembled perpendicular to the plane of the gripper as guides for the pilot to rotate the locking mechanism 180 degrees. Our manipulator parts were designed based on the steel structure idea of less material and high strength. 10 mm & 6 mm HDPE sheets were used for the main parts and manufactured by CNC.

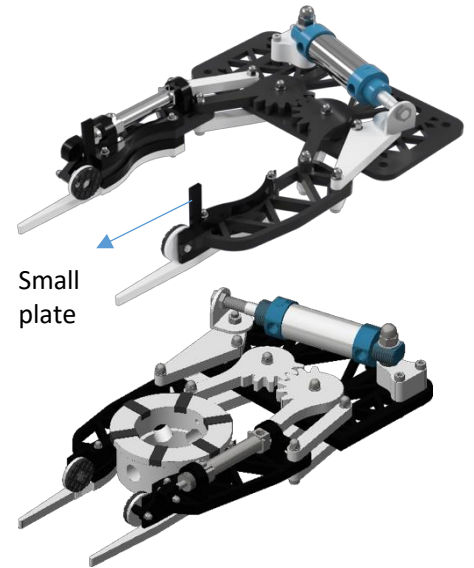


Figure 38. Manipulator features.

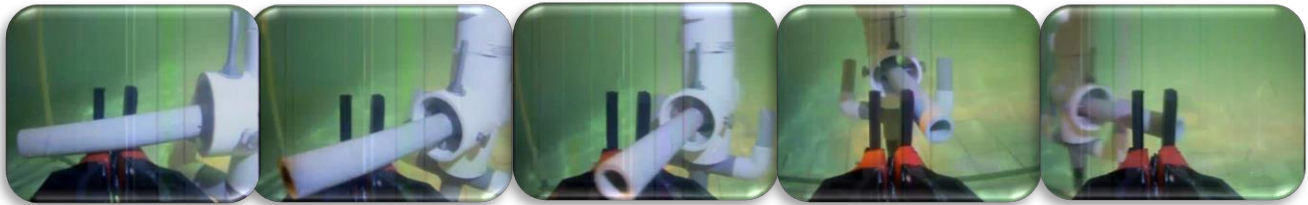


Figure 39. Illustration of how locking mechanism is turned using one of the 2 small plates.

B. Rotating Manipulator

Our design sub team in our company designed a second manipulator, fixed on the back of the ROV, which is a one DOF simple rotating mechanism. It's end effector has 4 jaws, taking the size of cone shape. When the ROV approaches the rotating valve, it keeps pushing until the valve is tightly fit into the cone-shaped jaws and then rotates 1080 degrees, performing the task with minimum effort and maximum efficiency. 6 mm HDPE was used for the the parts and manufactured by CNC laser cutting. DC motor specifications are 20 kg.cm torque and 133 RPM.

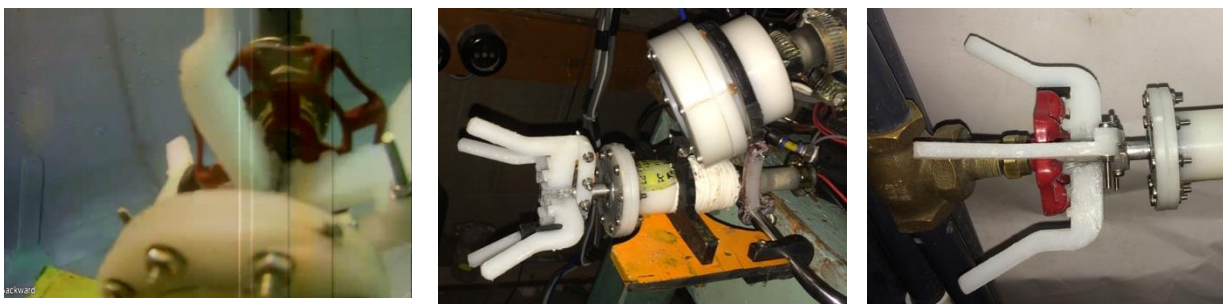


Figure 40. *Latro's* rotating manipulator underwater and its fixation.

C. HC-05 Bluetooth Module

In Order to connect to the Bluetooth modules in the fourth product demonstration task, we used the HC-05 Bluetooth module. We sealed the HC-05 Bluetooth module by placing it in a hose and small rubber rings form each end (wire sealing technique). C code was written in order to interface the product demonstration's master Bluetooth module.

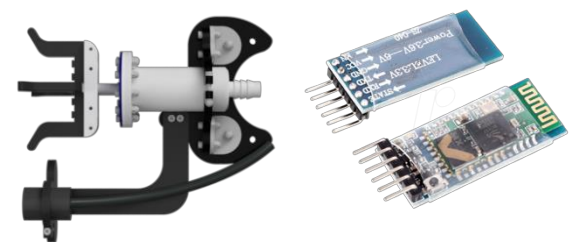


Figure 41. Bluetooth module used inside the hose beside the rotating manipulator.

