Oceanus Company

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Acknowledgments

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Abstract

Oceanus Company has been working in the underwater robotics field for almost five years, designing and building customized ROVs with a wide range of distinctive attributes. Our employees' experience is focused on building efficient manipulators and resilient frames, aiming to provide the customer the professional service they require. In addition to supremacy and efficiency, *Oceanus* has always been aware that the economical aspect is of major importance.

This year, our ground zero is helping the MATE Center, NASA, and Oceaneering to explore the ocean of Europa, Jupiter's moon, which might harbor life. In the Gulf of Mexico, *Oceanus* aims to help conserve its eco-life by identifying oil fingerprints and the consequences of the oil spill on the corals, alongside turning a former oil extraction site into reefs.

Hera, *Oceanus*' ROV, was premeditated to professionally explore Europa's ocean and accomplish tasks in the Gulf of Mexico. Via manipulating, *Hera* is capable of connecting an Environmental Sample Processor (ESP) to a power and communication hub, seize the CubeSats and assign them in the collection basket, transport an oil sample to the surface, return two samples of coral colonies to the surface and install a flange on top of the wellhead. *Hera*'s HD camera is able to photograph two corals, allowing us to compare them to photos from previous years to assess their condition. To measure the temperature of the venting fluid, a separate temperature sensor is used. Using the 'Netted Box', the coral samples are retrieved to the surface.

(Word count: 247)

Figure 1: Oceanus 2016, before the Bibliotheca Alexandrina . Captured by Mariam M.Attallah.

Mission Theme

This year's ROV competition has five tasks which are all unrelated but unite to have one goal which is linking experiments in outer space and applying them on Earth and the opposite. One task takes place in outer space, on Jupiter's moon: Europa and the rest in the Gulf of Mexico.

Mission to Europa

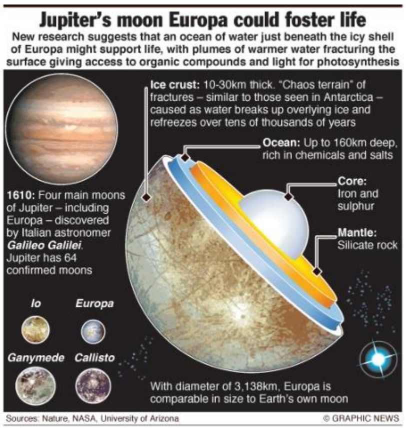

Figure 2: Europa's structure.

Europa, one of the 63 discovered moons of Jupiter and among the four largest ones, fascinated the scientists for being the brightest in the solar system. This brightness is due to sunlight reflecting on its icy crust which may have, or had in the past, liquid water that can harbor life. Therefore, it is considered to be the prime focus of the scientists. [1] [2]

Mission-Critical Equipment Recovery

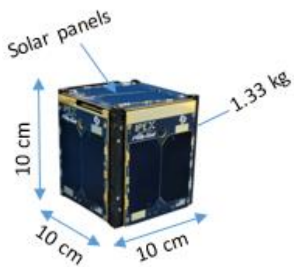

Figure 3: CubeSat specifications. Created by Samaa.

They are small satellites that originally were part of university projects founded in 1999 and launched in 2003 by professors at American universities. There specifications are explained in figure 3. Their initial aim was allowing undergraduates to design, construct and experiment spacecrafts similar to the first ever, Sputnik. Experimenting with CubeSats is actually beneficial as techniques that work on them can be applied on larger real-life spacecrafts that accomplish more vital missions in space. Today, almost anyone can build a CubeSat as all they need in hard work and around $50,000. CubeSats perform space imaging, communications and atmospheric research. [3] [4]

Forensic Fingerprinting

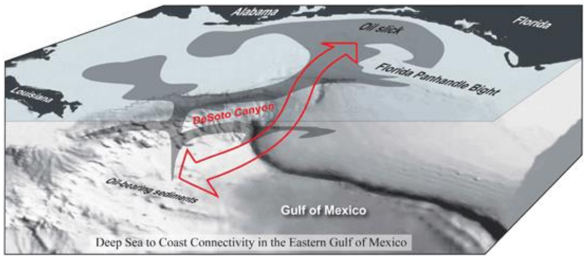

Figure 4: Deep-C. Credit: deep-c.org.

The Deep-C Consortium is the Deep Sea to Coast Connectivity in the Eastern Gulf of Mexico. Deep-C is a study in the aim to investigate the geomorphologic, hydrologic and biochemical consequences of petroleum release in the deep gulf. This study benefits the marine eco-life and ensures its safety and continuity. And since mankind benefits in various ways from the marine life and creatures, Deep-C has a huge importance and deserves such attention and experiments frequently going on.

In order to detect spilled oil and its origin, samples are separated using the new technique CGxCG. CGxCG (gas chromatography x gas chromatography) basically separates mixtures composed of compounds with close molecular weight, which means it is more accurate than chromatography when dealing with petroleum. Determining the origin of the oil spill ensures the ability to stop the environmental disaster before it evolves and spreads. [5]

Deepwater Coral Study


Figure 5:Lophelia reefs, found in the Gulf of Mexico. Credit: oceanexplorer.noaa.gov.

The fatal Deepwater Horizon explosion on 20th April and the huge Deepwater Horizon oil spill on 15th July 2010 both left the area of the Gulf of Mexico in need of some maintenance and care, especially for the cold-water corals. These corals make an important part of the marine eco-life in that area, as they are used for food and shelter. Scientists needed to take samples of the corals and inspect the changes that occur to them over time. [6]

Rigs-to-Reefs

The Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement both developed the American program "Rigs-to-Reefs". The aim of this program is turning anything from retired ships to oil platforms to be used for creating artificial reefs in order to support the marine life. In the ROV competition, it is our mission to convert a former wellhead into a reef by securing it and adding bolts on its top. Wellheads are the ideal artificial reefs as they are durable; they are made from strong material and have been in the seawater for long with no corrosion.

Figure 6: Rigs-to-Reefs map. Credit: boem.gov.

Strategy

Figure 7: The crew discussing the missions and making a strategy. Captured by Mahmoud.

After several timed training sessions and discussions, the crew reached the strategy in figure 8. This strategy's main goal is to obtain the maximum score possible in the least time. *Oceanus* Company also took into consideration the props' placement in the field when planning the steps, as the area of the playfield is vast this year. In addition, due to the need to dive to a depth of 4.6 m to reach the props, a Netted Box is used, thus Hera returns to the surface only once.

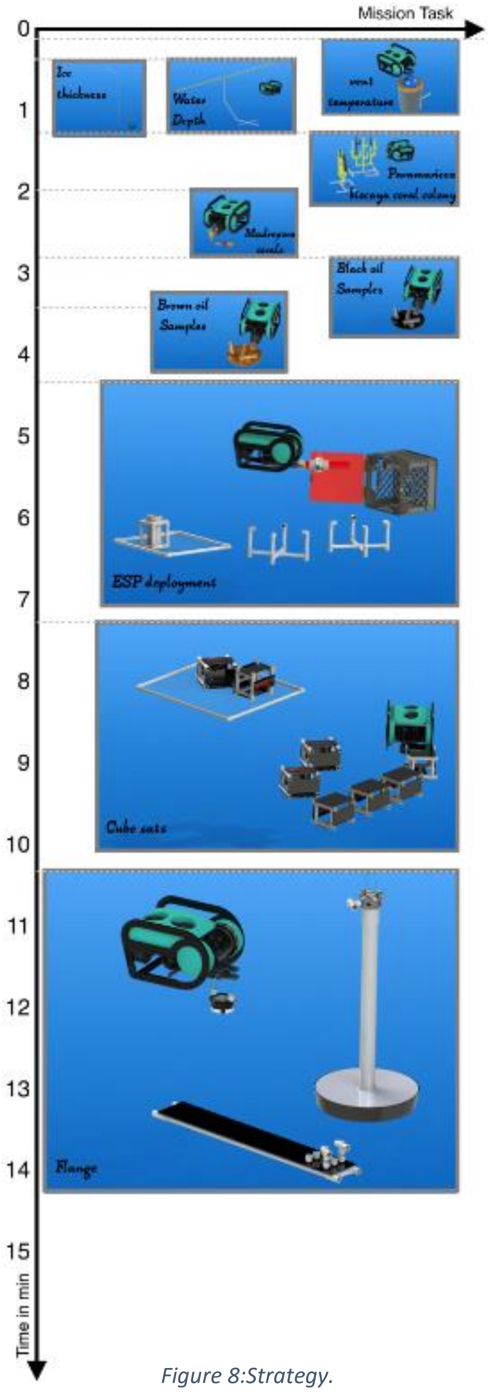

Figure 8:Strategy.

