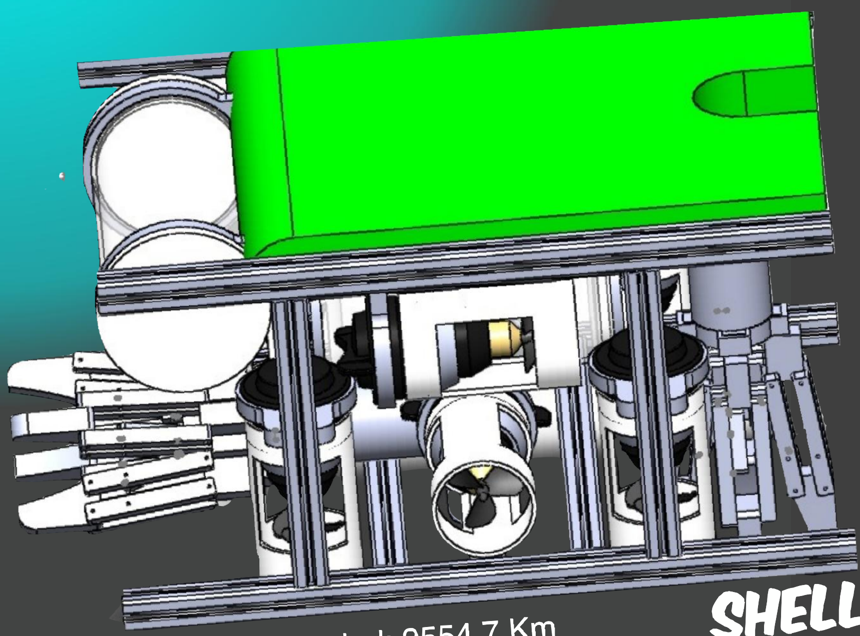
SEA PEARL

EXPLORING THE DEEP

Notions Development Academy,
Alexandria, Egypt.



SHELL

Distance Traveled: 9554.7 Km

Team Members:

Salma Mohamed: CEO, Chief Electrical Engineer & Co-pilot (1st year).
Farah Amr: CFO, Chief Mechanical Engineer & TetherWoman (1st year).
Samaa Mohamed: R&D & HR Manager (3rd year).
Nouran Khaled: Media Designer & Marketing Manager (1st year).
Aly Elazazy: Software Developer & Pilot (1st year).
Ahmad Ashraf: Electrical Engineer (1st year).
Omar Khaled: Mechanical Engineer (1st year).
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Yassin Tamer: Safety Officer (1st year).

Team Mentors:

Mohamed elKholy.
Nouran Soliman.

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Abstract:

Sea Pearl Company is working in the underwater robotics field, designing and building ROVs with a wide range of special features; depending on customers' requirements. Our employees' deep experience is harnessed to build polyethylene motor housings, efficient manipulators and aluminum frames, aiming to provide the customer the sophisticated service demanded. Apart from high-quality and efficiency; *Sea Pearl* has always been aware that the low cost is an essential factor that must be taken into consideration.

For the first time, our main aim is helping the scientists and conservation groups to diminish the corrosion of the Thunder Bay National Marine Sanctuary (TBNMS), which was spoiled by the human species in the first place. These archaeological areas are believed to be vital as they cover significant features such as the groundwater, which is rich in minerals, emerging from sinkholes, and microbes expanding in sinkholes as well. *Shell*, *Sea Pearl*'s ROV was designed to professionally explore a recently- discovered shipwreck, identify it, and remove litter from and around it. Adding to this, *Shell* is capable of collecting microbial samples from sinkholes, along with measuring the conductivity of groundwater emerging from it. ***(Word count: 188)***

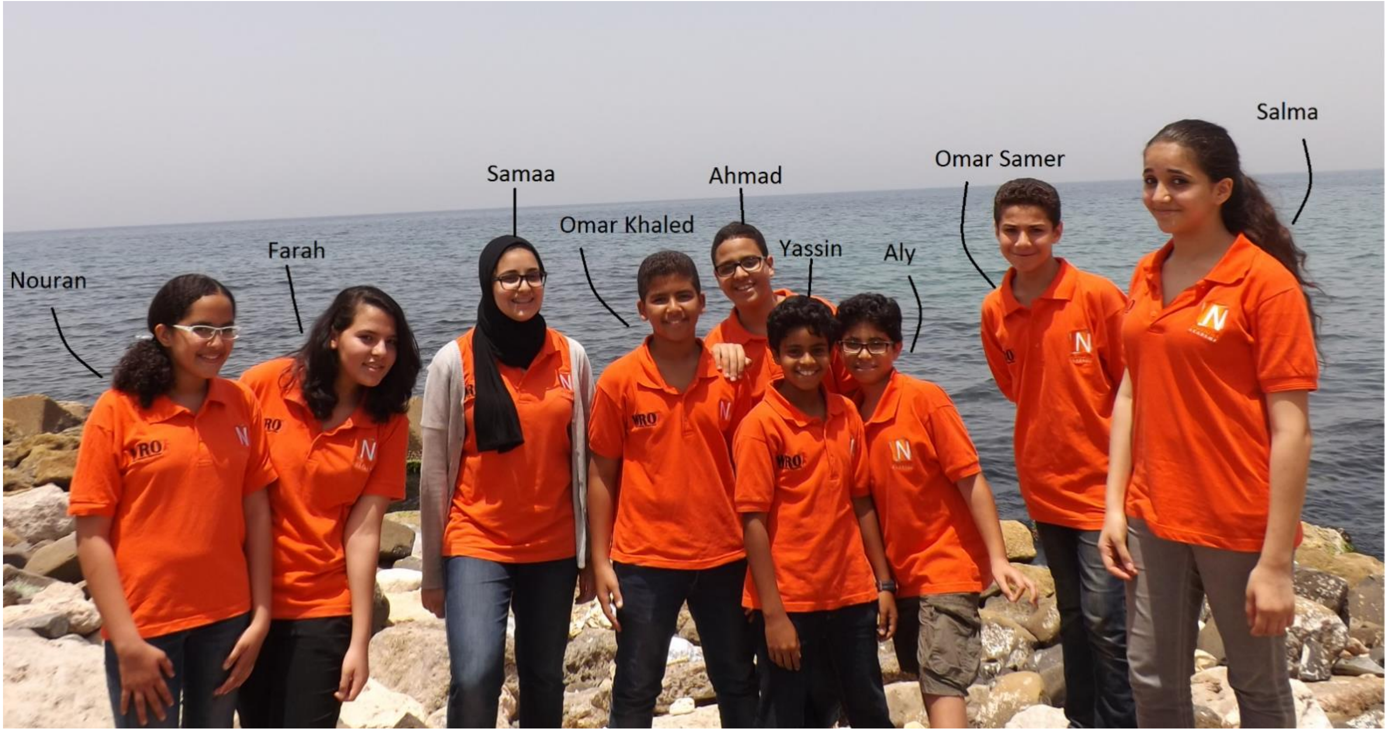


Figure 1 Sea Pearl team

Mission Theme:

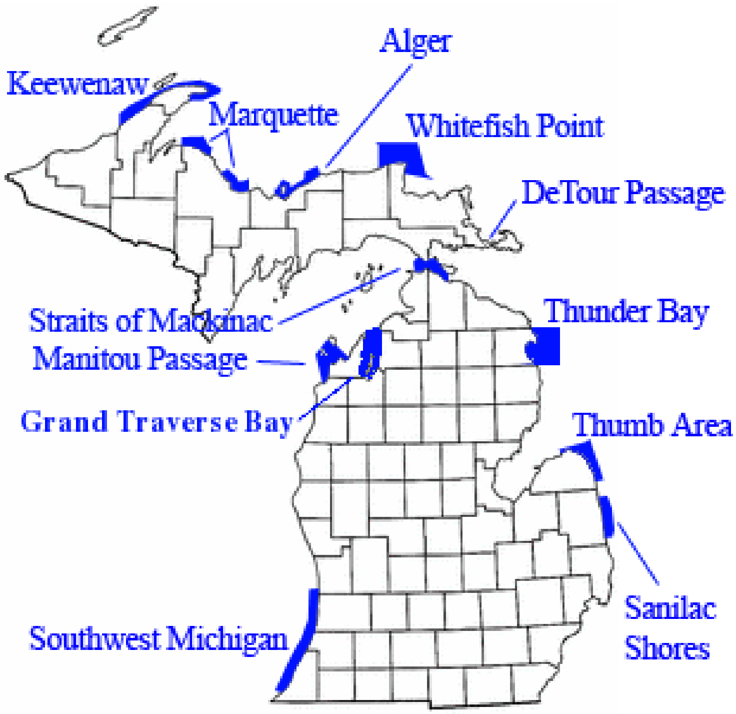


Figure 2 Map of Michigan

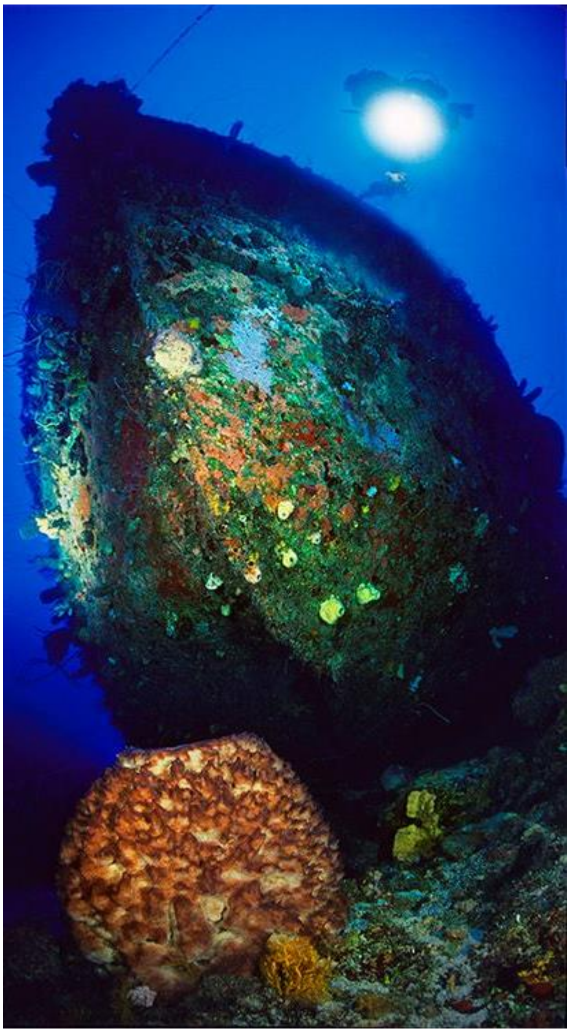


Figure 3 Shipwreck

The **Thunder Bay National Marine Sanctuary (TBNMS)** is a U.S. Sanctuary, within the state of Michigan, Figure 2 clearly shows its location. Thunder Bay has acquired the nickname "Shipwreck Alley" for good reason as it is estimated that over 100 zebra mussel-covered shipwrecks lie inside its current boundaries as shown in Figure 3. This special place is important to the regional economy and protects world-class historical and recreational shipwreck sites. The TBNMS is also home to some unique geological formations, for example: the finger-like Misery Bay Sinkholes which are in shallow water and are deep fissures in the natural limestone.