D. Agar Suction Mechanism and Buoy Marker

We used an Archimedes screw to collect agar from cup. It consists of a horizontal screw which is connected to a screw adjusted with an angle of 120 degrees with a universal joint. The two screws are inside a pipe. When shaft rotates, agar is trapped on the screw itself, collecting the required volume. A buoy marker needed to be set, fixed on one of the cargo boxes. Company members designed a spring joint. The spring is pressed by the ROV moving force onto one of the cargo boxes' body. The buoy marker joint opens when pressed and closes again when force is removed, trapping the box body inside. Consequently, buoy marker is fixed.

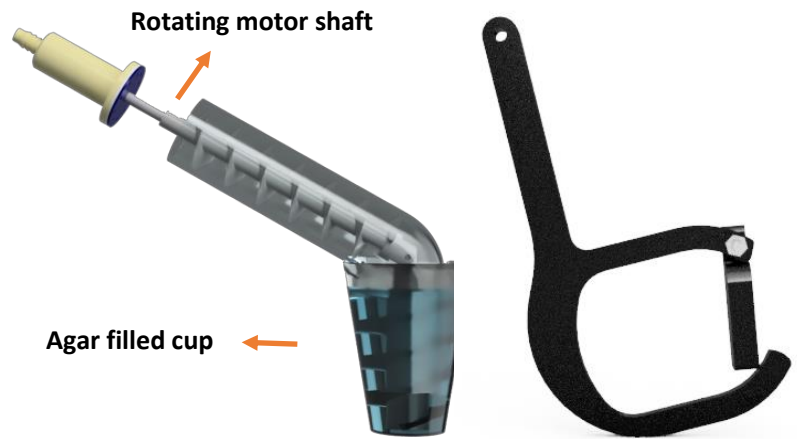


Figure 42. Archimedes screw mechanism and Buoy Marker.

II. Safety

A. Design Safety and Philosophy

As safety is the main priority to our company, safety procedures are strictly imposed during the designing, manufacturing, handling and testing. Our mechanical team designed safe parts with fillets to prevent sharp edges, ensured well sealing and used covers for moving parts, so all propellers are shrouded with kort nozzles. Screw caps for no sharp ends of bolts and warning stickers were also added to highlight dangerous components, such as high pressure air.

B. Workshop

Our team members' safety comes first, so as to keep everyone safe without injuries or accidents. We had put some rules to follow, all members must wear personal protective equipment (PPE), such as gloves, goggles, and face masks while existing in the workshop during manufacturing. Cords are kept out of aisles and walkways to keep the area neat and prevent tripping. We also followed the instructions of material safety data sheets for every product used in the production phase.

C. Electrical Safety

- I. All electrical equipment has been enclosed in a sealed housing with padded insulating material.
- II. All hardware circuits are connected to fuses according to the maximum load.
- III. A 25A circuit breaker incorporated to avoid short circuit or overload hazards.
- IV. Polarized 8-pin connector and XT60 power connector to avoid any accidental wiring
- V. View and monitoring of feedback from all thrusters to avoid any overload.
- VI. Our TCU is equipped with an emergency switch, in case of any urgent situation.



Figure 43. Moataz Gamal drilling while using PPE.

D. Operational and Safety Checklists

Offshore Safety

- ✓ The ROV is transported to the competition playground covered in bubble wrap to protect it against impacts.
- ✓ Check that cameras are properly sealed and fixed.
- ✓ Check that the tether is well connected to the ROV.
- ✓ Check the strain relief of tether.
- ✓ Make sure the pneumatic hose has no leaks.
- ✓ Make sure all cameras are displaying their video on the screen via the DVR.
- ✓ Perform a dry test to make sure all is well before submerging the ROV.

Under water-before mission safety

- ✓ Make sure the electric box isn't leaking (no bubbles are going up).
- ✓ Adjust buoyancy.
- ✓ Perform a short-wet test to make sure all manipulators and thrusters are fully functional.
- ✓ Make sure cameras' signals aren't distorted.
- ✓ Test the main gripper to make sure the air compressor is properly connected and functioning.
- ✓ If any of the above isn't as described, turn off main power line and lift the ROV out of water for maintenance.

Under water-during mission safety

- ✓ Make sure the tether doesn't surround the ROV so that it would not be damaged.
- ✓ If any leaking occurs, turn off main power immediately and lift the ROV out of water for maintenance.

After mission safety

- ✓ Lift the ROV out of water.
- ✓ Turn off main power supply.
- ✓ Turn off the air compressor.
- ✓ Cover the ROV in the bubble wrap to transport it back to Torpedo headquarters.

III. Conclusion

A. Technical Challenges

Mechanical

This year's ROV weight and dimensions limitations were the most difficult challenges for our company. We needed to manufacture a high quality ROV, keeping in mind the material used, its weight, dimensions, and efficiency. Our company members proposed lots of creative ideas to tackle this challenge, some of these seemed to work fine, and some were not. The electrical aluminum housings we used provided less weight and high strength. ROV frame was designed in a way that keeps it standing well against all stresses while cutting the material usage as much as possible. Mechanical members cooperated with electrical members, stressing on implementing compact electronics to reduce size, hence, reduce weight.