1. Design Rational and Vehicle System

The mechanical team's aim is designing an efficient ROV to accomplish the missions while withstanding unexpected and extreme conditions. *Hera* meets the specific parameters required by the customers such as having a diameter less than 48 centimeters and weighing less than 11 kg.

The vehicle's design includes a choice of thrusters and a configuration to perform in different degrees of freedom. Also, it includes the placement of the electrical canister, cameras, payloads, manipulator and sensors. Without a doubt, every detail placed had to be studied from numerous perspectives to create a stable efficient vehicle. This study includes calculating its weight and buoyancy for further uses as explained in details in the following sections.

Figure 9: Hera, Oceanus' 2016 ROV. Captured by Samaa.

1.1. Frame

Hera's frame is made from laser-cut PEX which is a chemically cross-linked polyethylene. There are many holes in the frame, they allow the customer to easily change the configuration of the thrusters and add payloads.

PEX has outstanding mechanical and physical properties such as

- no water absorption.
- thermal and chemical insulation.
- shock absorption.

Amongst its other beneficial properties are its durability and stability as *Oceanus*' aim is to build durable configurable ROVs to perform many variant missions and not only one type of tasks.

Hera has a simple compact design consisting of three PEX sheets:

- <u>two identical side sheets:</u> act as bumpers and aid in absorbing minor impacts.

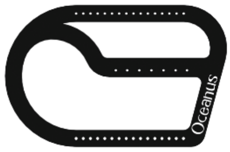

Figure 10: SolidWorks design of the side sheet. Designed by Rana.

- <u>one main sheet:</u> (shown in figure 11) houses all the components; encloses a total of six thrusters (four laterally and two vertically), the electrical canister and the float. Both vertical thrusters are mounted on this sheet using 3D-printed brackets shown in figure 12. In addition, the lateral thrusters are secured directly using four screws.

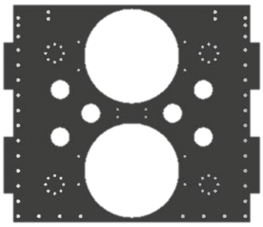

Figure 11: SolidWorks design of the main sheet. Designed by

Figure 12: Laser-cut side sheet.

1.2. Thrusters

Throughout the years, the crew gained huge experience as they tested and compared many components, the thrusters for instance. Thus, they were able to choose the optimal thruster type this year. T100 brushless motor is light, compact and has a small control. Its thrust is relatively high, taking the cost into consideration.

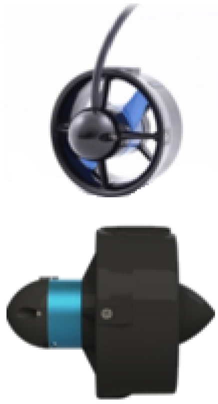

Figure 13: T-100 thrusters used this year.

Hera has six T100 electric brushless motors. The top thrusters are fixed using 3D-printed brackets as shown in figure 14. The rest of the thrusters are directly mounted on the main sheet.

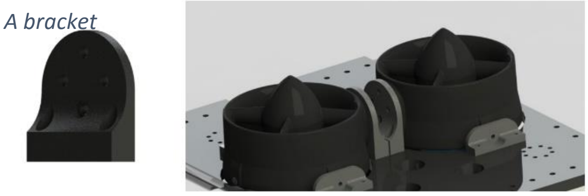

Figure 14: SolidWorks of thrusters fixed to the sheet with the 3D-printed brackets, by Rana.

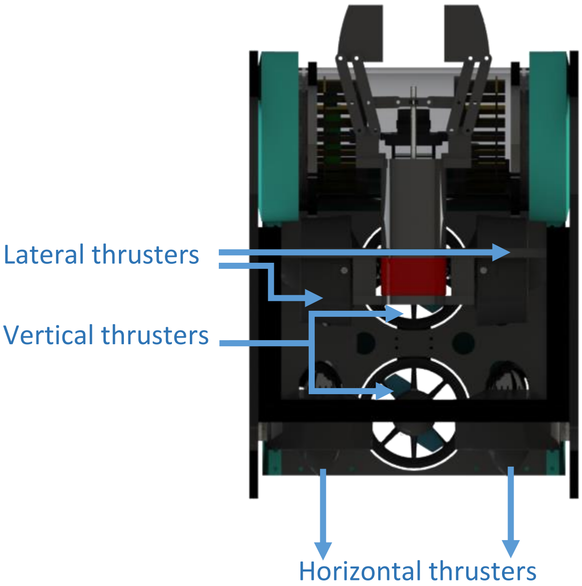

Figure 15: The configuration of the motors of Hera. Created by Samaa.

These motors were chosen for their high power-to-thrust ratio and their cost-effectiveness compared to similarly priced motors. They are also controlled via an Electronic Speed Controller (ESC). These features provided an easy and stable maneuvering which is required in performing mission tasks. A proof of this built-up years of trials is the table in the [appendix](#) where it provides the comparison of all the thrusters *Oceanus* team has tested and used before. The six motors' configuration can be seen in the SolidWorks' design in figure 15.

1.3. Degrees of Freedom

Hera's design has six thrusters which provide five degrees of freedom (shown in figure 16):

- three translations: surge, heave and sway, along the longitudinal, vertical, and transverse (lateral) axes, respectively.
- two rotations: yaw and pitch about these same respective axes.

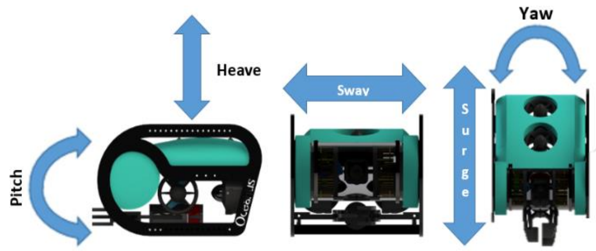

Figure 16: Degree of Freedom of Hera. Created by Samaa.

Each degree of freedom is needed for a different purpose:

- ***Heave***:
    - Task #1: insert the temperature sensor into the venting fluid.
    - Task #2: place the CubeSats in the basket.
    - Task #3: collect oil mat from the bottom.
    - Task #5: install a flange.
- Surge:
    - Task#1: Connect ESP.

The rest of the degrees of freedom ease the piloting of *Hera*.

1.4. Buoyancy

Buoyancy was a crucial factor in *Hera*'s designing process. The mechanical team of *Oceanus* Company thought that it was better to design the vehicle for the most favorable buoyancy first rather than building the vehicle and then adjusting the buoyancy by adding weights or floats.

Buoyancy is defined as the upward force exerted by the fluid on a body that is immersed in it and according to Archimedes' principle; the magnitude of this force -buoyant force- is equal to the magnitude of the weight of fluid displaced by this body, in our case *Hera* as shown in figure 17.

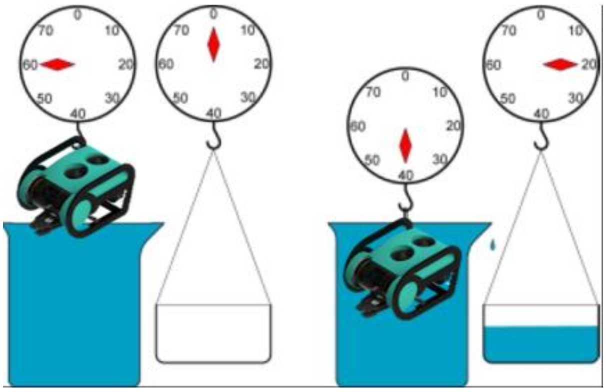

Figure 17: Calculating buoyancy. Created by Rana.