Robots, in general, are used to accomplish tasks which humans are incapable of undertaking. The TBNMS's conditions are tough to be survived by divers, such as the unpredictable weather, cloudy fog banks, huge depth, and rocky shoals. Thus, the ROVs are used to explore and discover the shipwrecks, as they document sceneries using their high-definition cameras, to the screens at the piloting station. In addition, these ROVs are capable of collecting microbial samples from sinkholes, using their manipulators, as well as measuring the conductivity of the groundwater; emerging from sinkholes too, using sensitive sensors. Furthermore, the ROVs are used to remove the litter from and around the shipwrecks, as to conserve heritage.

Strategy:

Sea Pearl Company managed to put a sequenced strategy in order to organize and facilitate accomplishing the mission tasks for the pilot Aly Elazazy, as you can see in Figure 4. The strategy consists of two main parts, inside and outside the shipwreck, and the tasks performed using the floating box used for carrying the mission tools are underlined:

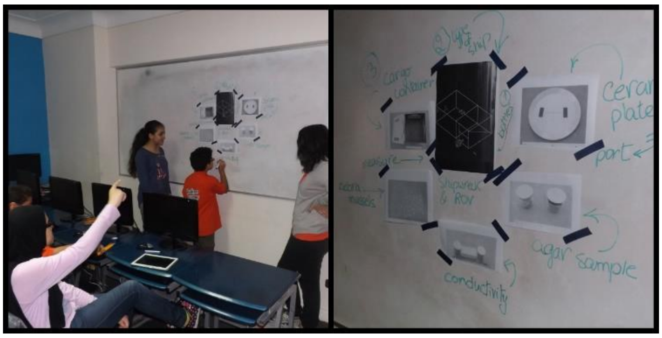


Figure 4 *Sea Pearl* Discussing the strategy

1) Outside the shipwreck:
   a) <u>Collect the plastic and glass bottle</u>
   b) Determine the type of the ship: propeller-driven, steam-driven paddlewheel or wooden sailing schooner.
   c) Unlocking then opening the cargo container, to determine the cargo type.
   d) Closing the cargo container and then locking it.
   e) Calculating the dimensions of the shipwreck and comparing it with the Zebra-quadrat.
   f) Placing the quadrat on top of the ship, counting the zebra mussels inside it and finally estimate the total number of zebra mussels on the shipwreck.
   g) Correctly scanning the target.
   h) Determining which groundwater conducts electricity.
   i) Collect microbial sample using the Dipper (the agar) then bring it to the surface.
   j) Replace the sensor string with a new one in the correct place.
   k) <u>Remove the anchor line rope then return it to surface.</u>
2) Inside the shipwreck:
   a) <u>Finding then returning the ceramic plate to surface, to determine the home port of the ship.</u>
   b) Search for the date of building of the ship from port.

Acknowledgments

Sea Pearl Company had taken effort to accomplish this ROV the way it functions. However, it would not have been possible without the support and help of many individuals and organizations. We would like to extend our sincere gratefulness to all of them, especially our sponsors Pylux Solutions and Sainte Jeanne Antide School.

First of all, we are grateful to the Marine Advanced Technology Education Centre (MATE) and the Arab Academy for Science, Technology and Maritime Transport (AASTMT), for giving our company this opportunity to compete in this event.

In addition, we would like to express our gratitude towards our parents for their financial and moral support.

Furthermore, we are highly thankful to Notions Development Academy and Eng. Mamdouh Azmy and Eng. Mohamed Essam for the guidance and constant supervision as well as for the technical and academic support.

We desire to express our special gratitude to our mentors Nouran Soliman and Eng.Mohamed Elkholy for giving us such precious attention and time, as well as teaching us the bases of electronics, mechanics and programming.

Finally, we would like to show our gratitude towards Aquabotics and Oceanus previous teams for their help and support.

Figure 5 *Sea Pearl* sponsors.

1. Design rationale:

The innovation and construction of *Shell* ROV is professionally based on an organized plan. *Sea Pearl* staff determined what is exactly needed; they researched, developed ideas, and concluded the required methods and materials. Beforehand the actual construction of *Shell*, it was CAD-designed and modified using SolidWorks until *Sea Pearl* staff settled on the most suitable design.

1.1. Frame:

Before the regional competition, a frame made from PVC was constructed, which you can see its SolidWorks design in Figure 6, to sustain a low price and a very light mass. However, PVC has proven to be non-practical as it disturbs the buoyancy due to water leakage inside the body of the ROV.

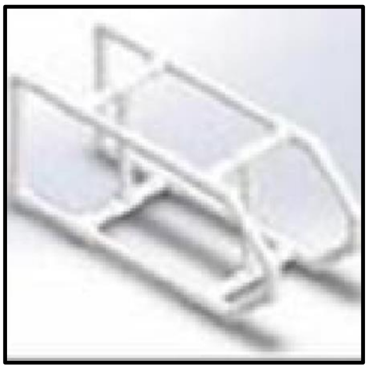


Figure 6 Previous PVC ROV SolidWorks design by Omar Samer.

High strength-to-weight ratio, reasonable cost, availability and ease of machining were the major factors considered by *Sea Pearl* during the design and building processes. To acquire such aims, *Sea Pearl* staff had to pick another material for the frame which came out to be aluminum.

Several designs were simulated by the staff using different methods, before taking the "actual building" step. First of all, the ROV was simulated using LEGO as shown in Figure 7. Afterwards, the ROV was designed on SolidWorks as Figure 8 shows. Finally, *Sea Pearl* started the actual implementation process after making sure of the efficiency of the design and materials.

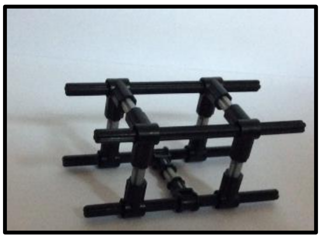


Figure 7 *Shell* designed using Lego by Omar Khaled.

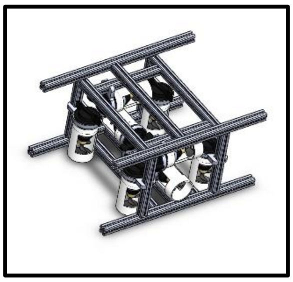


Figure 8 *Shell* designed on SolidWorks by Farah.

Shell possess a symmetrical frame designed out of 1/2 inch high aluminum tubes with dimensions 42*32*23.8 cm (L*W*H). Using aluminum tubes is practical and efficient as they are corrosion-resistant, light, budget friendly, close at hand and are considered an excellent safety feature as they have no sharp edges. The small surface area of the aluminum bars, which is 2cm, reduces water drag force on the frame.

Furthermore, the crew made sure of maintaining the dimensions required to pass through the 60cm*60cm hole in the shipwreck shown in Figure 9. Shell's dimensions have proven to be compact and efficient with a low water drag on the body.

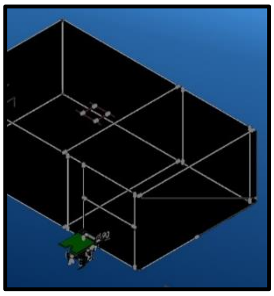


Figure 9 Shell passing through the hole to the shipwreck by Farah.

1.2. Buoyancy:

Sea Pearl managed to make the center buoyancy and the center gravity to, almost, balanced by adding weight and floating device as shown in Figure 10.

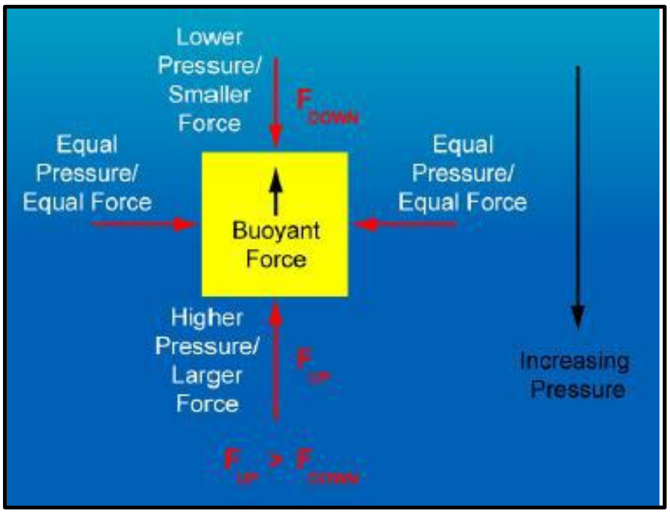


Figure 10 ROV Buoyancy [1].

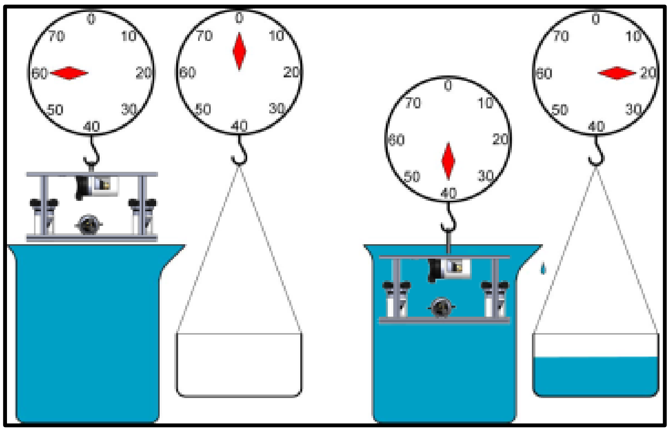


Figure 11 Measuring buoyancy.