Electrical

Our two main challenges were loss of communication on the RS-485 bus and the size of the internals of the Electronics box. We figured out the cause of the communication loss, which was a result of bad quality of integrated circuits sold on the market, we tackled it by shifting our path to use RS-232 instead. It proved to be extremely stable under harsh conditions and also being stable due to its simplicity in PCB design. For the size issue, we had to fit a huge amount of wires into the available small box space. Company members proposed different PCB designs of mother-board like electric board that converts wire complexity into PCB tracks. The results were very satisfying, as the time consumed to finish our wiring decreased by 70%.

B. Non-Technical Challenges

Increasing the harmony and understanding between team members is such a great challenge that needs prior planning and real-time problem solving. Our new members were of less experience, but the seniors and mentors managed to let them engage quickly by providing advices and helping in organizing their schedules. Funding wise, we faced many difficulties in finding a sponsor to our work. Thanks to our supervisor who helped us to make a deal with a sponsor that could provide us with sufficient fund.

C. Technical Lessons Learned

How communication protocols work, and learning what to choose according to our needs. Programming skills in C, C++, and C# were enhanced, due to problem solving and extensive debugging. New methods of housing electronics were explored, learned, and tested, providing more experience to our young and senior members. Studying the kinematics of ROV and implementing it in software (Vector algorithm). Gain of experience in creating an intuitive Graphical User Interface (GUI).

D. Interpersonal Skills Gained

Since all our company members are college enrolled, they have to keep track of their college studies, they managed to separate the time of work and studying, by putting a clear realistic plan to follow, eventually increasing their time management skills. Our sponsorship directors learned to communicate efficiently with company representatives and managed to persuade some of them of our work. Eventually, supporting us financially. This year, our company has a role in community, our members volunteer in teaching robotics to the young people in Torpedo Academy, improving their presentation and communication skills.

E. Reflections



“Being a mechanical team member in Torpedo is such a life changing experience. I have gained so many technical and non-technical skills. I’ve learnt how to manage my time between studies and working in Torpedo. In addition, I got to implement the CAD designs into real world models. I’m glad I was able to give and learn so much.”

- *Ahmed El-Erian, Fabrication.*

"I've always wanted to do more and push myself to exploit my potentials. Here, I found the opportunity to work on what I love. During work, we faced a lot of different troubles in which I've learnt how to tackle them. Team work was great and I'm now a better problem-solver, thanks to the team."

-Ahmed Kassem, Software Developer.



"I've spent so much time with my team-mates working to achieve our goal. Now I work better under stress and organize work between our company members. Torpedo is now my second family"

-Ayman Hamed, CAD designer.

F. Full CAD Design Show

[Using this hyperlink, Latro's 3D Design can be viewed in detail. An exploded view is also provided for viewing each part separately.](#)

G. Future Improvements

- Automatic buoyancy system that would adjust ROV buoyancy in just a few seconds.
- Improving sealing system for increased working depth.
- Improving reliable waterproof plugs for faster maintenance or replacements.
- Investing in IP cameras for improved visibility.

H. References

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I. Acknowledgments

Torpedo company would like to thank the following benefactors:

- Prof. Dr. Kamel Elshorbagy, for his technical/non-technical assistance, and being supportive all the time.
- Mohammed Attia, Ehab Abdelrahman, and Ahmed Hady, for transferring their experience from past years.
- Omar Samak (high school student), for his outstanding efforts and generous help to our mechanical team.
- Faculty of Engineering, Alexandria university, for logistics and transportation.
- Makers Electronics, for providing reduced electronic parts' rates.
- AAST, MATE for organizing the local and regional competitions.
- Alexandria Language School for giving us access to their pool 5 days a week.
- Our parents, for providing constant support to us.



Figure 44. Acknowledgments.

IV. Appendices

A. Job Assignments

Moustafa Zaky Sharaf	
CEO	
PR	
Ahmed Ibrahim Khames	
CFO	
PR	
Mohamed Mustafa Abusetta	Mohab Said
Electrical Team Leader	Mechanical Team Leader
Karim Emad Genina	Mostafa Walid
Surface Control Co-ordinator	CAD Design
Mohamed Yousry Kamal	Abd-Elrahman Yousry
Communication Co-ordinator	CAD Design - Diver
Mohamed Gomaa	Ayman Hamed
Co-pilot- GUI Specialist	CAD Design - Tether man
Ahmed Kassem	Mohamed Shaaban
Software developer	CAD Design - R&D
Troubleshooting & Maintenance	Ahmed El-Erian
Toka Abd-Elhakeem	Fabrication - Diver
Camera Specialist	Hadeer Sadik
Mahmoud Beltagy	Mission Specialist - Fabrication
Software Developer	Moataz Gamal
Troubleshooting & Maintenance	R&D - Maintenance
Nevine Said	
Software Developer	
Technical Writing director	
Mohamed Karam	
Software Developer-PCB Designer	
Moatassem Abd-Elhaleem	
Pilot	
Software developer - Media	
Mo'men Amin	
Electrical Fabrication	
Media - Poster	
Ola Abd-Elwanees	
Electrical Fabrication	
Ahmed El-Defrawy	
Electrical Fabrication	
Troubleshooting and maintenance	

Figure 45. Job assignments of Torpedo team members.