Hera will float, sink or remain critically floating depending on the net force of both the weight and the buoyant force generated by the ROV body, this net force may result in one of these three conditions:

- Positive: buoyant force > weight: the ROV floats.
- Neutral: buoyant force = weight: the ROV neither floats nor sinks.
- Negative: buoyant force < weight: the ROV sinks.

An ROV is preferred to be slightly positive buoyant, in other words critically floating, as this allows it to gradually move upward when no thrust is applied. An advantage of *Hera* having a slightly positive buoyant is that it saves power and time to return to the surface.

While carrying out missions, the ROV needs to be stable and almost stationary; therefore, buoyancy is adjusted to ease the pilot's task as he will not need to operate the thrusters as the ROV returns on its own. Also, this buoyancy also prevents obscure video footage from the onboard cameras.

Another important consideration is the position each force is acting through; a favored state is hydrostatic equilibrium which is when the weight and buoyant forces are equal and collinear. In our case, the buoyant force is slightly larger than the weight but it must be collinear.

1.5. Stability

To ensure stability, the mechanical team designed a symmetric ROV so that forces would be distributed equally, thus no moment is acting. In addition, they maintained a sufficient aspect ratio (total mean length of the vehicle versus total mean width of the vehicle) which is 1.2:1 providing high stability as shown in figure 18.

Figure 18: Hera's dimensions. Created by Samaa.

The crew also placed the vertical motion motor in the middle of the ROV to avoid tilting when moving up or down. The crew also made sure that the tether pull-point is on the same line as the motors to sustain high stability.

1.6. Floatation

In any moving body, the center of buoyancy (CB) is always above the center of gravity (CG). The longer this distance is, the more stable the vehicle becomes; the shorter the distance, the less stable, but the more maneuverable. Since ROVs are created to pick things up, pull them or document them, they need a stable structure to do this; therefore, the mechanical team had to increase the distance between the CB and the CG. That's why *Hera* is tall enough to be stable and short enough to be maneuverable.

Due to *Oceanus*' limited workshop facilities, the mechanical team had to divide the design of the floatation into six parts as shown in figure 19.

Figure 19: Floatation's parts.

Figure 20: Assembled floatation.

These six parts are assembled to form the shape shown in figure 20. The team settled down on 3D printing because it produces custom-made, price efficient and rapid prototypes and it is also available. The PLA was the material used as it is a strong plastic.

Shape	C_d
Sphere	0.47
Halfsphere	0.42
Cone	0.50
Cube	1.05
Angled Cube	0.80
Long Cylinder	0.82
Short Cylinder	1.15
Streamlined Body	0.04
Streamlined Halfbody	0.09

Figure 21: Drag coeffcients by shape. Credit: The ROV Manual, 2nd edition.

The shape of the floatation was decided after a study on the least possible drag force on bodies. *Hera*'s floatation's shape is such as the streamline half-body, and according to figure 21, this shape applies one of the least drag forces which provides a better and faster maneuvering underwater as well as a more efficient use of the thrusters.

1.7. Payloads

1.7.1. Temperature sensor

This temperature sensor is separately attached to another tether to *Hera*. Its use is measuring the temperature of the venting fluid in task #1.

Figure 22: Temperature sensor and its housing .

1.7.2. 'Netted Box'

Figure 23: 'Netted Box'. Captured by Hossam.

This is basically a PVC box with a net from the bottom, as you can see in figure 23. This 'Netted Box' is used to collect the two samples of corals in task #4. The pilot uses *Hera*'s manipulators to grab the corals then put them inside the box. *Hera* then successfully pulls the box while ascending to the surface and the crew now has the corals on the surface.

1.8. Manipulator

Figure 24: Rana building the manipulator. Taken by Hossam.

Hera possesses a PEX manipulator fixed in the middle as shown in figure 24. The manipulator is controlled by a Bilge Pump motor, as it is cheap, efficient and fast. The end effector of the manipulator are two fingers which have three contact points; to increase the grip of the mission props. The fingers are covered with rubber sheets to ensure secure clamping. During the design process, the ratio between the two fingers was adjusted to allow the manipulator to have an opening as wide as 8 cm (as in figure 25) so it can hold the biggest diameter in the mission props.

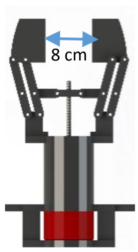

Figure 25: Maximum opening of the manipulator.

The whole Screw-and-Nut mechanism slides outwards and inwards as shown in figure 26. The mechanical team decided to build the manipulator using this mechanism to reduce the dimensions of the ROV; making it as compact as possible. The mechanism is easily and rapidly calibrated by loosening and tightening just two screws, yet stable and reliable.

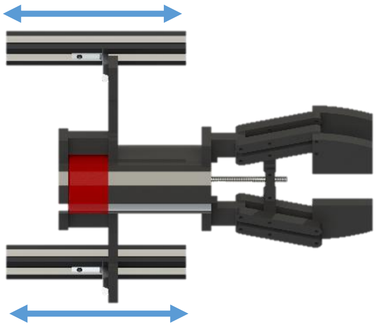

Figure 26: SolidWorks design of the manipulator's mechanism. Designed by Hossam and Rana.

The manipulator can successfully:

- In task #1:
  - Retrieve the ESP's cable connector.
  - Lay the ESP through the waypoint.
- In task #2: Put the CubeSats in the collecting basket.
- In task #3: Collect the oil mat from the bottom.
- In task #4: Return the corals to the surface.
- In task #5: Install then secure the flange on the wellhead.

2. Electrical

2.1. Electric canister

Our mechanical team decided to use a transparent acrylic enclosure (shown in figure 27) for the electric stack with the following features:

- cylindrical shape: withstands high pressure due to the forces acting on a circular arch effect, as shown in figure 28.

Figure 27: The electrical canister. Captured by Samaa.

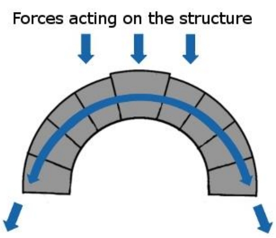

Figure 28: Pressure distribution on a cylinder.

- transparent: gives a clear view of the electrical boards to diagnose any problem if found.
- thickness of its enclosure is 5mm which can be easily cut to the specified length.

2.2. Electric boards

For the past years, *Oceanus* Company has been innovating their electrical systems and boards. Starting from relay boards for just on-and-off control to control the thrusters, then H-Bridges to control the speeds of DC thrusters. Finally reaching ESCs (Electronic Speed Control) to control brushless motors' speeds. In the last product, seven layers were used to control five thrusters but in this product, it was optimized to just two layers to control six thrusters.

This year, the electric team's aim when designing the PCB boards was to have a modular compact system that can be changed by just modifying one layer not the whole system, to reduce the cost, time and effort spent. Also, to have an easily inspected system that can be easily diagnosed in case of problems. The boards had to be compact due to the dimensions and weight restriction this year.

Figure 29: Shehab welding an electric board. Photographed by Rana.

And so the electrical team came to their stacks design where the customer can have one stack with many layers and adapt the layers based on his/her needs and the required missions. More thrusters are needed? Increase motor boards in the stack. More DC thrusters for manipulators are required? Increase H-Bridges layers in the boards.

The two layers are connected using copper spacers which allow the crew avoid tanglement of cables and to trace the connections easier:

1. <u>The motor control board</u>: has four ESCs, four current sensors and two relays for an on-and-off control for instance flashlights.

2. <u>The main control and sensors board:</u> has a Pololu 18-Channel Maestro which controls the six thrusters, the DC motors for the manipulator using a Pololu VNH5019 Motor Driver and takes the reading from the sensor and sends them to the main station serially.

Figure 30: Main board. Captured by Rana.