The buoyancy was calculated as shown in Figure 11.
The mass of the ROV outside water (m) = 1.96Kg
ROV weight (w) = m*g = 19.6 N (g≈10)
Up thrust force (f) = ρ*g*h
=1000*10*23.8
= 233478 N

Net force (ΣF) = 233478-19.6

=*233458.4 N*

Sea Pearl's mechanical team planed an experiment to calculate the amount of foam needed to carry the ROV. Thus, they cut a uniform cubic foam piece of volume 1 cm^3 and added weights until it was balanced in the water, as calculated as follow:

$1cm^3 \rightarrow 1.1g$

$V \rightarrow 1.96/10$

Where V is the volume of floating material needed for critical floating of the whole ROV.

$V=\frac{1.96/10}{1.1} = 0.178cm^3$

The staff calibrates the ballast of the ROV before each trial; as the water is different in each pool due to different densities as a result of a difference of percentage of chemicals such as salts and chlorine. Besides, the temperature affects the water.

1.2. Stability:

Stability was a major concern during the design and building process, as a very stable ROV is essential for scanning target locations as well as entering through the 60*60 cm hole to the shipwreck. This is maintained through a number of factors, as equal distribution of forces which gives very high stability in water. One of the other design characteristics that affect the stability of the vehicle is the aspect ratio (total mean length of the vehicle versus total mean width of the vehicle). For ROVs, the optimal aspect ratio depends upon the anticipated top speed of the vehicle, alongside with the need to maneuver in tiny spaces. The ratio of Shell's length-to-width is 3:2, providing high stability [2]. In addition, the distance between the center of buoyancy and center of gravity of the vehicle determines the ROV's stability; as it is a factor of the righting moment [3].

The fourth factor considered by Sea Pearl's mechanical staff to sustain high stability is the tether pull point as shown in Figure 12 [2].

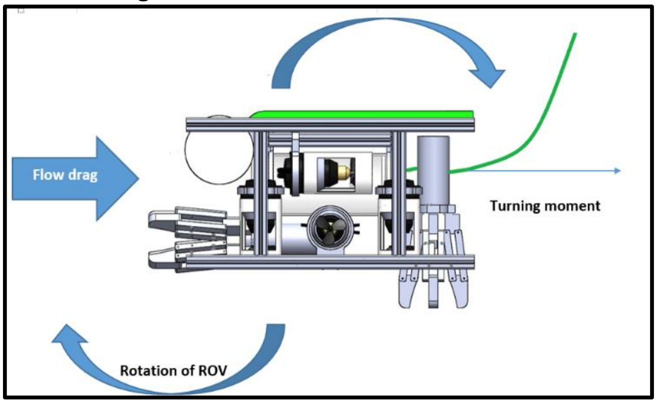


Figure 12 Tether pull point.

The tether pull point is on the same horizontal plane of the horizontal thrusters, which reduces the moment on the body, therefore reducing the turning effect.

1.3. Isolation:

In order to prevent water leakage, the mechanical team designed and built camera's sealed Polyethylene housing.

Besides, the isolation in the electric can used by *Sea Pearl* staff improved from wax and rubber to the O-rings as they were easier to apply and remove, more efficient and cheaper as well.

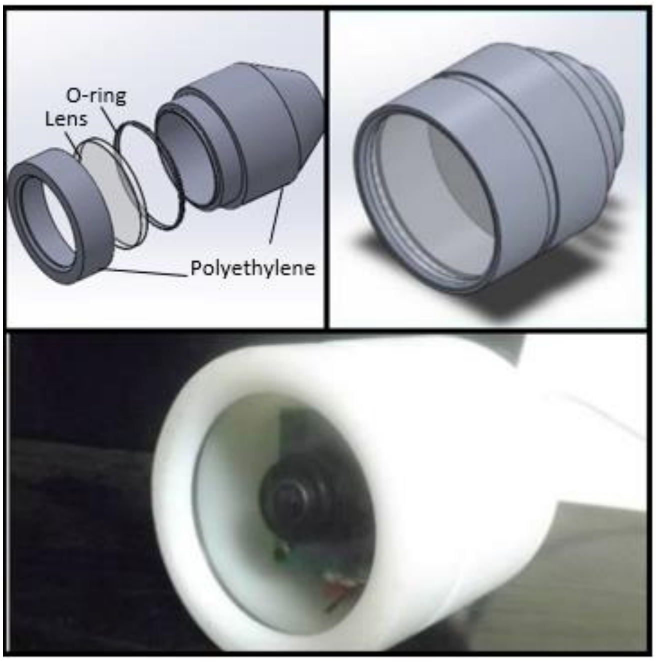


Figure 13 Camera housing.

1.4. Thrusters:

Shell is pushed by eight Johnson Pump thrust motors of 1250 G/H power, which are shown in Figure 14.

Figure 14 Johnson Pump motors, designed on SolidWorks.

The Johnson Pump motor was used after several tests on different combinations of motors and propellers in order to obtain the best thrusters. [You may see Appendix- table of comparison of motors]

Besides to thrusters' tests, the motor housing was tested in order to diminish the water resistance and improve the water flow [Figure 15].

Figure 15 Motor housing.

1.4.1 Motor settings:

In Figure 16, the motors setting can be clearly identified: four thrusters are arranged horizontally and four vertically.

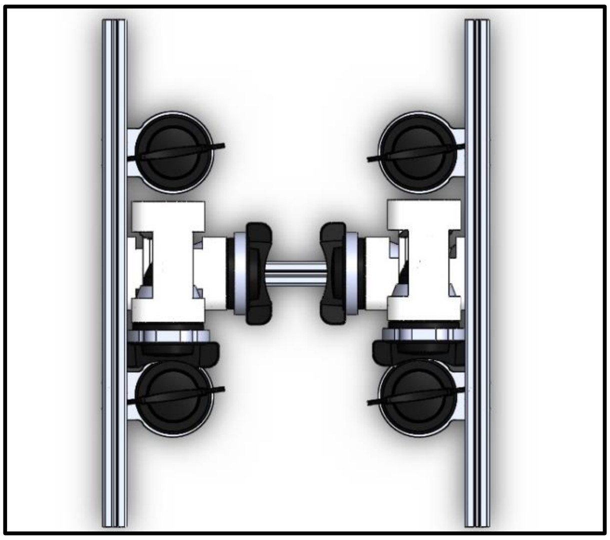


Figure 16 Motor setting, top view.

1.4.2. Degrees of freedom:

Shell moves around six degrees of freedom. Four horizontal thrusters are installed for three different movements (surging, heaving and axes respectively) and four vertical thrusters are installed for three rotations (rolling, yawing, and pitching around these same respective axes). All these degrees of freedom are illustrated in Figure 17.

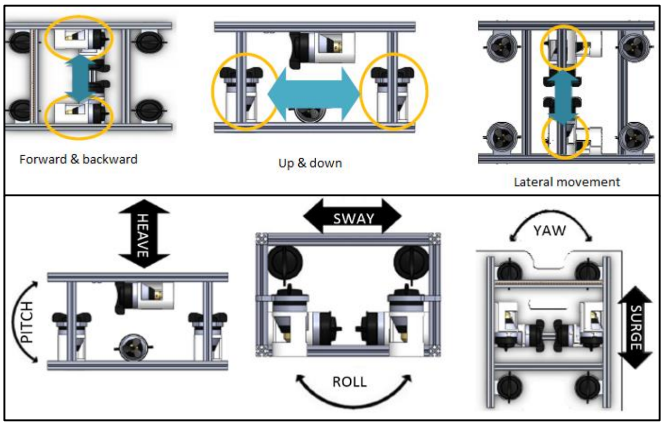


Figure 17 Degrees of freedom.

1.5. Kort nozzles:

They are surrounding the motors, mainly for safety issues; to avoid the harm caused by the propellers' continuous movement to the underwater creatures and prevent the entrance of any foreign object to the propellers.

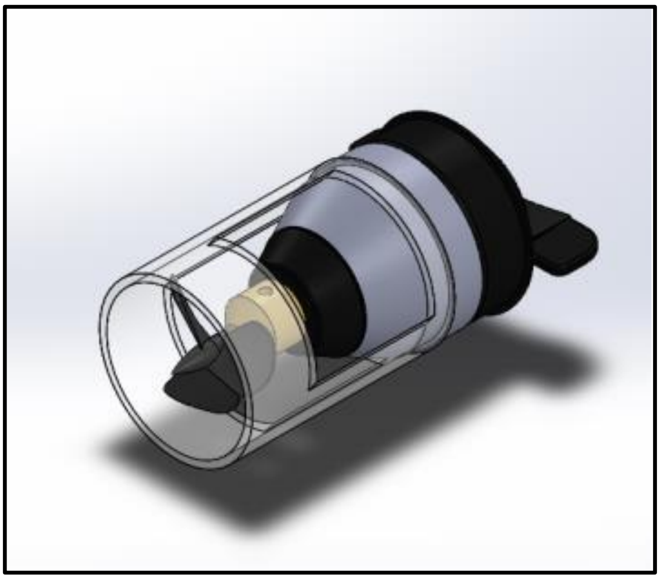


Figure 18 Kort nozzle.

Technically, the Kort nozzles, which are shown in Figure 18 above, are used to boost the thrust of the motors along with reducing the current intensity by 0.6A which is a significant value on the long-term use of *Shell*.

They also improve both the propulsion efficiency and water flow. Salma and Ahmad measured the current of the Johnson Pump 1250GPH motor with Kort nozzles and without, combined with both 5mm and 6mm propellers, and compared the results as below:

Propeller	Current/A	Kort nozzle	Without Kort nozzle
5mm		4.0	4.3
6mm		5.7	4.0

Table 1 Testing Current with and without Kort nozzle, by Ahmad Ashraf.

1.6. Propellers:

Sea Pearl's staff considered choosing suitable propellers to combine between the best efficiency and the less current consumption possible. Thus, figure 18 shows the harbor model 50 mm propeller with three blades as it was the ideal propeller after comparing it with the propellers in table 1. Also *Sea Pearl*'s staff has distributed the thrusters with left and right propellers to provide stable movement in the ROV as shown in Figure 19 [4].

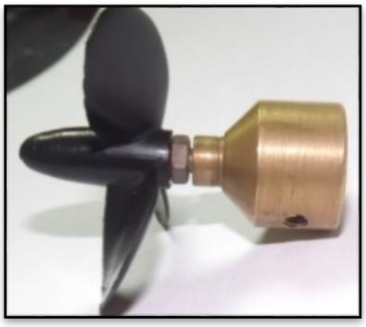


Figure 19 Propeller.