B. Budget

OPERATION EXPENSES	Item	amount	Income	
	Rov components	\$2,700.00		
	machining	\$50.00		
	transportation	\$200.00		
	new tools	\$100.00		
	cnc	\$100.00		
	pool rent	\$300.00		
	welding	\$60.00		
	printing	\$50.00		
	competition registration	\$150.00		
	competition Travel (775\$/each)	\$15,500.00		
	competition Accommodation	\$2,500.00		
Total expenses	\$21,710.00	item	amount	
balance		alexandria unversity	\$180.00	
		members dues (105 each one)	\$2,100.00	
		sponsorship	\$18,000.00	
		total income	\$20,280.00	
			\$1,430.00	

Figure 46. Torpedo budget for the year 2017.

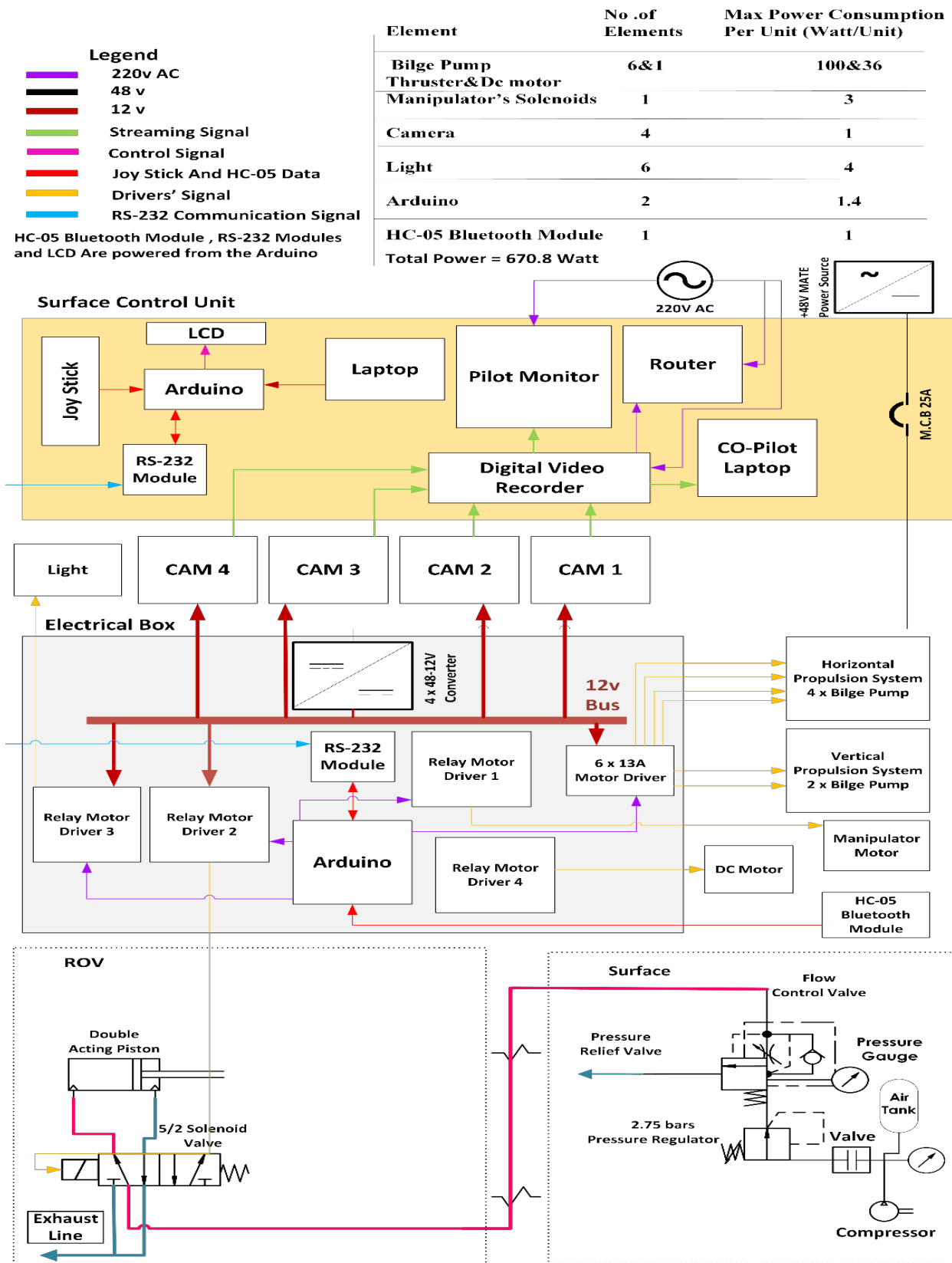
C. Project Costing and Income

	Item	Note	Qty	Amount	Total
Income	Sponsorship			\$ 17,660.00	\$ 17,660.00
	Members dues		20	\$ 105.00	\$ 2,100.00
	Alexandria University	local Travelling and accommodation	1	\$ 180.00	\$ 180.00
	Total Income				\$ 19,940.00