2.3. Sensors

2.3.1. Pressure sensor:

Figure 31:Pressure sensor.

A *Blue Robotics* pressure sensor which is shown in figure 31 is used to measure the water depth necessary for task #1. The sensor can measure water pressure up to 30 bar, which rounds to the depth of 300m, with depth resolution of 2mm. With a maximum error allowed of 10cm, this resolution will enhance the efficiency in measuring the depth. Using an interface, the pressure reading is converted into a value of depth.

2.3.2. Temperature sensor:

Figure 32: Temperature sensor.

A *Blue Robotics* LM35 temperature sensor shown in figure 32, capable of measuring temperatures from -40°C to 125°C, is used for task #1 to determine the temperature of the venting fluid. This sensor is connected separately to tether using four wires: 5V, ground and I^2C.

2.3.3. Water detection sensor:

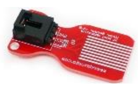

Figure 33: Water detection sensor.

This *Pololu* sensor, shown in figure 33, is fixed next to the end caps of the electric canister. It is essential as it detects water leakage in the electric canister for safety reasons and notifies the pilot.

2.3.4. Current sensor:

Pololu current sensor is used for overcurrent detection. In *Hera*'s design, every motor has a current sensor connected in series with it to ensure the maximum safety of the ROV and to monitor the behavior of the motors. The current sensors' reading are displayed on the main driving station.

2.4. Controller

Figure 34: Thrustmaster T-Flight Hotas X Flight Stick controller.

Oceanus' pilot concluded using Thrustmaster T-Flight Hotas X Flight Stick (shown in figure 34) as it is easy to use and allows *Hera* all the degrees of freedom it needs to accomplish the missions. Also, it has 12 programmable buttons and five axles, allowing the pilot to control all at once. The controller is connected to the laptop as well as all different components of the tether. The stick's configuration is illustrated in the <u>appendix</u>.

2.5. Camera

Hera is mounted with three cameras: a front camera in the electronic can, a rear camera and a camera fixed on the manipulators.

Figure 35: Main camera.

Figure 36: Tilt mechanism of the camera.

Figure 37: Camera on manipulator.

The front IP camera (shown in figure 35) gives the pilot a wide view of playfield underwater the camera is mounted on a servo to tilt it up and down 180º, shown in figure 36. The rear camera (shown in figure 37) helps the pilot avoid hitting coral reefs. Also, it helps him ensure the ESP cable through the waypoints. The camera fixed on the manipulator allows the pilot to observe what *Hera* grabs or pulls, which is really useful when collecting the coral samples in task #4, retrieving the CubeSats in task #2 or putting the flange on top of the wellhead and the wellhead cap on top of the flange in task #5.

2.6. Lightning

As shown in figure 38, increasing the water depth leads to decreasing the ambient light. The strength of the light absorption also depends on the cleanliness of the water. Although *Hera* is equipped with cameras with IR light, with decreasing the brightness the image noise increases making the missions harder to accomplish.

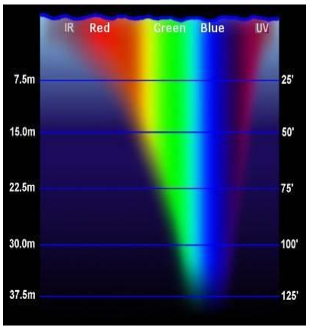

Figure 38: Light penetration in open ocean. Credit: wildcatlighting.com[7]

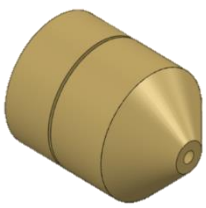

Figure 39: Lighting copper housing. Created by Mahmoud.

To provide a clearer vision for the pilot, two spotlights are mounted on *Hera*. The spotlights housing shown in figure 39 are copper as it is strong and successfully withstands pressure. The LED used (shown in figure 40) provides strong light, however this means its temperature will rise while operating for a long time. With the copper housing, the cold water will reduce the temperature of the housing thus avoiding any problem due to the heat.

Figure 40: LEDs. Captured by Salma.

2.7. Driving Station

Figure 41: Salma and Khadeja working on the driving station. Taken by Rana.

Hera's driving station is designed to facilitate piloting and ensure safety for the ROV electric supply:

- A Thrustmaster T-Flight Hotas X Flight Stick controller to allow the pilot to control the ROV.
- A screen for each camera to give a complete vision to the pilot simultaneously.
- An emergency button that shuts the whole system for safety reasons.
- A voltmeter to know the voltage supplied by the power supply before connecting the ROV and a fuse to shut-down the system in case of high current.
- A laptop to receive and transmit data from and to the Maestro servo controller and capture photos from the main driving camera.

3. Tether

This year's product has a different tether, as it a nylon braided sleeving. It is light, expandable, abrasion resistant to protect it from excessive wear and ultraviolet resistant.

The tether is 20 m long, since it needs to dive 4.6 m to reach the playfield and 8 m to navigate through the props, also considering that the station is 5 m away from the playfield. The tether weighs 3.4 kg and has a diameter of 2.5 cm. The relations between the tether drag, the speed, and the diameter are illustrated in the graphs (figure 42).

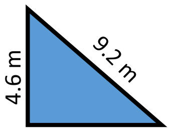

Figure 43: Tether length calculation. Created by Rana.

The coefficient of drag of cables ranges from 1.2 for apart cables; 0.5-0.6 for hair-faired cable; and 0.1-0.2 for faired cables which depends on the diameter of the cable. Since the cylindrical form has the highest coefficient of drag, the crew used cable fairings to aid in drag reduction can have a significant impact. Therefore, *Oceanus* managed to reduce the coefficient of drag of the tether by the diameter reduction.

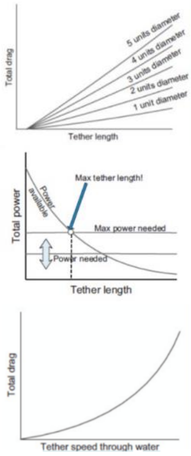

Figure 42: Tether drag, speed and diameter relations graph. Credit: The ROV Manual, 2nd edition.

The tether lines are distributed as shown in the SID. The other side of the tether is terminated inside the electronics can with a 12-pin water-sealed connector. This connector is easily plugged in and out allowing a customizable tether.

4. Software


Figure 44: Ahmed coding. Captured by Samaa.

The software consists of the surface Graphical User Interface (GUI) C# code.

The GUI gives the pilot the exact heading of the ROV and the depth reached via the compass and pressure sensor. By using an error correcting algorithm, the ROV can remain stationary during missions that need high precision.

The current sensors connected on each thruster enable *Hera* to utilize the maximum speed for maneuvering, below the current limit: 25 A.

4. Isolation System

The isolation techniques were improved this year, as the mechanical crew tested newer methods to produce a safer and more reliable ROV. Thus, all circuit boards are put inside an acrylic canister which is sealed with end caps (figure 45) with 2 O-rings around, to prevent any water leakage to the boards.

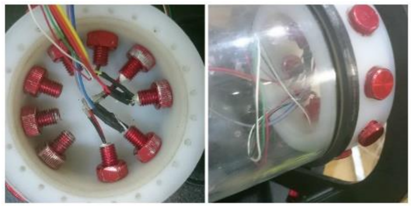
Figure 45: End caps. Captured by Samaa.


Figure 46: O-rings in the cable penetrators. Captured by Samaa.

The cable penetrators are new things this year. They proved to be more efficient and easier to use. Despite their high price after shipping and tariff. They have O-rings as well, as you can see in figure 46. With a vacuum hand pump, air is removed from the canister and a gauge is monitored for leaks. This test is conducted prior to every operation of the vehicle.

5. Safety

5.1. Safety Philosophy

Safety has always been on top of *Oceanus*' priorities for both staff and ROV. The company's safety philosophy can be resumed in "*Safe working and efficient learning*". Mentors have trained members to deal with tools and machinery safely. Also, strict rules and guidelines have been enforced when handling the components and the ROV itself as there is a safety checklist placed in the lab.