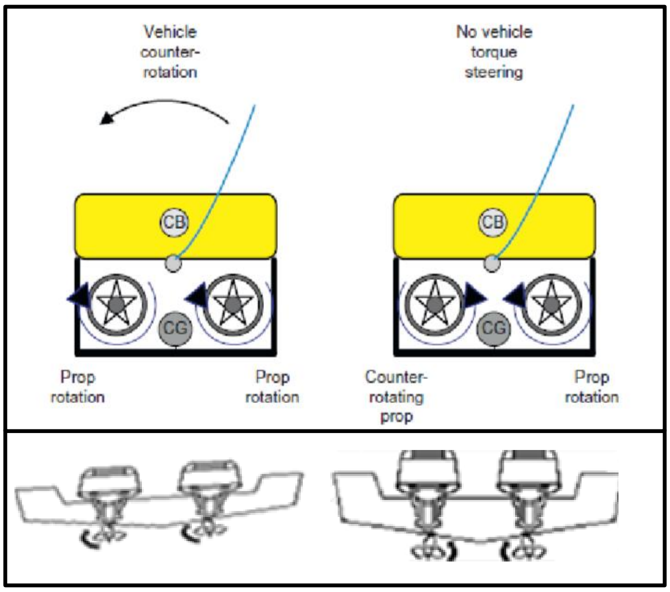


Figure 20 Propeller setting.

1.7. Manipulators:

Shell possesses two nylon 101 manipulators as this year's missions require lifting several objects from the seafloor and often in the same time, such as the plastic and glass bottles. Both manipulators are controlled by DC motors and possess four fingers as shown in Figure 21.

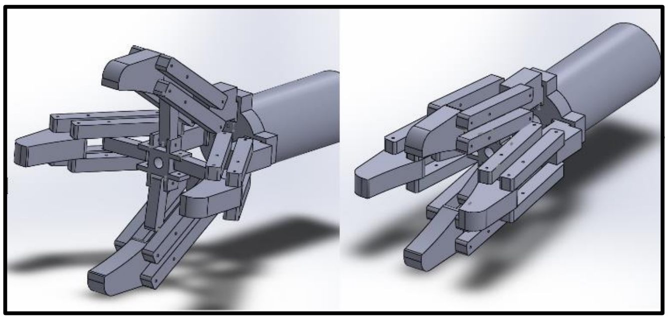


Figure 21 Manipulator open and closed.

What's more, the DC motors are able to give the manipulator enough power to be able to lift weights such as the sensor string weighing 10N in Task #2 and the plate in Task #1.

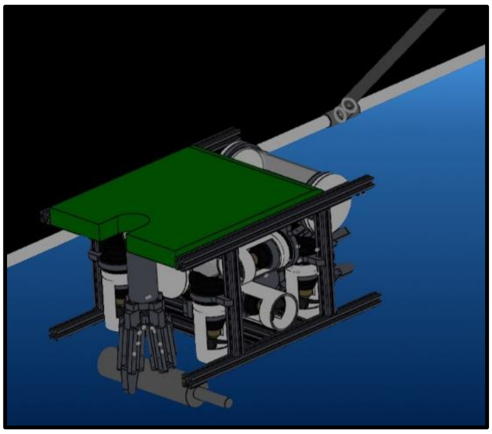


Figure 22 Shell grabbing the PVC bottle from the seafloor, designed by Farah.

These manipulators have a maximum opening of 15 cm which enables holding the plastic and PVC bottle (as shown in Figure 22) as well as unlocking and opening the cargo container; in Task #3.

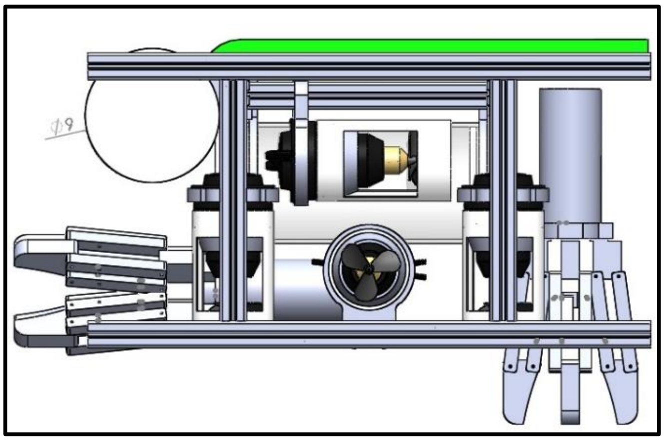


Figure 23 Manipulators' position in *Shell*.

1.8. Lighting:

As shown in Figure 24, increasing the water depth leads to decrease in the light penetration in the open ocean. Although *Shell* is equipped with cameras with IR light and four 360° LED arrays, with decreasing the brightness the image noise increases.

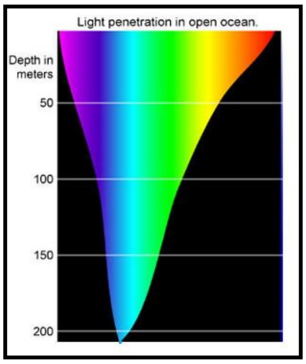


Figure 24 Light penetration in Open Ocean. [6]

Besides, in this year's MATE ROV competition, ROVs must enter an opaque shipwreck to be able to perform certain missions which are grabbing the ceramic plate to bring it back to s surface and determining the date of manufacture of the ship. The previous missions require a strong lighting, thus Shell is equipped with four 360° white LED arrays in the front electronic can, which are shown in Figure 25.

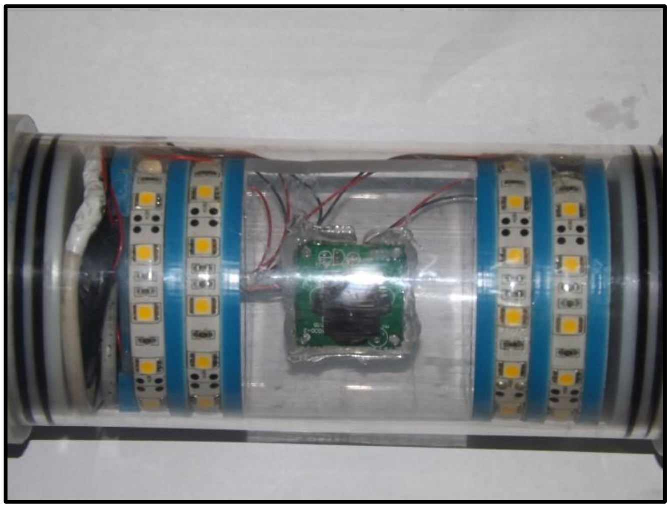


Figure 25 Four 360° LED arrays.

1.9. Payload description:

Shell possesses multi-purpose payloads which are designed to complete the MATE ROV 2013 mission tasks as well as a variance of general uses.

1.9.1. Normandy:

The idea of the floating box was initially inspired by the ROV of the American ocean explorer Robert Ballard. The floating box *Normandy* is made of PVC tubes, its dimensions are: 60*60*20cm (L*W*H), it is shown in Figure 26.

Figure 26 Omar constructing the floating box, *Normandy*.

Shell is set off the shore with *Normandy* pushed by its manipulator. When piloting underwater, the items needed to be returned to the surface are placed in the floating box and these are the ceramic plate, the sensor string, the anchor rope and both bottles. Then, the floating box is set free by pulling the release pin and *Shell* pushes *Normandy* to the shore then the tetherwoman, Farah Amr, grabs it using its handle. This method has two advantages: firstly, it reduces the surfacing frequency which means benefiting the most of the 15-minutes underwater mission performance. Secondly, the floating box has a sufficiently large surface area to hold all the items and it is more practical than using the manipulators only.

1.9.2. Zebra-quadrat:

Since this year's missions require building a 50*50 cm quadrat to perform Task #2: science, the ½ inch PVC quadrat shown in Figure 27 was built by the mechanical team members.

Figure 27 Zebra-quadrat.

It is easily placed in top of the shipwreck so the co-pilot can count the zebra mussels in the quadrat and then enter them in the software to calculate the estimate of the total number of mussels covering the shipwreck.

1.9.3. Dipper:

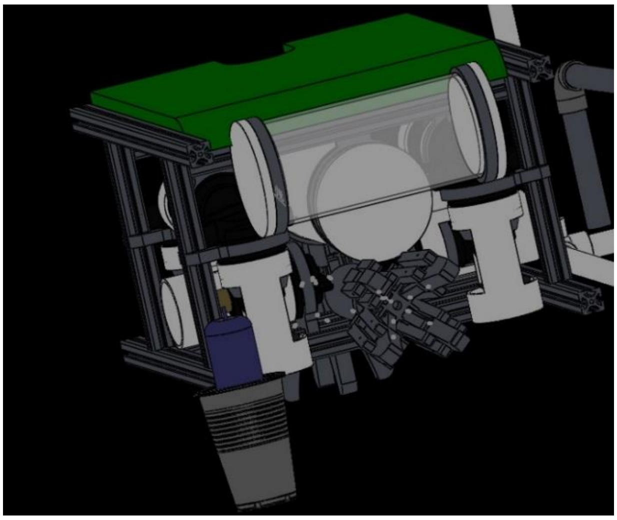


Figure 28 *Shell* taking a sample from the agar.

In order to take a sample from the agar container underwater, the staff built a *Dipper* which is a polyethylene tube fixed to *Shell* before the trials. Depending on the thick bulkiness of the agar, the Dipper penetrates it without the escape of the agar, while the pilot drives *Shell* upwards, as you can see in Figure 28.

1.9.4. Conductivity sensor:

Figure 29 shows a diagram of the circuit of the conductivity sensor. An analog input on the AVR is used to measure the voltage drop across the 10kΩ resistor. While the voltage drop could be easily measured across the conductivity sensor by making it the "resistor" closest to ground, configuring the circuit as shown causes the voltage measured at the analog input to increase as the water becomes more salty. Configuring the circuit so that more salt causes a higher system output makes analysis of system output more intuitive.