Torpedo 2017 Project Costing							
Type	Category	Expense	Sources/Notes	Qty	Amount	Total	
Electrical System	Purchased	Electronics	JOYSTICK	LOGITECH	1	\$62.50	\$ 62.50
	Purchased	Electronics	RELAY MODULE	4CH	2	\$3.60	\$ 7.20
	Purchased	electronics	DC-DC CONVERTER	20A 12V	8	\$40.00	\$ 320.00
	Purchased	Electronics	MOTOR DRIVER	13A CYTRON M.D.D	12	\$21.20	\$ 254.40
	Purchased	Electronics	ARDUINO MEGA	MICROCONTROLLER	4	\$13.50	\$ 54.00
	Purchased	Electronics	CAMERA	CCTV WIDE ANGLE	6	\$24.25	\$ 145.50
	Purchased	Electronics	CAMERA BALUN		8	\$2.50	\$ 20.00
	Purchased	Electronics	LED	12V LED HIGH POWER	6	\$0.60	\$ 3.60
	Purchased	Electronics	XT-60 CONNECTOR	60A POWER CONNECTOR	30	\$0.75	\$ 22.50
	Purchased	Electronics	FAST CONNECTOR	8 PIN SIGNAL CONNECTOR	4	\$0.60	\$ 2.40
	Purchased	Electronics	DC GEARED MOTOR	20KG.CM 133 RPM	4	\$13.70	\$ 54.80
	Purchased	Electronics	BLUETOOTH MODULE	HC-05	6	\$5.50	\$ 33.00
	Purchased	HARDWARE	PCB	COMPONENTS	1	\$107.00	\$ 107.00
	Purchased	Electronics	TETHER	POWER CABLE 13AWG AND ETHERNET CAT 6	1	\$60.00	\$ 60.00
	Mechanical System	RE-used	HARDWARE	SOLENOID		2	\$10.00
Purchased		MATERIAL	GRIPPER	POLYAMIDE	2	\$7.00	\$ 14.00
Purchased		MATERIAL	CAMERA HOUSING	POLYAMIDE	5	\$7.00	\$ 35.00
Purchased		MATERIAL	FRAME	STAINLESS STEEL ROD	1	\$12.50	\$ 12.50
Purchased		MATERIAL	BOLTS AND NUTS		1	\$21.00	\$ 21.00
Purchased		HARDWARE	BILGE PUMP	12V	10	\$45.50	\$ 455.00
RE-used		HARDWARE	PENUMATIC	DOUBLE ACTING	2	\$15.00	\$ 30.00
Purchased		HARDWARE	PROPELLER SET	T-100 PROPELLER	5	\$27.00	\$ 135.00
Purchased		HARDWARE	ELECTRICAL BOX	ALUMINUM SHEET	1	\$155.00	\$ 155.00
Purchased		HARDWARE	FIBER GLASS COVER		1	\$40.00	\$ 40.00
Services	Purchased	FABRICATION	WELDING	ALUMINUM ELECTRONICS BOX	1	\$40.00	\$ 40.00
	Purchased	FABRICATION	CNC	LASER CUTTING , PCB ROUTING	1	\$60.60	\$ 60.60
	Purchased	FABRICATION	MACHINING	CAMERA HOUSING , GRIPPER , COUPLING	1	\$45.00	\$ 45.00
Total Invested In ROV Vehicle						\$ 2,210.00	
Tether Control Unit	Purchased	HARDWARE	SURFACE CONTROL UNIT	FRAME	1	\$24.25	\$ 24.25
	Purchased	Electronics	USB HOST SHIELD	KEYES	2	\$8.80	\$ 17.60
	Purchased	Electronics	POWER SUPPLY	12V 2A	1	\$2.25	\$ 2.25
	RE-used	Electronics	DVR		2	\$24.50	\$ 49.00
	RE-used	Electronics	POWER SUPPLY	48V 40A MEANWELL	1	\$125.00	\$ 125.00
	RE-used	Electronics	DC CIRCUIT BREAKER	25A DOUBLE POLES	2	\$10.00	\$ 20.00
	Purchased	Electronics	CURRENT SENSOR	30A	1	\$4.00	\$ 4.00
	Purchased	Electronics	LCD	2004	1	\$7.30	\$ 7.30
	Purchased	Electronics	ANDIRESON CONNECTOR	30A	4	\$1.90	\$ 7.60
Purchased	Electronics	FLAT SCREEN MONITOR	17 INCH	2	\$52.00	\$ 104.00	
Total Invested In Tether Control Unit						\$ 361.00	
Extra Expenses	Purchased	OTHER	TRANSPORTATION	LOCAL AND REGIONAL	1	\$180.00	\$ 180.00
	Purchased	OTHER	LOCAL REGISTRATION FEES		1	\$150.00	\$ 150.00
	Purchased	OTHER	T-SHIRT s		30	\$5.45	\$ 163.50
	Purchased	OTHER	POOL RENT		1	\$363.00	\$ 363.00
	Purchased	OTHER	PRINTING	POSTER	1	\$41.00	\$ 41.00
	purchased	OTHER	COMPETITION TRAVEL	INTERNATIONAL TRANSPORTATION	20	\$757.00	\$ 15,140.00
	Purchased	OTHER	COMPETITION ACCOMODATION	INTERNATIONAL ACCOMODATION	1	\$2,590.00	\$ 2,590.00
	Purchased	TOOLS	NEW TOOLS		1	\$60.60	\$ 60.60
Total Invested "Purchased or Reused"						\$ 21,259.10	
Total Purchased						\$ 21,015.10	

Figure 47. Income and Project costing for the year 2017.