5.2. Safety checklist

In order to keep the crew safe in the workshop, the safety officer, *Rowan*'s job has been to maintain the workshops safe by checking daily the functionality of the equipment, the presence of caution sign on moving parts and more, you may refer to appendix to read the whole safety checklist.

5.3. Workshop

Providing a safe and well-organized workspace ensures physical safety and maximizes productivity as well. The crew always makes sure that there are no trailing cables that would cause anyone to trip and none of the tools or are placed on the ground; at all times our components and tools are placed orderly in the storage area. In addition, if any tools were worn out or damaged -such as cutting blades or drilling bits or cutters- they are immediately replaced with newer and safer models. Needless to say food and drinks are not allowed inside the workshop.

5.4. Crew Safety

Figure 47: Mahmoud using hearing protection while cutting. Captured by Rana.

To eliminate all sources of accidents, company members were committed to always have neither loose nor extremely short clothing on in addition to close toed shoes. Long hair was always tied and no jewelry or watches are allowed during handling *Hera*. While operating heavy machinery safety gloves and safety goggles must be worn, if the machine is loud ear protection is also a must. For instance, while using the cutting chop saw, these saws create dust, sparks, and debris, so eye protection is obligatory in addition to wearing thick gloves and hearing protection as shown by *Mahmoud* in figure 47.

5.5. Vehicle Safety

5.5.1. Mechanical wise

- *Hera*'s design has no sharp edges.
- Thrusters are securely attached to the frame.
- Caution stickers are present on each Kort nozzle.
- The tether is always neatly coiled, only during the mission the tether is fully untangled to facilitate *Hera*'s maneuverability.
- O-rings are incorporated into the end caps; to maintain complete isolation at a pressure of two bars.

5.5.2. Electrical wise

- 25 A fuse is present on the positive power line on the tether connector end.
- All wires are sealed and secured.
- A current sensor is connected to each thruster; to alarm the user if high current is consumed.
- A water detector sensor is installed inside the tube which automatically stops *Hera* if any leakage occurs.
- An emergency button is placed in the driving station to shut down the system in case of any emergencies.

Figure 48: Fuse used. Captured by Shehab.

Figure 49: Emergency button. Captured by Samaa.

6. Quality Assurance

6.1. Testing Methods

Previous years' experiences lead members to ameliorate testing skills to systematic testing during development of *Hera*; to minimize wasted time and to ensure high efficiency.

Each system -frame, circuits, or isolation- was tested separately before assembly; this helped us to diagnose problems and failures effortlessly and dedicate all our effort to eliminating the problem using our troubleshooting techniques.

Firstly, a pressure chamber (figure 50) was built by *Oceanus*' crew to test all the mechanical components used, such as the electronic can and the motor housing. This chamber simulates around a depth of 30 m (3 bars), which is approximately six times the specified in the MATE ROV competition rangers' class, because safety is what matters the most at *Oceanus* Company. The electrical boards were short-circuit tested then tested each separately before connecting them all together using the copper spacers to make sure everything is working efficiently.

Figure 50: Pressure chamber. Captured by Samaa.

To ensure all the system is efficiently working, *Hera* was tested before the regional competition as in figure 51. Aiming to obtain a high score this year, the pilot, *Shehab*, trained both before the regional and international competition.

Figure 51: Testing the buoyancy. Captured by Rana.

6.2. Troubleshooting

An ROV such as *Hera* 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 followed by the staff. For instance, one example of technical problems faced was the failure of the camera to operate. First of all, the power supply was checked, if it was working correctly, 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 *Ahmed* checks the software and searches for bugs to correct them.

7. Challenges

7.1. Non-technical

Figure 52: A Facebook post on Oceanus' group. Screenshot by Shehab.

As a team consisting of nine students, each one with busy schedule due to the number of responsibilities and studies each one has; it was sometimes hard to fix appointments on our Facebook private group (as shown in figure 52) to discuss the work done and the work 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.

To solve this challenge, it was suggested by some employees to change the meeting strategies by meeting according to the departments: electrical, mechanical and documentation. In other words, the CEO 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. Unquestionably, *Ahmed* held occasional meetings with the whole crew.

7.2. Technical

A big challenge was that the new members were at first unfamiliar with the programs used and it was their first time handling tools; so some time was spent for them to catch up with the former members. Making some effort and being fast learners helped and it all paid off in the end.

A mechanical difficulty *Rana* faced when designing the ROV on SolidWorks was to make it fit inside the 48-centimeter-diameter cylinder and weigh less than 11 kg. With these two parameters, making a convenient ROV was slightly harder than usual, taking into consideration stability and buoyancy laws. To overthrow this challenge, *Rana* designed a cylinder with a diameter of 48 cm to constantly ensure that *Hera* is still in dimensions as shown in figure 53. Simultaneously; the weight of every element enclosed in the ROV and tether was appraised and taken into account. By successfully overcoming this challenge *Hera* is able to accomplish task #1 with the least cost possible, as each kilogram sent into space can cost NASA around $20,000.

Figure 53: Dimension's circle on SolidWorks. Created by Rana.

8. Lessons Learnt

Throughout this beneficial experience, a wide range of lessons were learned which might be impossible to list all of them. And not only the new members gained new knowledge and skills, as the former members learned new ones too and excelled in the previously acquired ones.

8.1. Technical

The whole crew learned and professionally used various software; for instance, Altium for designing electronic PCB boards and SolidWorks for designing the ROV, as well as art design that is Photoshop and Illustrator. Also understanding the programming skills was helpful and useful skill learned by our programmer this year. The crew also learned how to handle all kind of tools such as: a driller, a soldering iron. Each member had a chance to test pilot *Hera* which was a significant experience for them. Not to mention the technical writing skills gained while writing this report.

Moreover, their presenting skills had been enhanced due to watching videos of well-skilled presenters, as they tried their best to learn the best ways to present *Oceanus*.

Figure 54: The regional competition's presentation. Taken by the photographer.

8.2. Interpersonal:

This year, our cooperation and teamwork skills were raised to a maximum, our responsibility to teach one another and excel together, hand in hand with no one left behind, helped us achieve this. In addition, our time management skills were improved as we had to balance team meeting timing with our school lessons, exams and homework.

9. Future Improvements

Still seeking perfection, *Oceanus* Company wishes to improve in the future, no matter how professionally it has excelled throughout the past years.

9.1. Non- technical

- The HR will supervise more activities which will ameliorate the teamwork spirit amongst the crew. By doing this, the working atmosphere will be more harmonized and the team will have stronger personal bonds.
- Improving the marketing plan of the company by introducing it to more magazines, newspapers and TV shows. This will upgrade the company and improve its insistence.
- Assign more variant jobs in the company for the crew to cover more non-technical areas.

9.2. Technical

- Building a manipulator with more degrees of freedom, allowing the pilot to have a more flexible control for the objects underwater.
- Using metal end caps. By doing this, the water will cool the electrical canister down as metal transfers heat unlike acrylic.
- Using a neutrally buoyant tether to combine rugged strength and durability to achieve a higher performance.
- Use virtual reality glasses. The pilot will have a first-person view underwater which will allow him/her to control the ROV more professionally and more easily.

10. Reflections

Samaa Mohamed Ali: "I must admit that participating this year was a big challenge for me, especially that I had to compromise between my senior year responsibilities and attending meetings and accomplishing my tasks. But, of course, it was worth it, like each year!"

Ahmed Nabil: "Despite that the responsibility was huge and it was my first time as a CEO, I tried my best to manage the crew: fix deadlines, allow rewards and punishments and make everyone in the team work as they're all equally vital."

Rana Hanno: "Since this is my last year to compete in the rangers' class, I was motivated to make the best of it and enhance my skills such as: mechanical illustration and designing and technical writing."

Shehab Ramy: "I think there's a massive force that keeps pulling us into joining every year since we knew about the competition! But this year my skills improved more than the previous years, which is very satisfying."

Mahmoud Alaa: "Definitely this year has taught me a lot of new and essential knowledge and skills in mechanics and electronics."