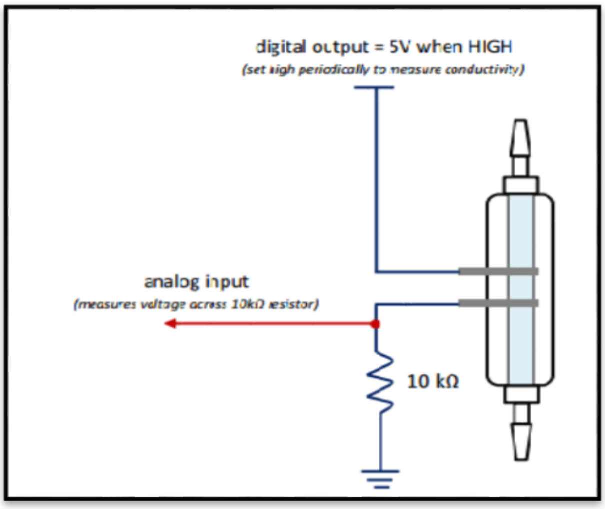


Figure 29 Conductivity sensor circuit.

1.9.5. *Tapload*:

In order to measure the dimensions of the shipwreck, a simple but yet efficient tape meter attached to a hook was built by the mechanical team: *Tapload,* seen in Figure 30. The pilot is able to view the scale of the tape meter by using the electric can's camera.

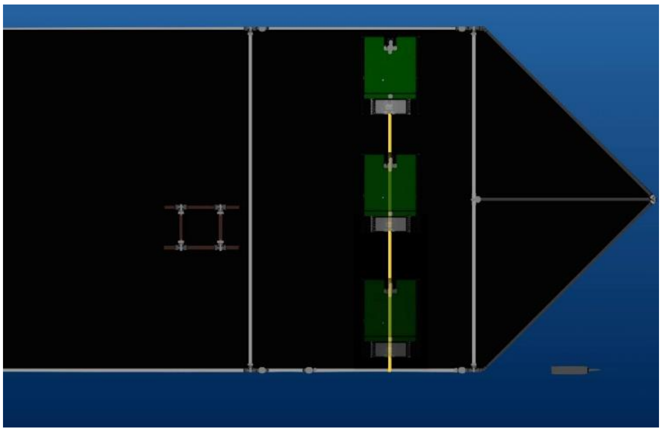


Figure 30 *Shell* measuring the ship width using the Tapload.

2. Control and communication:

2.1. Software:

Depending on the staff's own material instead of a commercial program allows both reducing the cost and adapting the features according to the missions. Aly; *Sea Pearl*'s software developer built two programs using C language in the regional competition, then he updated it using LabView such as in Figure 31.

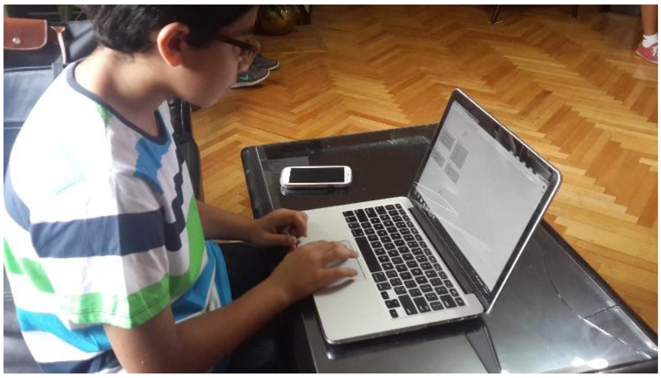


Figure 31 Aly programming using Labview

2.1.1. Ship data:

This program in used to accomplish most of Task #1 and identify the ship according to the port, date of building the ship, the cargo and the type of the ship by entering clicking few times in bullets as shown in Figure 32.

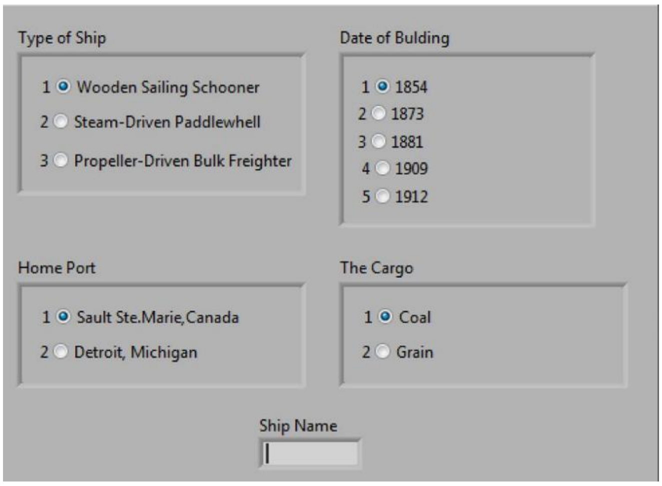


Figure 32 Ship identification LabView code.

2.1.2. Zebra mussels counter:

Salma's job is to estimate the number of zebra mussels covering the ship using the dimensions previously measured using the *Tapload*. Thus, a program, shown in Figure 33, was built which eases and fastens the process of calculating the zebra mussels and accomplishing Task #2.

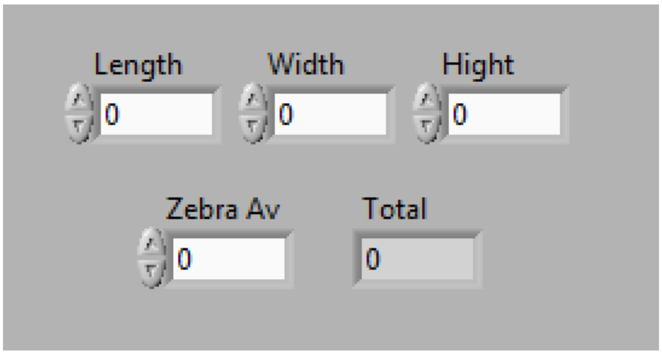


Figure 33 "Zebra mussels counter" LabView code.

2.2. Driving station:

Sea Pearl staff has designed a driving station to ease the piloting of Shell by providing two screens plugged to the tether, providing a wide range of vision of the mission field. An emergency button is fixed at the bottom of the driving station, it blacks the system out in case of any emergency. Besides, a 25A fuse is placed in order to open the circuit in case of any overconsumption of current.

A laptop is available as well, thus the co-pilot is able to estimate the number of zebra mussels and determine the type of the ship using a LabView code.

2.3. Camera:

Figure 34 Camera

In order to successfully navigate inside the shipwreck, Shell encloses three cameras, shown in Figure 34:

The main camera, which is placed inside transparent tube containing the 360° led arrays, gives a wide prospective of the mission filed. This tube is located in the center of the ROV.

Isolated using plastic housing, the second camera is directed to the arms on the left top of the vehicle as well as the Dipper. Its position is quite helpful while performing mission tasks such as lifting the ceramic plate, grabbing the bottles and taking an agar sample.

The third camera is positioned at the back of *Shell* as this privilege assists in piloting, giving the opportunity of exiting the shipwreck easily.

4. Tether:

The staff manufactured a tether with length 180cm, mass of 3 kg in air and diameter of 1.4 cm, shown in Figure 35. The tether contains 25 data cables: 0V and 12V cables for the motors, 0V and 12V cables for the camera, two others for the *Shell* power and 19 data wires.

Figure 35 Tether and tether management.

Every wire has an internal resistance, with this resistance, there is an associated power loss and voltage drop. So the voltage at the end of a tether is less than the voltage at power source. For example in Figure 36, a #22 gauge wire tether with length of 1800 cm has an internal resistance of 0.00491 Ω/m. The internal resistance produces a 0.4419 V voltage drop across the tether, leaving 9.7905 V for the ROV as shown in Figure 36.

As a result, *Sea Pearl* chose the current wire in order to reduce the lost voltage.

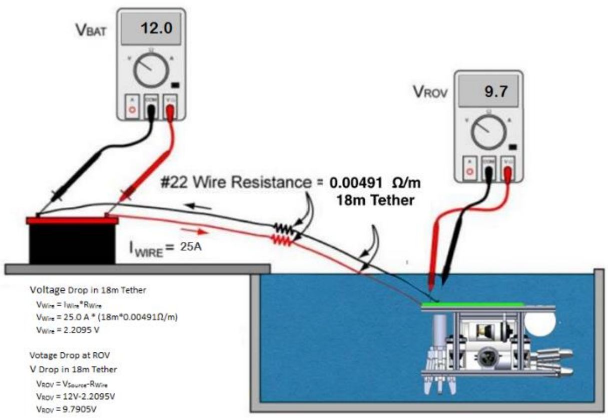


Figure 36 Example of calculating resistance of a wire.

Thus, the main options to reduce power loss in a tether:

1. Shorten the tether,

2. Increase the voltage,

3. Place the battery on board the vehicle,

4. Choose a larger gauge wire to reduce the internal resistance.

Thus, a large gauge wire was chosen because it is the only option available, as the other three options are not allowed in MATE ROV general rules.

The tether is ejected from the back of the ROV as it is situated in the middle of the end caps of the electric can, at the same level of forward and backward thrusters. The previous prevents the interference of the tether in the movement of Shell underwater. It is fully shielded to protect against any water interference in the wires as well as to avoid the entrance of water inside the electric can.

As all underwater missions, in the international event, will take place within 10 meters from the edge of the pool and the control station will be no more than 3 meters from the side of the pool, *Sea Pearl* staff had to take the decision of adding a tether splitter; also taking into consideration that the missions will be of 6.5 meters depth. The tether splitter offers the opportunity to extend the tether to the required length for this year's special mission floor.

5. Electronics:

Shell possess two electric cans, a can containing the main camera and the LEDs' array, the second can containing the electric circuits. Each electronic can is made of a clear acrylic cylinder of an inner diameter 9cm and thickness 0.3cm, enduring very high pressure underwater.

Generally, building the electronic circuits was a practical application on Proteus and Altium courses which the staff has accomplished before constructing Sea Pearl's electric system and cans.

Since it is their first time to join MATE ROV competition as well as their knowledge in electronics is still primary, *Sea Pearl*'s crew decided building a very simple, but yet well operated, control system which is shown in Figure 37 .The company chose the relays as the main control circuit board for Shell as reliability, stability and, above all, minimizing the tether's diameter- diminishing the drag force on it- , are just a few of the advantages of using a relay board.

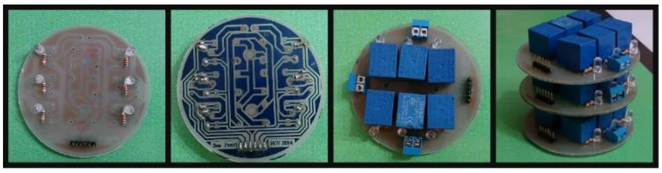


Figure 37 Relay boards development steps.