D. System Interconnection Diagram and Power Budget



Circuit Breaker Calculations:

- Max power Consumption = 670.8 Watt
- Input Voltage = 48V
- Converters Efficiency = 88%
- Overload Factor = 1.5

$$\text{Current Drawn} = (670.8/48)/.88 = 15.88 \text{ A}$$

$$\text{C.B Rating} = \text{Current Drawn} * 1.5 = 23.82 \text{ A}$$

A 25A C.B is used to protect Latro

Figure 48. System Interconnection Diagram with maximum power budget included.

E. Software Flowcharts

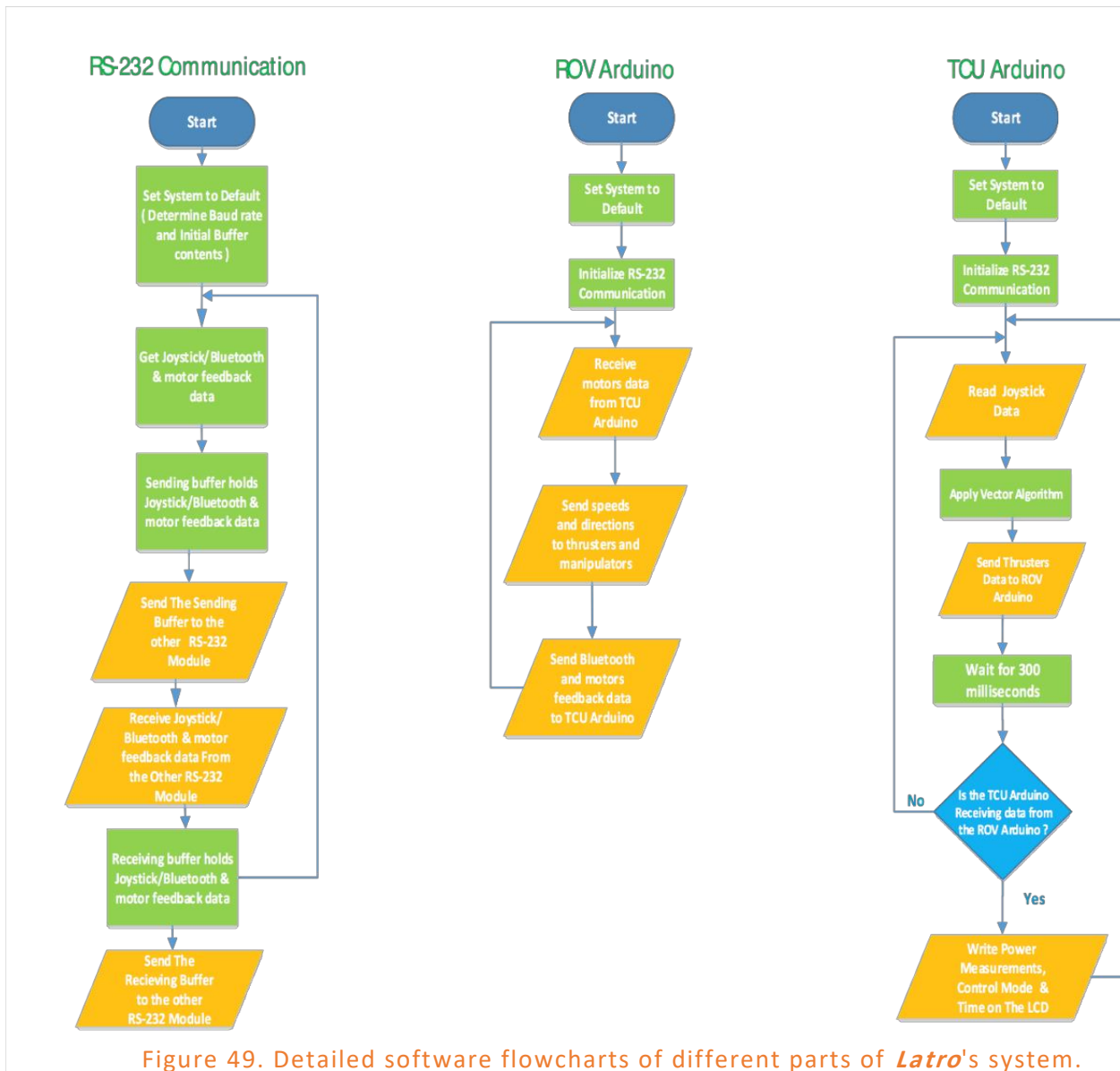


Figure 49. Detailed software flowcharts of different parts of *Latro's* system.