Khadeja Assem: "Initially, I wanted to participate in this competition to take a whole new step in my life and take a new risk! The part I liked the most about this experience was that everyone in the team shared every piece of information they had. Also, every day I was eager to know what we were doing next, even if it wasn't my task. And as this has been my first competition ever, I learnt how to work in a team and manage my time. Technically, I learnt how to design electronic boards on Altium and benefited from new information in general."

<u>*Rowan Rezq:*</u> “I really enjoyed my first ROV competition as I got to work in a big team and learn new interesting engineering topics.”

<u>*Salma Mohamed Ali:*</u>

“Participating in the ROV competition taught me an important everyday life skill: time management! Also, it offered me the opportunity to learn software, electrical and mechanical engineering which helped me in deciding my future career: studying computer science later in college.”

<u>*Hossam Hanno:*</u>
“This year my goal was not only learn but also compete internationally.”

11. Teamwork

An exceptional ROV cannot be accomplished with the lack of teamwork, as teamwork is considered a main factor in any company’s success. After dividing the staff into mechanical, electrical, software and documentation teams, former employees were chosen for leading positions: *Ahmed* became the CEO, *Rana* became the head of mechanical team and CFO and *Shehab* became the head of electrical team. By doing this, *Oceanus* ensured that each team member has a responsibility to contribute equally and offer their unique perspective on a problem to arrive to the best possible outcome.

Figure 55: Samaa and Rana working on the technical report. Captured by Salma.

Afterwards, *Hera* was manufactured from scratch, by *Oceanus* staff, though mentors’ advice and critique were still welcomed. In addition, each electrical and mechanical team member took part in writing brief Google Documents on the construction of the ROV; as these documents facilitated enormously writing the main technical report required by the MATE ROV competition which was *Samaa* and *Rana*’s task, the R&D and documentation officers. In other words, both of the writing of this technical report and the construction of the ROV were completely a company effort.

A detailed Gantt chart developed was developed by the CEO with the help of the HR manager and the chiefs of departments, in order to ensure that all the work will be done in time. He took so much care to make all the members meet the deadlines, to ensure that the team was progressing and the work was being done as it was supposed to. The table is also provided in the appendix.
The company members were always in touch.

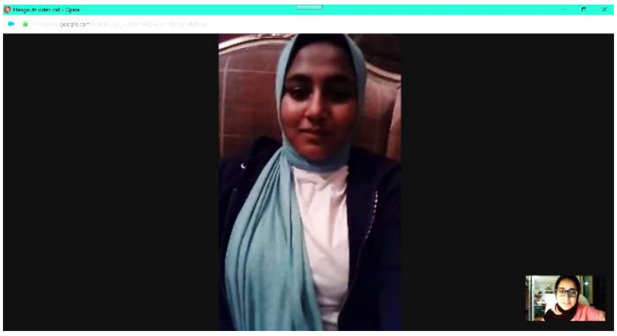

Figure 56: Samaa, the HR manager, video-calling Rowan on Hangouts to update her because she was out of town. Screenshot taken by Samaa.

They were communicating through phone calls and social media to synchronize weekly and occasionally meeting times and discuss their tasks together. These communications built a wonderful spirit of strong teamwork in the company which strengthened the cooperation between the staff members. As a result, the rate of work was enhanced too.

Figure 57: A meeting, few days before the regional competition. Captured by Eng. Kareem.

12. Project Management

Oceanus Company managed to develop *Hera* by following five main phases:

1. The initiating phase:
   - Analyzing the mission tasks and brainstorming how they will be accomplished.
   - Financial analysis and setting a border for the budget.
   - Carrying out company elections for leading positions and assigning roles.
   - Safety, SolidWorks, Altium, electronics and Proteus courses.

2. Planning phase:
   - Developing the budget.
   - Building up a Gantt chart with specific tasks while taking into consideration shipping time of materials and components used.

3. Execution phase:
   - Carrying out the tasks.
   - The HR manager ensuring the tasks were carried out.
   - Throughout this phase the mentors, parents, friends and colleagues were the ones who constantly kept the crew motivated and helped them push their limits.
4. Monitoring and controlling phase:
   - Ensuring the cost is as planned and the effort is equally distributed.
   - Troubleshooting.
5. Closure phase:
   - After the hard work and determination, the company finalized all tasks and tested *Hera*.

13. References

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[7]http://www.wildcatlighting.com/Light_Chart.html

[8] The ROV Manual, 2nd edition.

14. Media Outreach

Throughout the years, *Oceanus* crew had believed that media outreach is important in upgrading the company. Therefore, the crew members were hosted in many TV shows where they explained the ROV competition and discussed the field of marine technology in Egypt and worldwide.

In addition, the crew managed a Facebook page believing that this modern communication method brought them closer to the market and customers. This page can be visited by clicking on the hyperlink.

Also, two online newspapers: Sout Alomma and Al Barkeya AlTunseya interviewed the crew and wrote an article about them and the competition. During the second day of the regional competition, Samaa was interviewed by the journalist Sarah Kamel to feature "90 minutes" TV program. The national newspaper *Al- Ahram* also interviewed the CEO and it was published on 13/05/2016.

Last but not least, our team and *Hera*'s photos were uploaded in the gallery of BlueRobotics.

15. Project Costing

Type	Category	Expense	Description	Sources/Notes	Amount	Running Balance
Re-used	Hardware	Thrusters	5 T100 thrusters	4 used in Hera and 1 spare	$850.00	$850.00
Re-used	Electronics	Joystick	Thruster master T-flight Hotas xflight stick	Used for control system	$49.99	$899.99
Re-used	Sensors	Camera	3 bullet cameras	2 used and 1 spare	$84.00	$983.99
Re-used	Sensors	Camera	IP camera	Main camera	$99.00	$1,082.99
Purchased	Hardware	PEX sheets	Sheets used to build ROV frame		$85.25	$1,168.24
Purchased	Fabrication	Laser cutting	Cutting 3 sheets		$32.00	$1,200.24
Purchased	Hardware	Aluminum	Aluminum L shape rod	Used to mount sheets	$5.50	$1,205.74
Purchased	Hardware	V-slot	Aluminum v-slot trail	Used to mount manipulator	$21.00	$1,226.74
Purchased	Hardware	Screws & nuts		Used to assemble frame	$23.97	$1,250.71
Purchased	Hardware	Endcaps	PEX cylinders		$44.00	$1,294.71
Purchased	Fabrication	Hand milling	Hand milling the PEX cylinder into endcaps		$20.00	$1,314.71
Purchased	Hardware	Thrusters	2 T100 BlueESC thrusters	Both used for vertical thrusters	$390.00	$1,704.71
Purchased	Hardware	Copper board		Used for printing circuit boards	$14.00	$1,718.71
Purchased	Electronics	PCB	Printing circuit boards		$25.00	$1,743.71
Re-used	Electronics	ESC	Electronic speed control	Used in control system	$100.00	$1,843.71
Purchased	Electronics	Components	Electrical components for 2 PCBs		$67.00	$1,910.71
Re-used	Hardware	Acrylic tube	11 cm diameter acrylic tube	Used for electrical canister	$33.87	$1,944.58
New	Sensors	Temperature senor	Blue robotics temperature sensor	Payload for task 1	$56.00	$2,000.58
New	Sensors	Pressure senor	Blue robotics pressure sensor	Payload for task 1	$68.00	$2,068.58
Re-used	Sensors	Water detection sensor		Protection for electrical system	$1.50	$2,070.08
Re-used	Sensors	Current sensor		Protection for electrical system	$6.75	$2,076.83
Purchased	Hardware	Cable penetrator	24 cable penetrators + spare	Used in isolation system	$182.00	$2,258.83
Purchased	Hardware	O-rings		Used in isolation system	$46.30	$2,305.13
Purchased	Hardware	Marine silicone		Used in isolation system	$30.00	$2,335.13
Purchased	Hardware	Tether	25 meter power cable		$34.60	$2,293.43
Purchased	Hardware	Tether	25 meter signal cable		$28.00	$2,321.43
Purchased	Hardware	3D printing		Brackets for mounting vertical thruster	$13.00	$2,334.43
Purchased	Hardware	Spacers	300 copper spacers	Used in electrical system	$35.00	$2,369.43
Purchased	Electronics	Controller	Maestro servo controller		$39.50	$2,408.93
Purchased	Electronics	Servo	Micro servo	Used in rotation IP camera	$6.50	$2,415.43
Re-used	Hardware	Bilge pump	350rpm Rule bilge pump	Used for manipulator	$23.56	$2,432.49
Re-used	Hardware	Screen	3 screens for driving station		$69.00	$2,501.49
New	Hardware	3D printing	Floatation		$220.00	$2,652.49
Donated	General		Funds donated by Oxy Dive Company	Prize for winning first place in regional event	$100.00	$2,752.49
Donated	T-shirts		9 t-shirts for regional and international event		$90.00	$2,842.49
Purchased	Travel	Airfare	9 round-trips Alexandria to Texas		$6,300.00	$9,142.49
					Final Balance	$9,294.29

Table 1: Project costing. Developed by Rana.