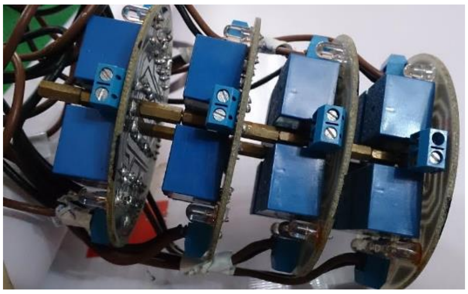


Figure 38 Four circular modules relay boards.

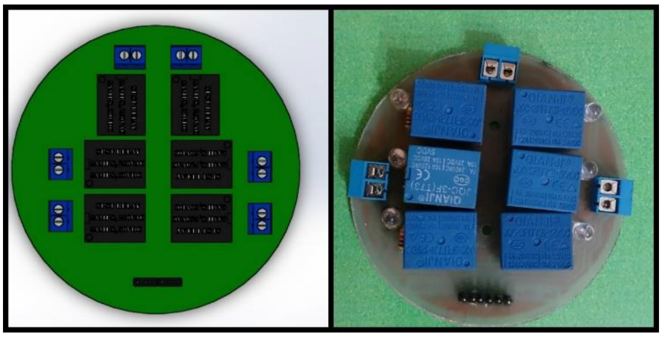


Figure 39 Relay board, designed on SolidWorks by Farah Amr, and then made by Salma Mohamed.

The electrical team's first experiment was connecting the motors cables to the remote control. However, the tether was heavy as a result of the Gage of the power wires. Thus, the relays were chosen as an option. Figures 37 till 39 show the relay main parameters as well as development.

Sea Pearl's staff designed four circular electrical modules each one operates three motors bi-directional shown in Appendix-. The crew tested the boards on Protues and they functioned correctly as shown in Figure 40. The diameter of each module is 8 cm.

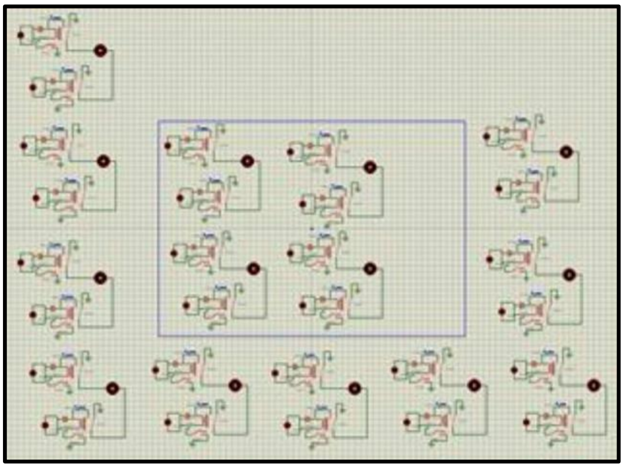


Figure 40 Proteus design by Salma and Ahmad.

The main advantage of using circular modules is providing a practical replacement and easy expansion.

Our staff used Altium Designer to build the electric circuit as shown in Figure 41.

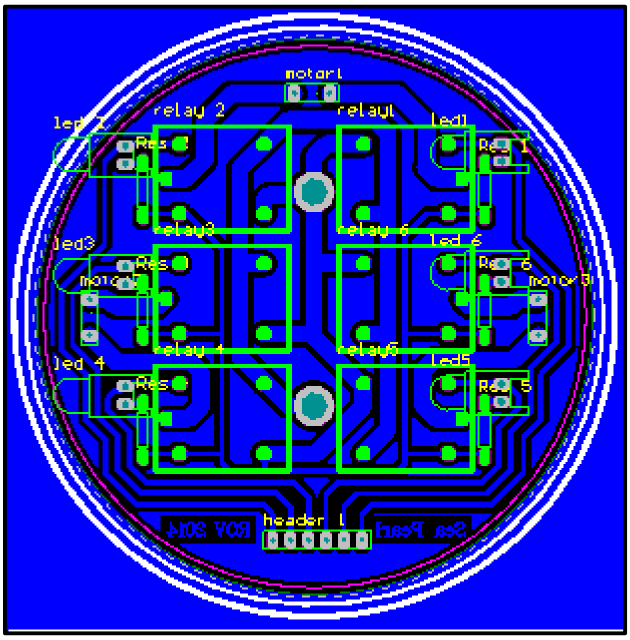


Figure 41 PCB design on Altium Designer by Salma and Ahmad.

The electrical system in Appendix shows the full system diagram which consists of:

• A source of electrical power.

• A fuse close to the power source for the safety of the electrical circuit.

• An ON/OFF switch.

• A joystick.

• A Tether which is used to deliver data and electrical power to Shell.

• A load – all of the electrical equipment onboard the vehicle.

6. Safety:

6.1. Safety philosophy:

Safety has always been in *Sea Pearls'* concern for both staff and ROV. The company's safety philosophy can be resumed in "Safe working and efficient learning". Strict rules and guidelines are enforced when handling the components and the ROV itself as there is a safety checklist placed in the lab (which is attached in the Appendix- Safety checklists) .

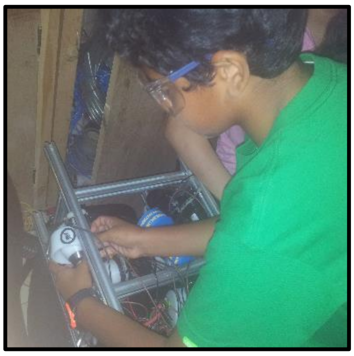


Figure 42 Yassin attaching Kort nozzle with caution sign on to thruster.

6.2. Crew safety:

Sea Pearl Co. imposed the list below on the crew before working inside the Notions' workshop:

• Wearing eye goggles as well as rubber gloves.
• Using insulated tools while working either electrically or mechanically.
• Ensuring the circuits are not connected to a power source while repairing any damaged circuits.
• Using a current tester to make sure the electric current is still passing through the wires.
• Working on wooden floor to avoid electric shock.
•Ensuring the floor is not slippery.

Sea Pearl staff has put the factor of safety of the ROV four times the range the staff could face so all our components were tested to a pressure of two bars which is approximately equal to 20.3 meters.

6.3. Safety checklist:

In order to keep the crew safe in the workshop Yassin's job, the safety officer, was to maintain the workshops safe by checking daily the functionality of the equipment, the presence of caution sign on moving parts as in figure 31 and more. You may return to [Appendix-Workshop safety checklist] to read the whole safety checklist.

6.4. Mechanical wise:

• O-rings are incorporated into the end caps; to maintain complete isolation at a pressure of two bars.

• A Kort nozzle is attached to each motor [You may read Kort nozzles section]
• *Shell* does not have any sharp edges.
• A caution sign is attached to moving parts, tether and Kort nozzles.

6.5. Electrical wise:

• A 25A fuse is connected to the power line of the tether placed in the driving station.
• A 5A fuse is placed on each motor.
• An emergency button is placed in the driving station to blackout the system in case of any emergencies.

7. Conclusion:

7.1. Challenges:

7.1.1. Non-technical challenge:

As a team consisting of nine students, each one with a number of responsibilities and studies; it was actually hard to fix appointments on our Facebook private group (as shown in fig 43) to discuss the work done and the one which has to be accomplished. This affected negatively the development of the company, adding that the members hardly kept following the track of its progress.

Figure 43 A post on *Sea Pearl* private group.

To solve this challenge, it was suggested by some team members to change the meeting strategies by dividing the team into departments: electrical, mechanical, media and marketing. In other words, the CEO, Salma Mohamed, holds a meeting with the head of each department to discuss the company's plan to finish building the ROV the best way the company can afford. Then, each head department holds a meeting with his/her team to fix deadlines, working appointments and materials used.

Another challenge faced was wasting time and energy in conflicts between the team crew one and another. Arguing with team members was, of course, a result a mental and physical fatigue. The more the team argued, the stress and negative attitude roam, reducing the group morale greatly. To solve this significant issue, Samaa Mohamed, the HR manager, advised the team to take breaks, discuss ideas with evidences instead of arguing and most importantly, resuming work in the next meeting or working day.

7.1.2. Technical challenge:

Fitting the wires inside the tether was quite a challenge for the mechanical and electrical team. As after the regional competition, the electrical team needed to add extra data wires. The problem was that after fitting the cables, they were cut in their middle.

The whole crew participated in the process of replacing them with new ones, as you can see in Figure 44, which was laborious and, of course, time consuming. Also, they covered the wires with Vaseline and duct tape in order to overcome the difficulty of passing them inside the tether.

Figure 44 *Sea Pearl* team members casing the wires.

Another significant challenge the crew faced was the electrical circuits and can dimensions. Due to lack of a wide range of choices of acrylic cylinders dimensions in our city and even in the capital, *Sea Pearl* had to be bounded by the current dimensions: a height of 20 cm, outer diameter of 9 cm and inner diameter 8cm. This forced the mechanical team to design the electrical circuit on SolidWorks with the dimensions which fit in the tube the most. The electrical team then had to design the circuits using Altium Design with the same configuration.

7.2. Teamwork:

An exceptional ROV cannot be accomplished with the lack of teamwork, as teamwork is considered a main factor in any company's success.

Figure 45 Samaa, the HR manager, holding a meeting about team work

After dividing the staff into mechanical and electrical teams, *Shell* was manufactured from scratch, by all team members. In addition, each electrical and mechanical team members took part in writing brief reports on the construction of the ROV; as these reports were useful in writing the main technical report required by the MATE ROV competition. In other words, both of the report and the construction of the ROV were **completely** a company effort.

Figure 46 *Sea Pearl* team members working in all fields.

Salma Mohamed, the CEO, developed a detailed schedule, in order to ensure that all the work will be done in time. The schedule table is also provided in the Appendix, where it is clear that there was no overlap in the work and each member was aware of his responsibility.

Every week, a table was filled with the tasks done consequently which also facilitated enormously writing the technical report which was Samaa Mohamed's task, the research and development officer.

Figure 47 Samaa Skyping Farah when she was sick.

The company staff was always in touch. They were communicating to synchronize meeting times and discuss their tasks together. As shown in Figure 47, Samaa was updating Farah with what they have been up to, when Farah was sick.

These communication methods built a strong bonds and a wonderful spirit of teamwork in the company which strengthened the cooperation between the staff members. As a result of the enhancement of the team spirit, the rate of work was enhanced as well.