F. Project Management and Timeline

Our company members needed a concise plan description to clarify the phases of work so that they can follow up their tasks and stick to the deadlines. Consequently, team leaders presented the work plan using Gantt chart. The chart displayed project deadlines, along with external deadlines set by the competition organizers. Afterwards, the team CEO distributed the tasks among sub-team leaders to accomplish all requirements and deliverables on time.

Torpedo company was divided into sub-teams to help accomplish tasks faster, neater and in a more effective way. Each leader distributed tasks among members according to their abilities and in a way to enhance their capabilities. A meeting was held at each workday's end to discuss the day's accomplishments and update the Gantt chart. Those who do not finish their work on time or violate the team's rules in general are penalized by contributing an amount of money to the team's CFO. Members who finish their work before time are given extra work to motivate them and exploit their potentials.

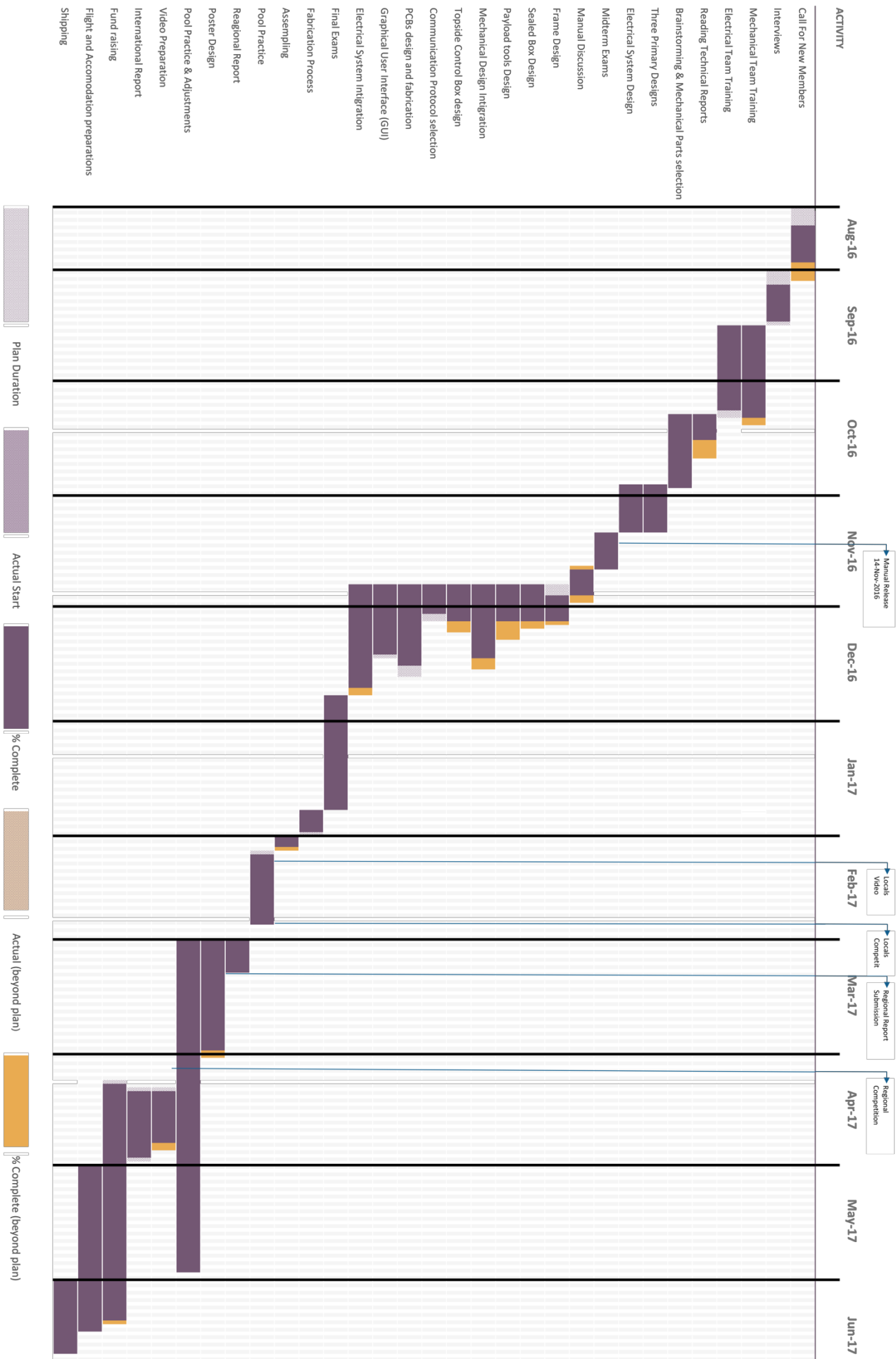


Figure 50. Torpedo's Gantt Chart.