16. Budget

Item	Description	Total/ $
Tether	including spare	62.00
Sensors	Water, current, pressure and temperature	280.75
Thrusters	Two new blue ESC T-100 thrusters	350.00
ROV body	Arm, frame and v-slots	302.15
Electric canister	Boards, components and PCB	211.50
Floatation	including 3D printing	220.00
Isolation	cable penetrators, O-rings and marine silicon	258.30
T-shirts	For competition days	90.00
Flight tickets	9 round-trips from Alexandria to Texas	6,300.00
	Total/ $	**8,074.70**
	Total without travel fare/ $	**1,684.70**

Table 2: Budget. Developed by Rana.

17.Appendix

17.1. System Interconnected Diagram

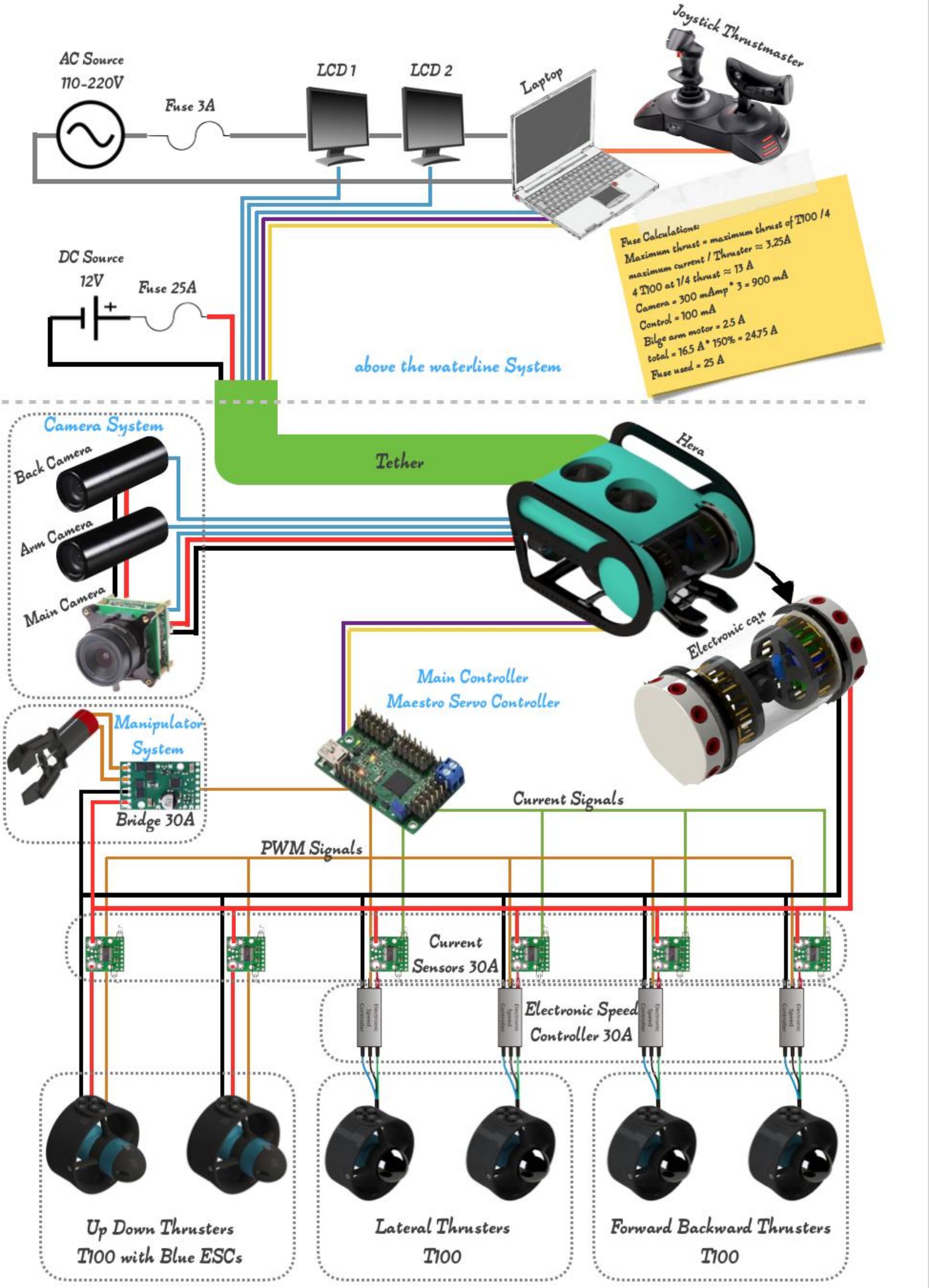

Figure 58: SID. Created by Ahmed, Shehab and Rana.

17.2. Motor Comparison Table

Motors	Propellers				Forward Thrust (kgf)	Backward Thrust (kgf)	Rotational Speed (rpm)	Current (Ampere)
	Diameter (mm)		Blades	Pitch (mm/rev)				
Rule Bilge Pump	50	Left	3	42	0.35	0.27	4100	2.07
		Right	3	42	0.41	0.12		2.03
	60	Left	3	45	0.48	0.12		2.45
		Right	3	45	0.48	0.12		2.45
	75	Left	3	?	0.6	0.4		4.35
		-	-	-	-	-		
	10	-	-	-	-	-		
		Right	4	65				
Rule Bilge Pump	50	Left	3	42	0.51	0.18	5770	2.85
		Right	3	42	0.51	0.14		2.855
	60	Left	3	45	0.46	0.31		2.9
		Right	3	45	0.49	0.44		3.055
	75	Left	3	?				
		-	-	-	-	-		
	10	Left	-	-	-	-		
		Right	4	65				
Johnson Bilge Pump	50	Left	3	42	0.45	0.16	5755	2.75
		Right	3	42	0.45	0.16		2.75
	60	Left	3	45	0.44	0.18		2.75
		Right	3	45	0.44	0.18		2.75
	75	Left	3	?				
		-	-	-	-	-		
	10	-	-	-	-	-		
		Right	4	65				6.15
Rule Bilge Pump	50	Left	3	42	0.75	0.25	7600	4.75
		Right	3	42	0.75	0.25		4.85
	60	Left	3	45	0.8	0.15		6.69
		Right	3	45	0.8	0.23		6.35
	75	Left	3	?				7.85
		Right	-	?	-	-		-
	10	-	-	-	-	-		-
		Right	4	65				9.5
Johnson Bilge Pump	50	Left	3	42	0.75	0.27	8225	4.35
		Right	3	42	0.75	0.26		4.7
	60	Left	3	45	0.82	0.54		6.45
		Right	3	45	0.82	0.54		6.45
	75	Left	3	?				7.7
		-	-	-	-	-		-
	10	-	-	-	-	-		-
		Right	4	65				8.85
Blue Robotics T100 Thruster	76.2	Left	3	48	2.36	1.82	300-4200	11.5
		Right	3					

Table 3: Motor comparison. Developed by the electrical engineers throughout the years.

17.3. Software Flowchart

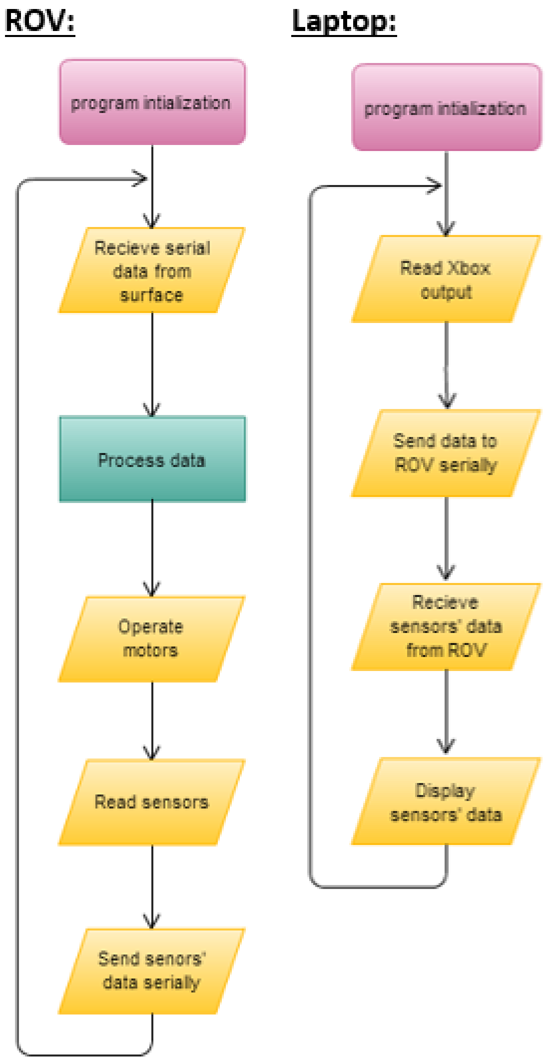

Figure 59: Code flowchart. Created by Ahmed.

17.4. Safety Checklist

General	
Safety gloves on, when dealing with dangerous corrosive substances.	
Wearing lab coats when dealing with acids.	
Ensuring the floor is not slippery.	
Ensuring all company staff are wearing close-toed shoes.	
No loose clothing, jewelry or scarves.	
The workshop is safe.	
All equipment is returned to their storing areas after working.	
The hair is tied 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.	
Keeping sharp and drilling tools in tool boxes when they are not in use.	
Pre-mission	
Five-minute clock is set up.	
Safety glasses on.	
Wearing closed-tied shoes.	
Manipulator is working.	
All cameras are working.	
Thrusters test.	
Operating controller.	
Verifying the laptop is fully charged and booted.	
Power source is connected.	
Green flag up and safety checklist is ready.	

Table 4: Safety checklist. Done by Rowan.

17.4. Gantt Chart

ID	Task Name	Assigned to	Start	Finish	Duration
1	Safety sessions	All team	01-Sep-15	03-Sep-15	3d
2	Electronics course	All team	01-Sep-15	07-Sep-15	1w
3	Proteus course	All team	08-Sep-15	14-Sep-15	1w
4	Altium course	All team	15-Sep-15	21-Sep-15	1w
5	Design boards	Shehab	22-Sep-15	28-Sep-15	1w
6	SolidWorks course	All team	22-Sep-15	28-Sep-15	1w
7	Sketch ROV frame	Rana and Hossam	29-Sep-15	02-Oct-15	4d
8	Begin weekly meetings	All team	01-Oct-15	23-Mar-16	25w
9	Marketing	Khadeja	01-Oct-15	23-Mar-16	25w
10	Managing Facebook page	Samaa, Rana, Ahmed and Shehab	01-Oct-15	23-Mar-16	25w
11	Software	Ahmed	01-Oct-15	30-Jan-16	17w 3d
12	Design the driving station's boards	Salma, Rowan and Khadeja	01-Oct-15	10-Oct-15	1w 3d
13	Build frame	Rana and Hossam	02-Oct-15	03-Oct-15	2d
14	Sketch arm	Hossam	07-Oct-15	11-Oct-15	5d
15	Build arm	Hossam	14-Oct-15	16-Oct-15	3d
16	Build the driving station	Salma, Rowan and Khadeja	15-Oct-15	19-Oct-15	5d
17	Fix thrusters	Hossam and Mahmoud	19-Oct-15	20-Oct-15	2d
18	Test and updating the ROV	Shehab, Nabil, Rana and Hossam	21-Oct-15	01-Apr-16	23w 3d
19	Sketch and build floating	Rana and Hossam	01-Mar-16	28-Mar-16	4w
20	Write report	Samaa and Rana	05-Mar-16	01-Apr-16	4w
21	Pilot training	Shehab, Nabil, Rana and Hossam	01-Apr-16	27-Apr-16	3w 6d
22	Design poster	Samaa	04-Apr-16	27-Apr-16	3w 3d
23	Presentation training	All team	23-Apr-16	29-Apr-16	1w
24	Pilot training for international qualifications	Shehab, Nabil, Rana and Hossam	18-May-16	01-Jun-16	2w 1d
25	Edit report for the international qualifications	Samaa	20-May-16	26-May-16	1w
26	Presentation training for the international qualifications	All team	01-Jun-16	22-Jun-16	3w 1d

Table 5: Gantt Chart. Created by all team members.

17.5. Joystick Configuration

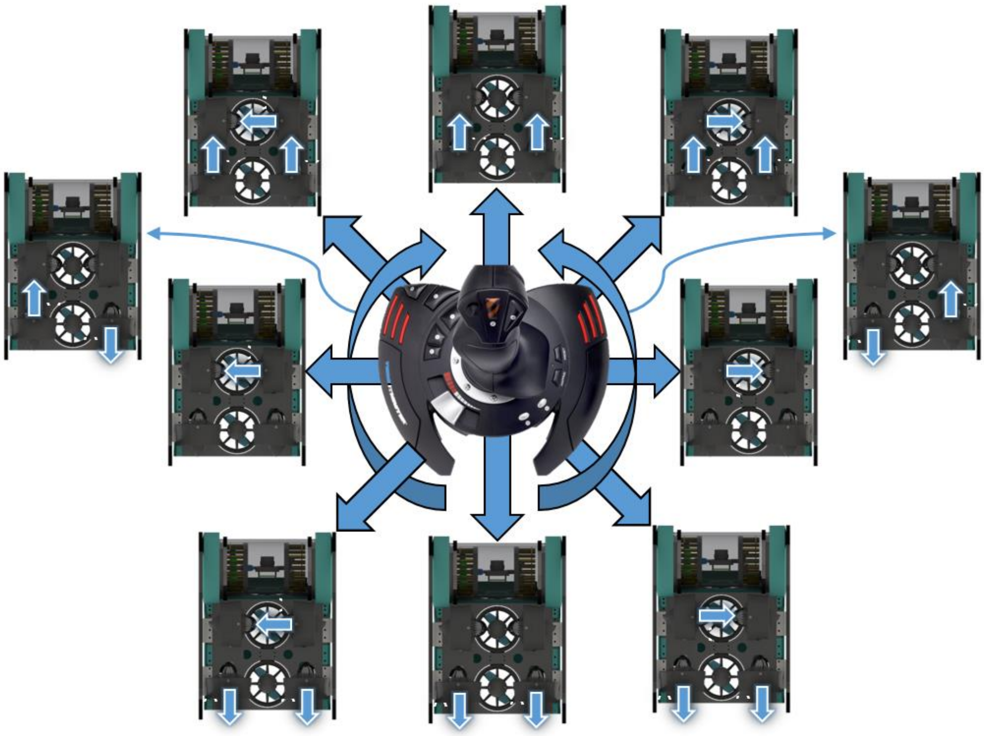

Figure 60: Joystick interface diagram. Created by Ahmed.