7.3. Troubleshooting and testing methods:

7.3.1. Troubleshooting techniques:

An ROV such as *Shell* is a complex machine where many things can go wrong. As it was developed, a number of issues were encountered and the staff had to figure out the reason of these "troubles" to solve them.

Therefore, "elimination technique" steps were developed and followed by the staff. For instance, one example of technical challenges faced was the failure of the camera to operate. First of all, the power supply was checked, if it was working rightly, then the connection of the on-board network switch has to be checked. If the network connection was eliminated and yet the camera was not working, the software engineer Aly checks the software and looks for bugs to correct them.

7.3.2. Testing techniques:

Firstly, a pressure chamber [Figure 38] was built by *Sea Pearl* crew to test all the mechanical components used, such as the electronic can and the motor housing.

This chamber simulates a depth of over 20.3m, which is approximately four times the specified in the MATE ROV competition rangers' class. In addition, in the regional competition's training, the fail of the isolation of the electronic can with a layer of wax and a thick layer of rubber made the staff use a new isolation method this competition: the O-rings, which is described in the isolation section.

Figure 48 The pressure chamber used to test components.

Most importantly, *Shell* was tested gradually as in the opposite pictures [Figure 49] as to test each ROV's isolation and floating part. And after accomplishing the whole ROV, it was tested in a swimming pool several times to check the reliability of the control, motors, arm and floating box.

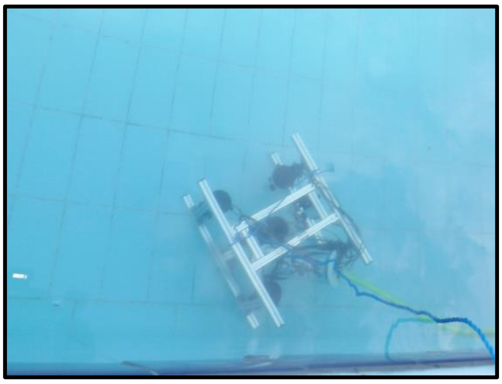


Figure 49 *Shell* being tested for the third time.

7.4. Lessons learned:

7.4.1. Technical:

Throughout this beneficial experience, a wide range of lessons were learned which might be impossible to list all of them. To begin with the technical lessons and skills, the whole crew learned and professionally used various electric and mechanic programs; for instance Altium Designer, Solid Works, Code Vision, LabView, Visual C as well as art design that is Photoshop.

Although, the majority of the company members had participated in other competitions, some of the members had never been trained on how to work with programs identical to these, however; now every member of the company can proudly say that he/she can deal with them brilliantly.

7.4.2. Interpersonal:

This ROV experience enhanced the staff time management skills quite a lot. This helped the team in their personal life, as they became able of comprise between the school life and the work of ROV. In addition, *Sea Pearl* enhanced their team work and communication skills. Punctuality was remarkably improved, which is really vital in staff's everyday life.

7.5. Reflections:

Salma Mohamed: "Participating in the ROV competition taught me an important everyday life skill: time managing! Also, it offered me the opportunity to learn electrical and mechanical engineering which helped me in deciding my future career: studying mechatronics (electrical and mechanical majors in the same time) later in college."

Farah Amr: "Becoming *Sea Pearl*'s CFO greatly changed my personality, as I became tidier and more precise. Besides, I started thinking thoroughly before taking any step especially to avoid spending money in useless stuff. In addition, I enjoyed learning and designing SolidWorks."

Samaa Mohamed Ali: ”Well, the ROV competition made me think of taking a major in marine robotics, but most importantly, I learnt some social skills that will extremely help me in achieving my personal aims later on.”

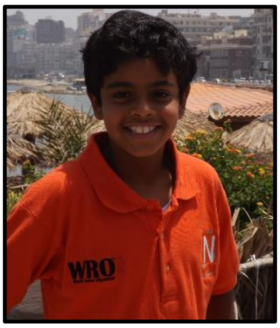
Aly Elazazy: “Becoming Sea Pearl’s pilot taught me piloting skills which are quite fun! Technical wise, I learnt C programming and LabView.”

Ahmad Ashraf: “Since it was my first time to participate in ANY competition, I learnt team work as well as time management. What I learnt technically the most was building circuits and understanding electronics.”

Omar Khaled: **“**It was a very useful experience working on Solid Works and manufacturing *Shell*.”

Omar Samer: “This ROV experience taught me taking responsibilities, self-learning and respecting deadlines.”

Yassin Tamer: “I am very happy working with Sea Pearl, the company staff had no problem to receive and share their experiences with new comers. Moreover, I learnt to use Solid Works and Altium Design.”



Nouran Khaled: **“**I applied my Photoshop and design skills as I was the media designer in Sea Pearl, as I designed the poster and report diagrams, which was wonderful!”

7.6. Future improvements:

7.6.1. Technical:

7.6.1.1. Mechanical:

* Using a manipulator with more degrees of freedom.

* Improving the frame design to diminish the drag force on the body.

7.6.1.1. Electrical:

* Add micro-controllers to decrease the cables in the tether; this will decrease the opposite force hitting the ROV and the tether.

7.6.2. Non- technical:

* Improving the marketing of the company as well as the media design.

8. Media outreach:

The marketing manager, Nouran in Figure 50, had taken great efforts to promote our newly developed company in a variance of ways.

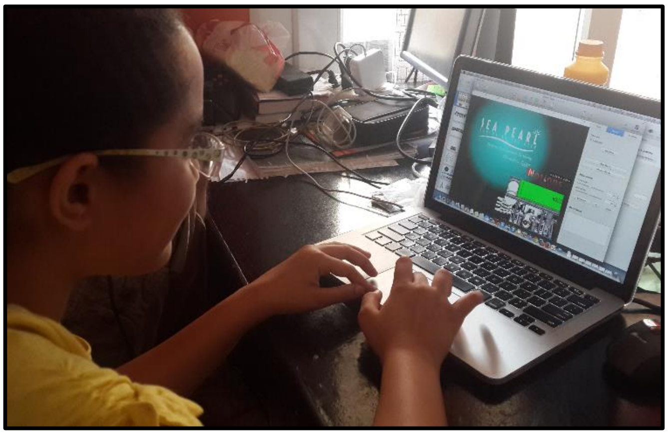


Figure 50 Nouran designing report's cover page.

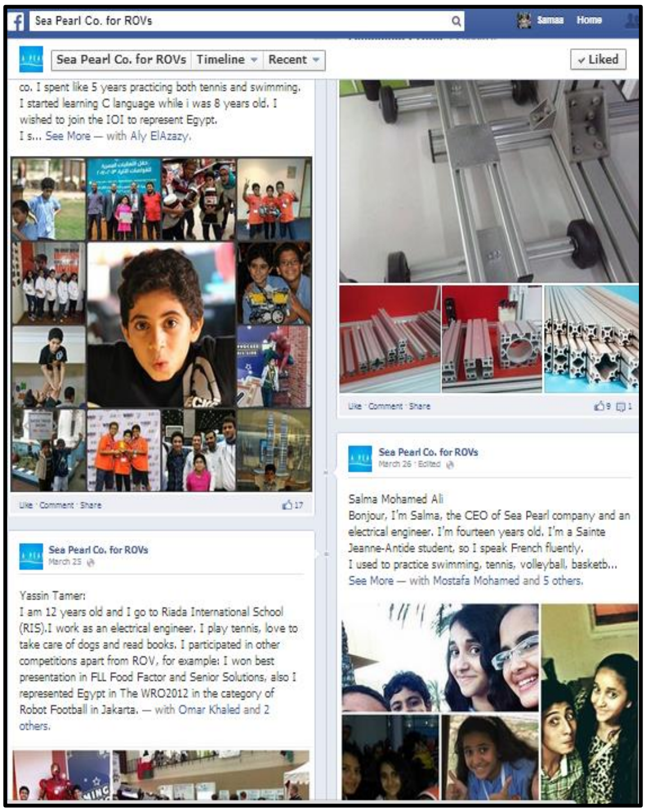


Figure 51 *Sea Pearl* page.

Figure 52 Samaa at the *Yessed Sabahak* local TV show, on Channel2.

Besides, some pamphlets were designed, printed then distributed in schools and clubs. Being host of two different TV programs, Samaa, Aly and Omar talked about Sea Pearl crew, Shell and the future plans, as you can see in Figures 48 and 49.

Figure 53 Omar Khaled and Aly at the *Yessed Sabahak* local TV show, on Channel2.

9. Budget:

9.1. Income:

#	From	Income/$	
1	*Sea Pearl* team	9,543.52	
2	Notions Development Academy	460.09	
3	Pylux Solutions, LCC.	285.71	
4	Sainte Jeanne Antide School	1,428.57	
		Total/$	11,717.8

Table 2 Income

9.2. Outcome:

Item	Number of Items	Donations/ $	Unit price/$	Reused/$	Total Price/$
MECHANICAL ITEMS					
Motors	8	176.00	22.00	-	176.00
Motor Axis	8	24.00	3.00	-	24.00
Propellers	8	90.88	11.36	-	90.88
Aluminum bars	11	-	8.57	-	94.29
Aluminum connectors	50	-	1.05	-	52.50
End Caps	4	-	2.86	-	11.43
Motor Holders	8	-	1.23	-	9.84
Arm	2	-	57.14	-	114.28
ELECTRICAL ITEMS					
Isolated Camera	2	-	50.27	100.54	100.54
Screen	3	10.42	10.42	20.84	31.26
Camera	1	26.74	26.74	-	26.74
Tether	1	53.48	53.48	-	53.48
Miscellaneous	-	13.37	-	26.74	40.11
Electric Tube	1	28.57	28.57	-	28.57
ROV TOTAL/$		**460.09**		**148.12**	**853.92**
					-608.21
					245.71
GENERAL					
Team shirts	9	-	8.02	-	72.18
Airline tickets	11		1,000		11,000
Accommodation	4		100		400
TOTAL /$					**11,472.18**
TOTAL EXPENSES/$					**11,717.89**

Table 3 Outcome

10. References:

[1].eriii28_final_rov_construction, http://cornerstonerobotics.org/curriculum/lessons_year3/eriii28_final_rov_construction.pdf.
Retrieved on: 08/02/2014.

[2]. Ratio between length-to-width, center of buoyancy, tether pull point, Kort nozzles, RS-232, tether, TMS, spotlights, Manipulator Title: ROV Manual, ISBN-10: 0080982883, Author: Robert D. Christ.