G. Troubleshooting Techniques

During the fabrication and implementation of our ROV, our company ensured thorough testing of all mechanical and electrical components. Mechanical components' sealing was tested under 10m depth and electrical system's components were tested solely and then tested together until all features worked fine. Sometimes, issues happen, resulting from human error or random error, therefore, a clear troubleshooting plan was made to trace and take action on problems faced.

There are several techniques that our company use in troubleshooting problems. When an issue appears, we begin identifying the problem by testing step by step. The affected or malfunctioned components of the ROV determine the exact cause. Problems can be caused by loose connections, leakage resulting in electronics damage, firmware not updated, etc.

Tips followed as a standard approach to solving problems:

- Follow the system checklist.
- Analyze symptoms and factors.
- Isolate the source of the problem.
- Define an action plan.
- Reboot and check if everything is working fine.

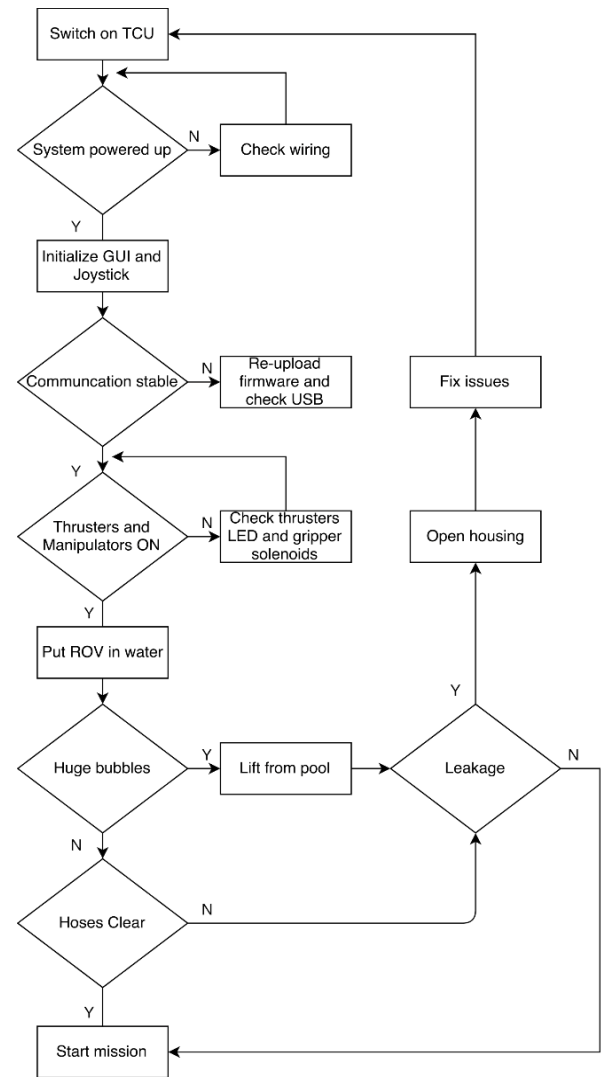


Figure 51. Flowchart of full vehicle troubleshooting.

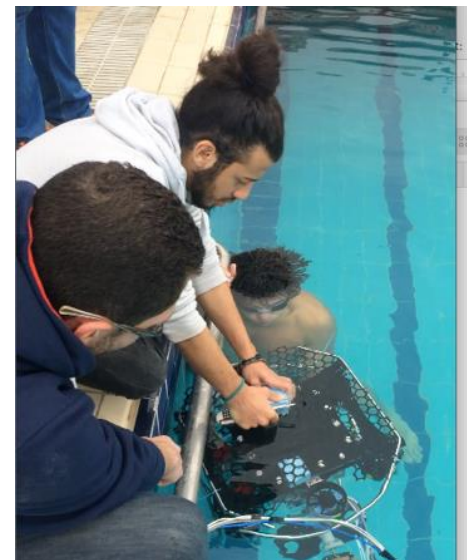


Figure 52. Troubleshooting and adjusting parts of ROV, such as buoyancy.

H. Community Service and Media Outreach

Torpedo Academy

Torpedo company has a great impact on the community. We established Torpedo Academy in 2015, assisting young school and college students in the robotics field, specially ROV. Torpedo Academy sessions are held every week, teaching students the basics of electronics, programming, and mechanics. We believe that in order for the community to advance, we must engage and share the knowledge for all. Emphasizing that the knowledge is passed to next generations.



Figure 53. Mo'men Amin introducing robotics concepts to new students in Torpedo Academy.

Media Outreach

Our team conducted an interview on Egyptian national television, where they spoke about MATE, the ROV industry and the ROV competition, reaching out thousands of viewers. We also shared our experiences with the host and discussed future improvements and future plans.

I. Company Effort

All our work wholly was done and contributed by company members themselves. We did not need any external technical support or professional assistance for any reason. Thanks to our mentors who passed on their experience and provided us with a lot of encouragement and psychological support, we were able to handle our problems and develop our skills in technical and non-technical fields. Besides technical work, company members spent a great deal of time on technical documentation. Our technical documentation director distributed tasks among members to be written according to MATE's scoring sheets, where each point was precisely taken into consideration and every detail was looked into with greatest care.



Figure 54. Karim Genina and Mohab Said speaking about ROVs on National TV.