[3]. Advantages of polyethylene and acrylic Title: Underwater robotics, ISBN-10: 0984173706, Author: Steven W. Moore.

[4]. Left and right propellers URL: http://www.boatfix.com/how/props.html, Retrieved on: 13/12/2013

[5] The ROV Manual By: Robert D. Christ and Robert L. Wernli, Sr. ISBN: 978-0-08-098288-5.

[6] http://www.wildcatlighting.com/Light_Chart.html Retrieved on: 20/03/2014

11. Appendix:

11.1. Motor comparison table:

Motors	Propellers				Forward Thrust	Backward Thrust	Motor RPM	Current	
	Diameter		Blades	Pitch					
Rule Bilge Pump 350 GPH	50 mm	Left	3	42	0.35	0.27	4100 RPM	2.14	2
		Right	3	42	0.41	0.12		2.16	1.9
	60 mm	Left	3	45	0.48	0.12		3	1.9
		Right	3	45	0.48	0.12		3	1.9
	75 mm	Left	3	?	0.6	0.4		4.7	4
		-	-	-	-	-		-	-
	10 mm	-	-	-	-	-		-	-
		Right	4	65					
Rule Bilge Pump 500 GPH	50 mm	Left	3	42	0.51	0.18	5770 RPM	3.7	2
		Right	3	42	0.51	0.14		3.75	1.96
	60 mm	Left	3	45	0.46	0.31		3	2.8
		Right	3	45	0.49	0.44		3.11	3
	75 mm	Left	3	?					
		-	-	-	-	-		-	-
	10 mm	Left	-	-	-	-		-	-
		Right	4	65					
Johnson Bilge Pump 500 GPH	50 mm	Left	3	42	0.45	0.16	5755 RPM	3.5	2
		Right	3	42	0.45	0.16		3.5	2
	60 mm	Left	3	45	0.44	0.18		3.5	2
		Right	3	45	0.44	0.18		3.5	2
	75 mm	Left	3	?					
		-	-	-	-	-		-	-
	10 mm	-	-	-	-	-		-	-
		Right	4	65				6.8	5.5
Rule Bilge Pump 1100 GPH	50 mm	Left	3	42	0.75	0.25	7600 RPM	5.1	4.4
		Right	3	42	0.75	0.25		5.1	4.6
	60 mm	Left	3	45	0.80	0.15		7.08	6.3
		Right	3	45	0.80	0.23		6.6	6.1
	75 mm	Left	3	?				9	6.7
		Right	-	?	-	-		-	-
	10 mm	-	-	-	-	-		-	-
		Right	4	65				10	9
Johnson Bilge Pump 1250 GPH	50 mm	Left	3	42	0.75	0.27	8225 RPM	4.7	4.0
		Right	3	42	0.75	0.26		4.8	4.6
	60 mm	Left	3	45	0.82	0.54		6.8	6.1
		Right	3	45	0.82	0.54		6.8	6.1
	75 mm	Left	3	?				9	6.4
		-	-	-	-	-		-	-
	10 mm	-	-	-	-	-		-	-
		Right	4	65				9.2	8.5

Table 2 Motor comparison.

11.2. System Diagram:

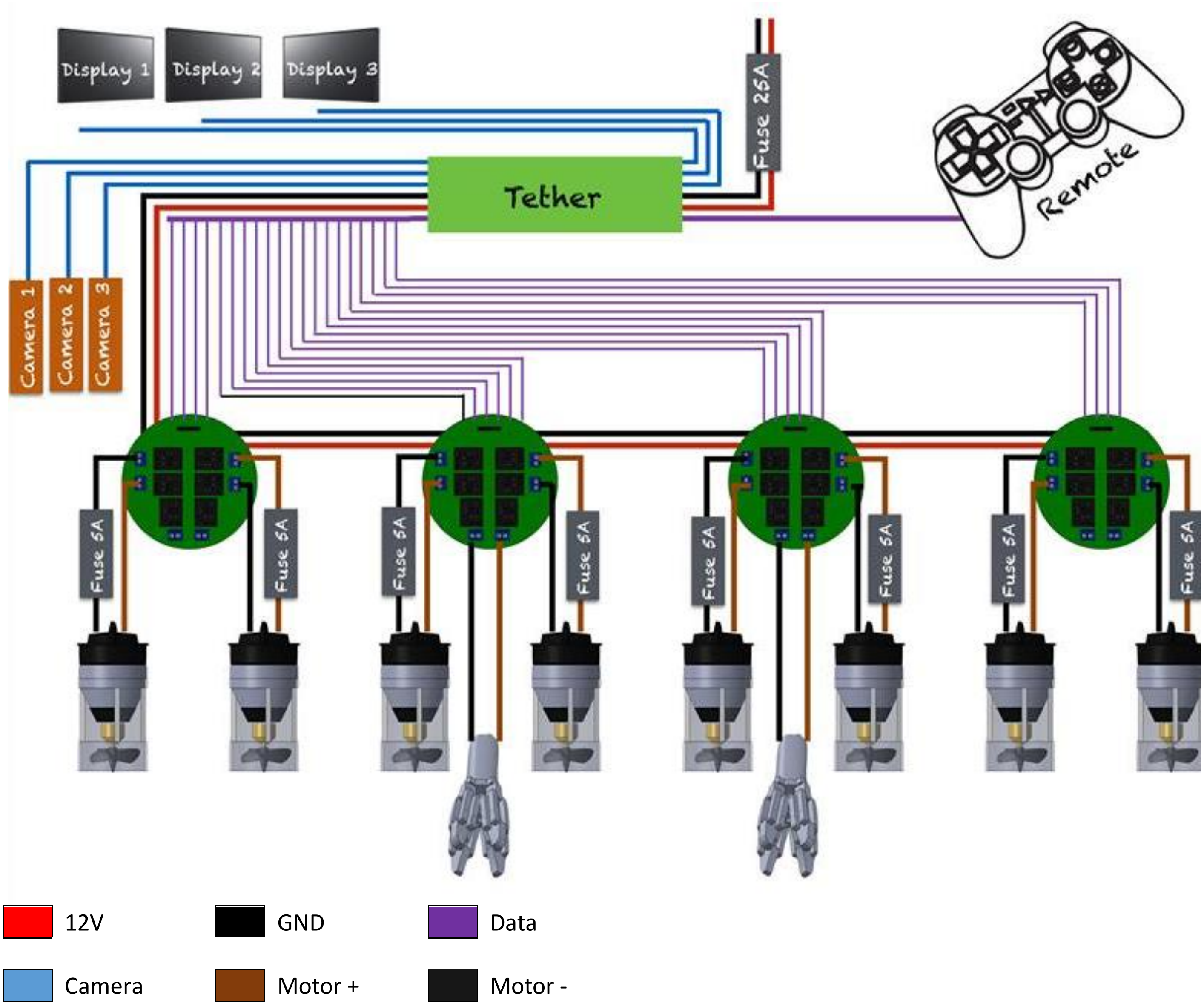
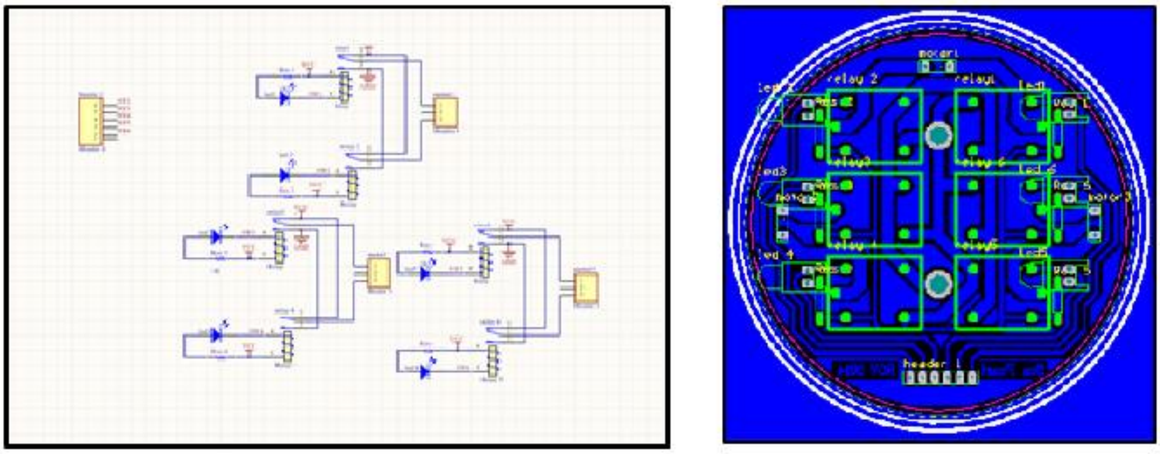


Diagram of system

11.3. Electrical Diagrams



Altium design of circuits.

11.4. Schedule

	September	October	November	December	January	February	March	April	May	June
Electronics course					Midyear Exams				Final Exams	
Proteus course										
Altium course										
SolidWorks course										
Safety sessions										
Sketch ROV frame										
Begin weekly meetings										
Design relay board										
Build frame										
Sketch camera & lighting housing										
Sketch arm										
Sketch & build controller board										
Build arm										
Software										
Fix thrusters										
Sketch & build floating										
Write report										
Presentation training										
Design poster										
Test ROV										
Piloting training										
Regional Competition										

Table of the schedule followed by *Sea Pearl* staff

11.5. Safety checklists:

Workshop Checklist

General

Presence of our coach or our mentor while working.

Safety gloves on, when dealing with dangerous corrosive substances.

Wearing lab coats when dealing with acids.

Ensure the floor is not slippery.

Ensure all Company staff are wearing close-toed shoes.

No loose clothing, jewelry or scarves.

The workshop is safe.

All equipment are returned to their storing areas after working.

Tie hair back.

Electrical

Working on a wooden floor to avoid electric shock.

Using insulated tools only.

Unplugging the power while repairing any damaged circuits.

A fuse is implanted in each circuit.

Using current tester when testing the electric current.

No damaged wire insulation.

Isolation sheets are placed between stored circuits

Drilling and cutting

Wearing eye goggles.

Wearing hearing protection.

Keep sharp and drilling tools in tool boxes when they are not in use.

Pre-mission checklist

Five-minute clock is set up.

Safety glasses on.

Wearing closed-tied shoes.

Manipulator is working.

Both cameras are working.

Thrusters test.

Operate gamepad.

Verify the laptop is fully charged and booted.

Power source is connected.

Green flag up and safety checklist is ready.

11.6. Software flowchart: