POSEIDON

OverFlow Robotics Co.

Alexandria, Egypt

OVERFLOW ROBOTICS
CONTROL THE FLOW

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MATE ROV COMPETITION Egypt

PCBWay

MECHANISM

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1.0 Abstract

"According to Eleanor Roosevelt, 'the future belongs to those who believe in the beauty of their dreams.' Overflow Robotics is a non-profit organization that specializes in building ROVs. Every large company started out as a small company with big dreams, including ours. In 2021, five teenagers in Alexandria, Egypt had a dream and realized that dreams without goals are just dreams. Although they started with no money and little knowledge, they made huge progress. Today, Overflow Robotics is made up of 13 passionate and determined students divided into two sub-teams: the mechanical team and the electrical team. Each team has its own set of responsibilities to achieve the best possible results. Our company has developed a high-level ROV that can perform in harsh sea environments.

Equipped with six T200 thrusters, three manipulators, and four cameras, our ROV is designed to withstand high pressure and face the toughest obstacles with impeccable performance. Our ROV can successfully complete all three required Mate ROV competition tasks, as well as image processing tasks. We believe that developing the skills associated with the Mate ROV competition is essential in addressing the problems of ocean preservation and undoing humanity's impact on the ocean. By doing so, we can improve the health and viability of the earth and its ecosystems."

Figure 1 Overflow Robotics 23" Team

2.0 Design Rational

We focused all of our ideas to these three primary factors: maneuverability, modularity, and functionality. As the year dragged on, we generated a number of design concepts. We updated the Arsenik (2022 Vehicle) with an emphasis on fixing all of the design issues from the prior year. Our 2023 product, "***Poseidon***," is a culmination of years of experience, a lot of labor, and dedication. It outperforms our previous vehicles and has greater features. Six T-200 thrusters, three pneumatic manipulators, four cameras, and a watertight container are all part of ***Poseidon's*** equipment. ***Poseidon*** is more advanced than anything we've ever encountered in terms of its payload section and manipulation. Possessing three manipulators with additional mechanism add-ons greatly enhances ***Poseidon's*** capabilities.

Figure 2 Poseidon Render

Poseidon is a 55 X 55 X 35 cm vehicle only weighing 11 KGs at the air. We made sure that our vehicle was less than 85 X 85 cm to dock in the docking station & also made sure that our vehicle weighs less than 25 KGs to avoid being DQ. We made sure that we have multiple manipulators so we can do most of the underwater tasks. The 3 manipulators allowed us to achieve high points underwater.

2.1 Design Process

Conceptual, preliminary, and detailed designs are the three main stages in ***Poseidon's*** complex design process. This method enables the business to pay close attention to the little things and carefully evaluate every component of the ROV without losing sight of the big picture, thus avoiding sliding into the pit of narrow-mindedness.

Figure 3 Frame Render

• Conceptual design: After conducting in-depth research and engaging in a brainstorming session, a collection of ideas and solutions that satisfy the RFP was produced. A number of parameters, including as size, weight, cost, complexity, manufacturability, safety, and reliability, were used to evaluate several design approaches. The best design was then selected with the use of a trade-off matrix.

• Preliminary design: Following agreement on a design concept, a proof of concept containing fundamental 1 0design ideas was produced. The team then reassembled to discuss the prototypes' practicality in order to arrive at the best options.

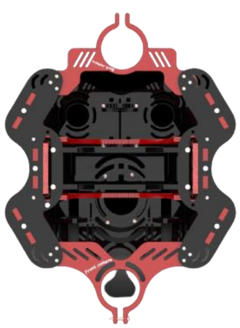

Figure 4 Frame Top view

• Detailed design: Following the validation of the concepts, the preliminary design was 3D modelled using a variety of programs, including Altium for modelling printed circuit boards and Solid works for mechanical designs. When necessary, flow simulations and force analyses were also performed, which helped Overflow arrive at a thorough design that is prepared for manufacturing.

• Manufacturing: The manufacturing method guarantees build integrity and dimensional precision, making it as efficient and cost-effective as it can be. Lathes were used to create cylindrical parts, while CNC routers were used to route acrylic and High Density Polyethylene (HDPE) plates. 2D CAD drawing files were created for CNC routing with the goal of utilizing the least amount of space possible on a sheet to minimize material waste. The components were then put together and prepared for testing.

2.2 Frame

Poseidon’s frame is constructed of 2 HDPE plates connected with 6 HDPE rods all of them Router machined. We decided to go with a 2 layers design specifically to have enough fixation space between upper plate and lower plate. We had 2 ways of assembling our vehicle either tab and slot or screws and nuts, all of the used screws and nuts are stainless steel due to rust problems with regular steel nuts. We connected the watertight enclosure with the lower plate and the upper plate by a support which increased the design durability.

Figure 5 Side View from Frame

We faced a big challenge while designing, drag force is a huge effector on any vehicle’s speed so while designing we needed to put in mind that drag force can lower our vehicle speed and we overcame that by making ***Poseidon’s*** frame in an open way by creating open slots and holes everywhere and reducing the used materials we achieved what we wanted. We decided to create a compact small frame so we can meet all mission requirements and our Rov can maneuver all around the underwater tasks without any problems. We have 4 cameras connected to ***Poseidon*** to offer the best vision system, all of them connected with HDPE parts. To boost total underwater stability, we constructed our rods, mounted T-200 thrusters on them, and added various fixation points. This allows us to locate the drag line and fix the thrusters to meet it. Our frame is rounded for all edges so we don’t have any sharp edges.

2.3 Material Selection

We had to choose the material for our mechanical frame, but mechanically speaking, we focused on three key factors: Density, cost, and production methods all have regulations that forced us to be very discerning when selecting our materials. First, density was a major factor in our search for a strong, lightweight material that had a density similar to that of water (997 kg/m3)., we conducted that we had multiple choices in term of density Despite the fact that all options were excellent, HDPE turned out to have a density that was most similar to that of water. We discovered that HDPE was the most affordable material, allowing us to stay within our budget.

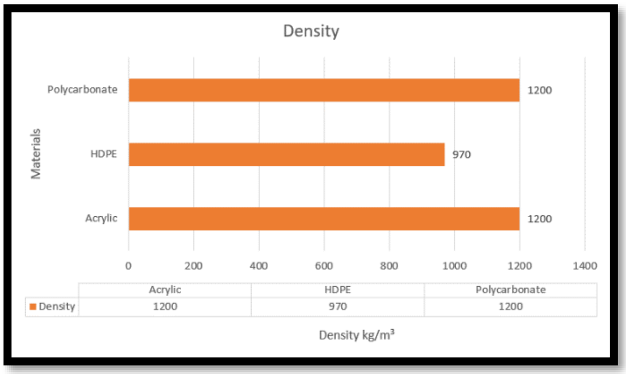

Figure 6 Density comparison

Finally, HDPE provided us with a variety of fabrication options, including CNC routers and CNC laser machines. Both of these machines can produce excellent results, but we decided to use the router machine because it was slightly less expensive and provided 3 dimensions of cutting, making it simple to make groves and 3D shapes.

2.4 Stress analysis

Stress analysis is a crucial step in the material selection process to determine a material's capacity to sustain the stresses placed on it and prevent unexpected bending deformation or material failure. Using the ANSYS software, the stress analysis procedure is carried out by modelling actual loads, fixes, and material specifications. After running different analysis on ANSYS we found out that HDPE was the best option for our vehicle main plates and we can either use 5083 alloys or HDPE for the rods, we decided to go with HDPE due to low cost that can save up to 40 % from our material cost. After stress analysis we started the drag analysis and by using Solid works flow simulation we found out the ***Poseidon*** can reach a max speed of 110 cm/s which was fabulous. We conducted from our simulation that most of the drag force was created due to the water tight enclosure so as a future improvement we are thinking of creating a DOME which can reduce overall drag by more than 60%, moreover it will allow ***Poseidon*** to reach 170 cm/s underwater.

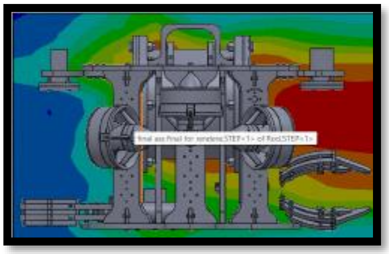

Figure 7 Poseidon Ansys analysis

2.5 Sealing Philosophy

Mechanically wise we had 2 main types of sealing to choose from either chemical sealing or non-chemical sealing (Gasket sealing), after searching and getting results from R&D we conducted that non-chemical sealing had much more advantages than chemical sealing which made it easy to choose between them, We chose to go with gasket sealing as our primary philosophy mainly, it is an easy philosophy used in enclosures that need to go in high depth levels, easy connect both of your parts in our case the enclosure body with the cover and attach between them a high density rubber gasket by applying the pressure equally while tightening easily you have a sealed system.

As we had a High-leveled electrical system we was determined to use an on-board electronic enclosure to protect all of our PCB boards. We used 2 gasket for our main enclosure and applied the force equally till we reached high results, after multiple tests we reached a max depth of 30 meters moreover, We faced another sealing problem in all of our enclosures and it was cable sealing but we found a winning product that helped us which was stainless steel cabled glands by applying prefect pressure it can handle high pressure levels easily.

Chemical	gasket
One time use	Multiple time use
Epoxy seal	Rubber seal
Hard to remove	Easy to Remove
Low depth margins	High depth margins
Low cost	Average cost

Figure 8 Chemical and gasket sealing comparison

2.6 Innovation

Poseidon was a developed vehicle, so we tried to come up with a few ideas to cut costs and improve functionality. For example, we wanted to expand our manipulating systems and increase the number of mechanisms, but that would increase the size and cost of our vehicle, so we came up with the idea of a clever attachment. Our manipulator end effector is connected to all the mechanisms we wanted to add, and it can be changed and removed by simply inserting the new mechanism into the appropriate slot. The new mechanism will be held firmly in place until it can be removed by hand. As we tried to stick with our budget we had some extra ideas that cut down costs and helped us to reach high levels of functionality.

We saw that most of the 2023 tasks needed to be held vertically so we discussed creating a vertical dc gripper, which would have cost about 130$. Instead, we created a pneumatic operated 4-fin manipulator which held in both ways vertically and horizontally and that just gave our manipulation system a blast and we created it at a lower cost coming only at 80$, it helped us to do tasks like, installing the syringe and the camera. We have developed two tools: a fish box and an airbag. The fish box is a lidless box diagonally split in two, with a rectangular piece that slides into the manipulator's end-effector and a tether. It is closed to gather and opened to release. The airbag is made from a plastic jug with a cut top, two holes opposite each other, and a rope with a carbineer on one end and a hook on the other. It is filled with water before attaching to Poseidon, and once on the ROV, it is filled with air to provide a lift force boost and it costed us about 5$.

Figure 9 4-fin Gripper

3.0 Payloads

3.1 Watertight enclosures

As we mentioned we needed to use on-board electronics which increased the bouncy challenges but helped us in the stability of our vehicle overall, we decided to go with a cylindrical shaped sealing enclosure which we had multiple alternatives our research result came out to 2 main enclosures either the Blue Robotics enclosure or a HDPE fabricated enclosure. Our R&D team did a comparison that resulted in choosing the HDPE fabricated one due to mainly offering low cost and meeting all our requirements.

	Blue Robotics Enclosure	HDPE Enclosure
Accesibality	Easy to open	Meduim difficulty opening
Cost	330-500 $	70-180 $
Quality	High-Quality	High-Quality
Depth	65 M	15-35 M

Figure 10 Enclosure comparison

Figure 11 Electronics watertight enclosure

We mainly aimed to achieve high FOS (factor of safety) so we can reach high depth levels which was achieved in the HDPE enclosure. After the sealing test we reached a max depth of 30 meters having a FOS of 5 which was fabulous for our low cost enclosure. Our enclosure had huge internal dimensions of 165mm X 165 mm which made the assembly of our PCBs easy. Furthermore, our watertight HDPE enclosure is consisted of multiple parts Main body, Rubber, Cover, Lens and Cable glands. We covered the main body with a lens from the front so we can insert a camera to provide the main view of the vehicle, and we covered it from the other side with a HDPE plate with sealed cable glands and between each cover and the body was a rubber gland for sealing. Our organisation had to decide whether to invest a significant portion of its financial resources in one due to the high cost of high-quality waterproof cameras or to purchase an HD camera and seal it in-house. The second alternative was chosen, and transparent 6mm thick acrylic sheets were manufactured to fit inside HDPE cylinders to contain the USB and CCTV cameras. In order to account for margin mistakes, we built an HDPE cylinder sealing box for our cameras covered by a 6mm acrylic sheet and used a center lathe machine to build each of the boxes. We used cable glands and O-rings to seal our cameras, and they held pressure up to 2.5 bars pretty well (25 meters).

3.2 Manipulators

Pneumatic power transmission methods are often the best way to move parts and tooling in industrial machines. These pneumatic systems perform a myriad of tasks in automated equipment such as clamping gripping positioning lifting. Gripper is a robotic ‘hand’ or ‘claw’ that attaches to an underwater remotely operated vehicle (ROV) to provide a means of interacting with the environment. We considered developing a DC motorized gripper as new tasks were published, but after learning that it might be expensive, we chose to reuse our pneumatic system from 2022 in our new vehicle. As a result, we reused all the pistons and solenoids. Our gripper and end-effectors were redesigned to work with the new tasks. After considering the new duties, we decided to build a 2-dimensional gripper (4-fins) that can hold both horizontal and vertical objects. This worked out well because it was useful for activities that the primary horizontal grippers couldn't handle. We used three pneumatically actuated grippers: one 4-fin gripper, two primary horizontal grippers. Due to the tremendous force and speed of pneumatic systems, we operated them pneumatically. We designed slots in the horizontal grippers to accommodate various additional mechanisms, enabling the gripper to perform a variety of tasks with the simple insertion of an additional mechanism. We

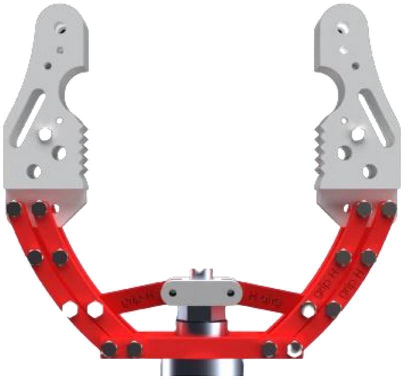

Figure 12 our main horizontal gripper

decided to create an attachable hook that holds a lift bag so we can lift the heavy container moreover, the 4-fined gripper was used in multiple tasks and created especially for them as: syringe, power connector and the long term camera.

3.3 Sensors

Inside our sealing box we had a water leakage sensor and a gyroscope sensor, we used the water leakage sensor while testing our sealing box to detect any leakage inside our enclosure moreover, we used a gyroscope sensor not an IMU sensor due to the difference in cost also our software team decided to use the gyroscope as it was easier in our system to get the needed feedback from the gyroscope.

3.4 Pneumatics

Because we chose pneumatics for our system, we had to take and pass the fluid power quiz. We attempted the question twice and passed the first time. Pneumatics are quite dangerous, thus we always followed basic guidelines to keep ourselves safe while dealing with them. To begin, the air pressure must be less than 40 psi while dealing with any pneumatics, and safety eyewear must be used.

We employed pneumatics to control our dual manipulators, but not for anything else.

Figure 13 5/2 Valve

Our pneumatic system was operated by one air compressor connected by air lines to the vehicle inside the vehicle we controlled the pistons by 5/2 valves to give us freedom controlling the pistons.

3.5 Thrusters

After creating our budget we found that we can afford buying new thruster so we had multiple options coming out to one of the most well-known world class thrusters T200 blue robotics thruster was our choice for our new vehicle, ***Poseidon*** is equipped with six T200 high-performance thrusters each performing at 12volts providing a thrust force of almost 20N per motor. The T200 thruster is unique compared to other thrusters.

Figure 14 T-200 Thruster

It allows the motor to be water-cooled and the plastic bushings to be water-lubricated. It eliminates the need for shaft seals, magnetic couplings, and air- or oil-filled compartments, making the thruster naturally pressure tolerant.

Also, the T200 thrusters are an affordable and a reliable option compared to bilge pump motors. We used 6 thrusters as our total budget didn't afford to buy 8 thrusters for extra power.

Thruster	Thrusft force	Current	Thrust current Ratio
T200	1.82 KGF	5.5	0.339
Seaflo pilge pump	0.71 KGF	5	0.142
Jhonson pige pump	0.9 KGF	6	0.15

Figure 15 Thrust to current ratio comparison

3.5.1 Propulsion

At first we had 3 options: T200 thrusters, Seaflo Bilge pump and Johnson bilge pump. We decided based on the Money-to-performance ratio and the voltage-to-performance ratio of each thruster/pump. After testing and searching we discovered that T200 thrusters will offer the best performance for the current withdrawn moreover, they stuck to our budget with ease. We used a vectored configuration fixing the thrusters on 30/60 degree configuration allowing ***Poseidon*** to have all the available horizontal movements at fabulous speed levels.

Figure 16 30/60 Thruster fixation

In further details, it sacrifices a small percentage of the forwards and backwards thrust force to provide us with various motion abilities such as: sliding and yawing, but why his configuration is so special is because it sacrifices the least speed forwards and backwards. After doing the calculations we calculated our thrust force based on a simple calculation (motor thrust * number of thrusters * Trigonometric ratio at specified angle) with five degrees of freedom in this arrangement, ***Poseidon*** is easy to steer and navigate between missions while maintaining the best stability while moving.

Direction	Thruster force	Angle	Num. of thrusters	Thrust force
Forward	1.82	30	4	7.192870223
Backward	1.44	30	4	5.691062155
Right Slide	1.66	60	4	1.024229627
Left Slide	1.66	60	4	1.024229627
Up	2.61	0	2	5.22
Down	2.1	0	2	4.2
All Thrust force is taken and current limit is in consideration				

Figure 17 Thrust force layout

3.6 Buoyancy

Buoyancy is the tendency or capacity to remain afloat in a liquid. The buoyancy will define if your object will sink or float while it is the combination of the ratio of your objects mass to surface area in contact with the fluid. Also, when an object floats, it has displaced the exact same weight of the fluid as the object which means if an object that is put in a fluid weighs more than the weight of the fluid it displaces, it will sink. Buoyancy is then directly related to the weight or density of the fluid, so denser or heavier fluids will be able to float heavier objects. In a column of fluid, pressure increases with depth as a result of the weight of the overlying fluid. Thus the pressure at the bottom of a column of fluid is greater than at the top of the column. Similarly, the pressure at the bottom of an object submerged in a fluid is greater than at the top of the object.

object	density	Bouyant force	Volume	Weight in air	Weight in water
Frame	970	27.0921	0.00285	28.17	1.0779
Acrylic	1200	11.8776	0.00101	13.11	1.2324
HDPE for cameras	970	5.13324	0.00054	5.9	0.76676
HDPE gripper	970	9.544024	0.001004	9.25	-0.294024
T-200 thruster				20.25	6.1
screws and nuts				15.2	11.1
Total				91.88	19.983036

Figure 18 Buoyancy excel sheet

An excel sheet was created to identify each object volume, buoyant force and weight in water. We concluded the total needed foam for our vehicle from that spreadsheet, we found out that ***Poseidon*** was slightly negative so it needed extra foam to float. Making the frame neutrally buoyant was one of the main design considerations that went into its creation. As a result of the removal of extra material, Poseidon weight was reduced to 10 kgf and its displacement volume to 12043 cm3. The following is how Archimedes' principle was used to produce neutral buoyancy: FBuoyancy = Vg, where the buoyancy force is 8.7 kgf, which is larger or less than the weight of the Nautilus. As a result, 1.3 kg of negative buoyant force affected Poseidon which meant we needed to add floating foam.

3.7 Trade-offs

Thinking of new vehicle you have so many options to choose between although difference in quality and price points, a lot of options were strong. First thruster option, we had to choose between T-200s or pilge pump there was a huge difference in price points and also a huge difference in effiecncy after running some tests to conclude thrust force and used an ammeter to measure current withdrawn, we concluded that T-200 was the most powerful and the least current consumption coming in at 0.339 Kgf/ampere although high price we decided to use T-200 to boost our maximum speed. Secondly coming to frame we had tons of options but at our budget we found out either HDPE or aluminum profiles will come in handy, so we started comparing between them which resulted of knowing that HDPE was lighter and less dense than aluminum but aluminum was more durable and modifiable so we started putting some constrains that we needed in our design moreover, we found that HDPE was better for ***Poseidon*** and was based on our design needs not only engineering comparisons. Thirdly manipulators as Arsenik was well-known for its grippers we didn't need to improve much except only changing end-effectors to be applicable with the 2023 new product demonstration tasks, we also decided to go with the same pneumatic system for our ROV. We decided not to go with Newton subsea gripper due to its high cost.

3.8 Buy VS Build

As the season started we had multiple options in multiple components but mainly it came to either build the device or the component or to buy it ready to use.

Thruster option, 2 main options were there to be made either to buy the T-200s or to build a thruster using Pilge pumps. After some studies we concluded that the T-200s have high thrust to current ratio which aids in developing overall speed and thrust force so we didn't really need to think about it and just stuck to the T-200s.

Manipulator option, we either had to build a dc gripper or a pneumatic one OR we can buy the blue robotics Subsea newton gripper, but due to huge cost difference we decided to create our own grippers using pneumatics. Pneumatic gripper costs about 60$ compared to Newton subsea which cost about 590$ nearly 10 times more expensive.

Figure 19 Newton subsea gripper

3.9 New VS Used

Arsenik's components were available to be used for this year season but not a lot met our new level of ***Poseidon*** so we didn't decide to use any of the vehicle components except the pneumatic system. We also used the old station and compressor to reduce in overall cost for new 2023 season.

4.0 Electrical

Since we decided to use on-board electronics we had to make multiple things from communication to control.

Our system is composed of 2 PCB boards that operates the whole vehicle. We use 6 ESCs, 4 CCTV cameras and 3 solenoids. Our vehicle have 3 codes an Arduino code, GUI and image processing code all of these work together to maximize our vehicle performance. We designed our PCBs using Altium designer and wrote our GUI using python language. We controlled the whole vehicle using an Arduino Nano chip. Our PCBs had some brilliant features mainly making our system very safe, we had overprotection on each thruster by putting a fuse in each thruster power line so it doesn't over consume power. The system is composed of 2 main systems power distribution system and a data communication system. We connect our 12v source to our PCB board and after that our PCB board distributes it among our cameras, motor drivers, and manipulators.

Figure 20 Arduino Nano

We connected the ESCs to our power PCB to get motors power and connected the cameras with USB ports for both power and signal. Since we used brushless motors we decided to control them by ESCs. We used the blue robotics ones. We decided not to use an IMU sensor due to its cost so we used a Gyroscope and we created a software that helps in the stability of movement of our underwater vehicle, the software mainly change speed of thruster if the vehicle drifted either sides, it came out pretty good as it increased the movement performance. We color coded all the cables inside our sealing box and TCU so we can identify any cable at any time with ease.

Figure 21 Blue Robotics ESC

4.1 PCB

PCB is among the most crucial components of a ROV. This year, we produced both a power and a signal PCB instead of just one. Power conducting rods are used to connect the two 15 cm in diameter PCBs, which are then put inside a tightly sealed cylinder. Power in, external 5v, buck circuit, protection, and motor out are among the circuits that make up the power PCB. The motor out provides the necessary power to the motors, the motor protection circuit stops energy from flowing backwards, and the buck circuit's job is to lower the voltage that enters some of the signal PCB's components.

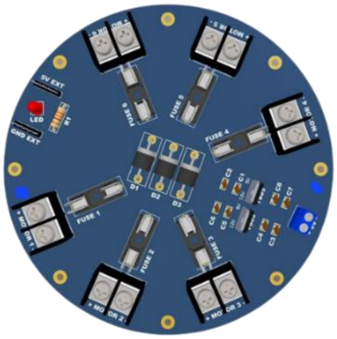

Figure 22 Power PCB

The signal PCB is further divided into numerous circuits, including those for the cameras, power input, sensors, Arduino, tether plug, and protective circuit. The Arduino circuit, which comprises of the Arduino and is coupled to the cameras, sensors, and motors controlling them all, is the brain of the entire ROV. Additionally, it uses the tether to send and receive messages from the pilot. We don’t convert any voltages at all.

4.2 Tether

Our tether is composed of 4 wires, 2 power cables, one signal cable, and one pneumatic cable. tether construction philosophy was to build a tether with minimum resistance to the vehicle that can use the maximum amount of energy that can be delivered from MATE PSU within the requirement with minimum power losses along the tether, thus we settled on using 4 AWG made from OFC with a maximum number of strands to the tether can be flexible yet able to carry a huge amount of electrical current. For our signal cable, we went with a multi-core twisted pair cable that is composed of 10 pairs of 20 cables total we only use 16 of them. Our pneumatic cable is highly rated and that makes our tether totally safe. We have strain relief at both of our ends of the tether so the tether is not damaged at all.

We have 2 tether managers one of them manages tether that is going to the rov and makes sure that it doesn’t become an obstacle on the rov, and the other one manages all the payloads. We had 2 strain reliefs created by cable gland one in our rov connected to the frame the other in the TCU connected to the handle.

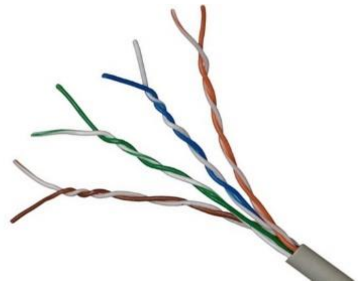

Figure 23 Twisted Pair cable

4.3 TCU (tether control unit)

The tether is the gathering of all the cables used to connect between ***Poseidon*** and the 25A power supply. It is also considered as one of the main parts of the ROV as it has several functions such as:

● allowing the Signal communication between the Control Unit and Poseidon by sending and receiving data (UART).

Figure 24 RJ-45

● Transmitting captured images by the camera
● including the pneumatic hose that controls the pneumatic manipulator. The tether provides all necessary connections from the topside control station to the ROV.

Our tether is composed of 4 wires, 2 power cables, 1 signal cable, and 1 pneumatic cable.

Our power cable is a regular copper cable that comes at a thickness of **6mm** which is really good in our condition.

For our signal cable, we went with a multi-core twisted pair cable that is composed of 10 pairs of 20 cables in total. 4 pairs for the cameras, 2 pair for the RJ45, 1 pair for the RS485 and 3 pairs as spare. The tether is 15 meters long and allows the ROV to reach all areas of the mission field. The pairs of wire are all inside the same cable to ensure it remains neat and manageable.

The tether is secured to the ROV with a strain relief system which center the tether on the top of the ROV, at both of our ends of the tether so the tether is not damaged at all. An expandable clip is used to keep the tether neatly coiled during transportation and storage.

The tether is carefully engineered using foam rings to be neutrally buoyant, which minimizes tether drag while navigating ***Poseidon***, making it easier to control and complete missions. We have 2 tether managers one of them manages tether that is going to the rov and makes sure that it does not become an obstacle on it, and the other one manages all the payloads. We had 2 strain reliefs created by cable gland one in ***Poseidon*** connected to the frame the other in the TCU connected to the handle.

4.4 Communication

We used RS-485 as our communicator we connected one RS in the vehicle and the other in the station outside each RS was connected with one Arduino Nano one acted as a master the other as a slave, We specifically used RS-485 because it can give us powerful signal up to 1200 meter with a stable connection.

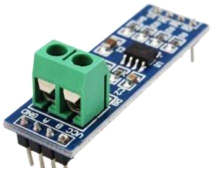

Figure 25 RS-485

Each RS had 8 pins 2 pins for power and the other 6 divided as follow, 2 of them called A and B those were connected with the other module in the same pins in twisted pairs wires, 2 more pins are connected together to set the state of the module and also are connected to the Arduino the last 2 are connected with the Arduino Nano to transmit data. We created a backup communication system because we were aware that failures frequently occur and we didn't want to stop working. The second system, which utilizes RJ-45 connectors, is linked to an Ethernet cable along our tether. It is connected to both the Arduino in the rov and the Arduino in the station.

4.5 Software

The software teams' tasks include coding ROVs and determining appropriate antonyms for each activity.

Because the Arduino is the best option and the most user-friendly for writing, our software team uses it to operate the ROV’s components.

(Arduino)

For our primary communication system between the (HC-12), which we utilize it for the float mission, and the ROV, we use Arduino code to control the ROV's mobility (Rs-485)

(GUI)

The software team gathered to review its strengths and weaknesses, determine the defects of last years’ software, and lay down the software development timeline. A training period was allocated early this year to improve the software development and relay past experiences to new company members. We continued with last year’s strategy of implementing simple, yet efficient software architecture that is divided into two layers: Top-side and Bottom-side. The Top-side layer Control Unit (TCU) controls the ROV through a Graphical User Interface (GUI) that was developed using Microsoft Visual Studio and coded entirely in C#. As for the Bottom-side, our primary communication system was between the (HC-12), which was utilize for the float mission along with (RS-485) which was developed in C++ using Arduino Boards. C++ language was chosen for its speed and efficiency and Arduino Nano Chip (Microcontroller) was used to take advantage of its size in order to reduce the tube’s volume, facilitate the boards’ design. For the tasks including image processing, we decided to work with OpenCV, Numpy and Turtle library due to its comprehensive documentation and the availability of online resources for it. Besides its aesthetic appearance, the GUI’s main purpose is to: 1) Act as an interface between the joystick and vanguard. 2) Control the thrusters’ speeds, and improve the user experience. 3) Navigating between different widgets for each mission in the GUI makes it more organized and user friendly. 4) For better accessibility, the GUI is designed such that it features a pilot Head-up display (HUD) that displays the ROV’s sensor readings (Gyroscope Sensor). 5) The unique, useful idea is to implement in our application. A 3-Dimensional model our app.

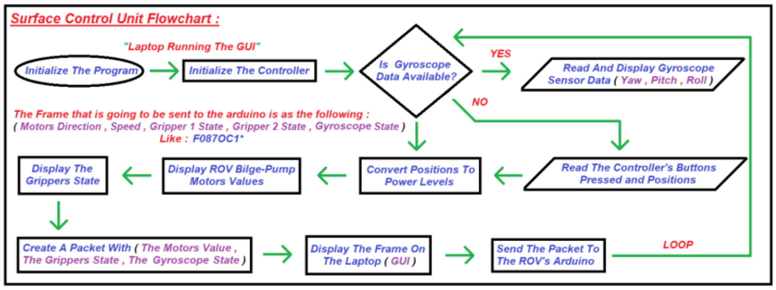

Figure 26 GUI Flowchart

Which replicates all of the ROV movements. The control system's purpose is to manage all of the electrical components on the ROV and give the pilot and co-pilot the ability to intuitively operate the vehicle. The system controls the motors through an onboard Arduino Nano Chip, which communicates with the topside controller to exchange information about motor power and sensor information with a communication protocol (UART). We used RS-485 as our communicator we connected one RS in the vehicle and the other in the station outside each RS was connected with one Arduino Nano one acted as a master the other as a slave, We specifically used RS-485 because it can give us powerful signal up to 1200 meter with a stable connection. Each RS had 8 pins 2 pins for power and 6 other for signal, 2 of the 6 signal pins were called A and B those were connected with the other module in the same pins, the other 4 were connected with the Arduino Nano to transmit data. We created a backup communication system because we were aware that failures frequently occur and we didn't want to stop working. The second system, which utilizes RJ45 connectors, is linked to an Ethernet cable along our tether. It is connected to both the Arduino in the rov and the Arduino in the station. The communication between the laptop and Arduino utilizes a packet based system (Arduino Special Frame) to ensure all data sent and received is accurate. The communication protocol packages the signal to be sent with a corresponding hash code (a unique check value generated for each possible Command signal). This hash code is verified at the receiving end of the signal to ensure all enclosed data is accurate. The topside control Station: The topside control station is operated by two pilots: The main pilot operates 3D Pro Joystick which steers the ROV via the 4 directional thrusters. The Joystick is connected to a laptop, which runs a Processing sketch communicating with the Arduino to send motor, grippers and sensor data. The co-pilot operates an intuitive user interface which allows adjustment of the camera or attachment positions from the computer. The Devices Used To Manufacture The TCU:

1. Laptop: The laptop is used to provide the Co-Pilot with all the specific software tools needed in missions during the product demonstration.

2. Joystick: ***Poseidon*** uses an extreme 3D Pro Joystick to communicate with a Python graphical user interface (GUI) on the laptop, then to the Ethernet module via the Ethernet cable in the tether.

Figure 27 Logitech 3d extreme pro

3. Switch Network: It was used to connect between what the Camera displays from the Vanguard on the DVR to the image processing laptop in order to perform the tasks smoothly.

4. Indication LED: They are used to ensure the proper connections of the bilge pumps by checking the corresponding LEDs are on.

5. Digital Video Recorder: The DVR is used to record the cameras' video in a digital format.

Figure 28 DVR

It also supports the HD camera display. The cameras signals are collected from the tether through the Control Unit amplifiers then enter the DVR which displays this video to the Monitor and the laptop.

6. LCD (Liquid Crystal Display) Screen: It is used to display the cameras stream for the Pilot from the main and manipulator cameras (the two on-side-cameras) & also the 2 other down and 4 fin gripper cameras.

(Image processing)

Image processing resembles machine learning, but it differs greatly from it in that it provides a ROV or other object with a picture that will face it in the real world so that it can recognize it and move toward it. To overcome the problem of fish length, we apply image processing. However, when we chose to use image processing to complete this assignment, we discovered a challenge: we needed to locate a fixed point with a length that could be compared to the fish. Following some deliberation among the members of the software team. The station (pool) tiles were chosen as the fixed point for image processing with (Python).

Figure 29 LCD

4.6 Communication technique

Our code was very simple we created functions for every motion with a specific symbol that we created when the Arduino receives that symbol from the GUI it starts creating that motion, every function have the acceleration code that Allows it to accelerate to the specified speed which allows our system to be more reliable. Our GUI have a pretty simple working method it takes the data coming from the joystick and specifies the required motion then send it to the Arduino to do it and control all the motors. We created functions in both of our codes GUI and Arduino in the GUI we had an IF condition and it is decided on the button clicked from the joystick and after that the GUI send a specified symbol like forward (F) and when the Arduino receive it calls the function with the specified symbol and controls the motors.

4.7 Cameras

Since visibility is essential to completing missions and having a functional ROV, the goal was to build a multi-camera system that provides effective sightlines for all missions and general navigation. In addition, the system had to be cost-effective, lightweight, and capable of viewing and managing multiple video feeds. In order to reach the widest field of view for the manipulators and the ROV's surroundings, ***Poseidon*** uses four CCTV Analog Video (AV) cameras that are classified to:

A. Main Navigational Camera:

The HD resolution camera is used as the main camera due to its wide angle of view which is up to 160 degrees and for its clear and high-resolution images. It is positioned at the center front of ***Poseidon*** and directly attached inside the water tight enclosure. It allows us to see all of the front view from our vehicle moreover allowing us to create the 3d model head

Figure 30 Main camera and Gripper camera fixation

Manipulator Cameras:

To achieve the maximum vision and profitability, three secondary cameras.

The first camera looked at our dual horizontal grippers, the second camera looked at our 4-fin gripper, and the third camera looked at the down view of our vehicle - are tilted downwards with a slight angle to cover the corresponding manipulator and vision on hand. The cameras were connected to PCB with USB cables inside of the sealed camera casing.

The power cables of the CCTV cameras were connected to a video balon and both of the signal cables were inserted in their places. This video balon was connected to the USB cable to the PCB. Moreover, the camera cables were connected to the tether. Furthermore, in the TCU, four video balloons were connected and then connected it to our DVR, and the DVR was connected by a computer screen.

Figure 31 CCTV Camera

B. Video balloon :

They are used to convert the camera signal into a differential pair that is sent up by the tether and converted back into a single wire on the surface by another video balloon. This reduces the effects of interference and noise to obtain a clearer and undistorted image.

Figure 32 Video Balloon

5.0 Logistics

5.1 Project management

"A dream does not become reality through magic; it takes sweat, determination, and hard work." Colin Powell. The journey started with a dream of 5 teenagers to create their own ROV Company and construct their ROVs. Consequently, they founded "Overflow Robotics company", which is a new ROV company founded in August 2021. A number of the company's previous members returned this year, and new members with similar goals joined the organisation as well. For the several

ROV departments, groups were formed in order to carry out the necessary tasks. Group members can supervise one another as they work on their assigned tasks, encouraging cooperation and educational opportunities. Since no one is operating machinery alone, safety may be guaranteed by team members keeping an eye on one another.

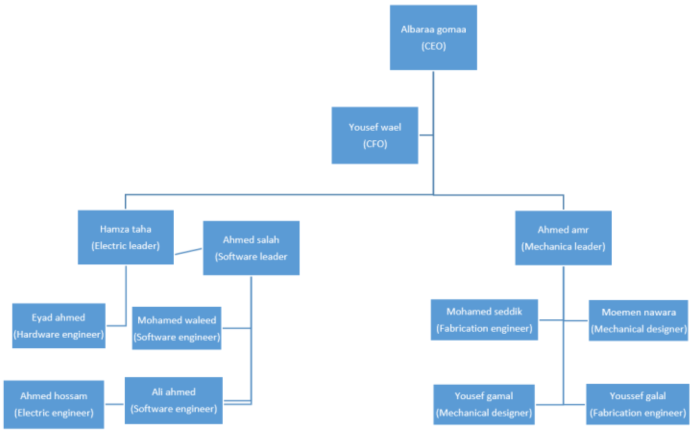

Figure 33 Team Tree

To increase efficiency, work were carefully allotted to each department based on their respective strengths. Coming into 2023 we had high potential levels to reach some world class system and be internationally ranked so we thought of multiple ideas so we can achieve what we can do, but all of this wasn’t easy due to the lack of management moreover, we chose 2 team leaders on can manage the team and the other will manage the financial status Our CEO & CFO, they came out very responsible and proved that they can manage the team, To run and create a high-level ROV, Our business is divided into three sub-teams: the electrical sub-team, the mechanical sub-team and the Non-technical sub-team. Each sub-team had its own team leader so they can oversee what is happening and to be capable of managing and dividing the available work. Our CEO was capable of overseeing each leader and track of each sub-team’s progress; with the help of the team leaders, he was also capable of team organization. We always followed all the regulations from the competition regulations to safety regulations to make sure that we produce the most powerful vehicle. The Non-technical sub-team always revised and read all the documents released by the competition so we make sure that we follow the updates. We dealt with a lot of day-to-day issues, primarily each while we were in the meeting. We divided up all the tasks among the team members, and everyone got to work. Any issues were assigned to the branch leader (sub-team leader), who began reviewing and resolving them with the team members engaged in that task.

5.2 Brainstorming

Our brainstorming process starts by the sub-team's leader assigning a specific topic requiring deep research containing as much

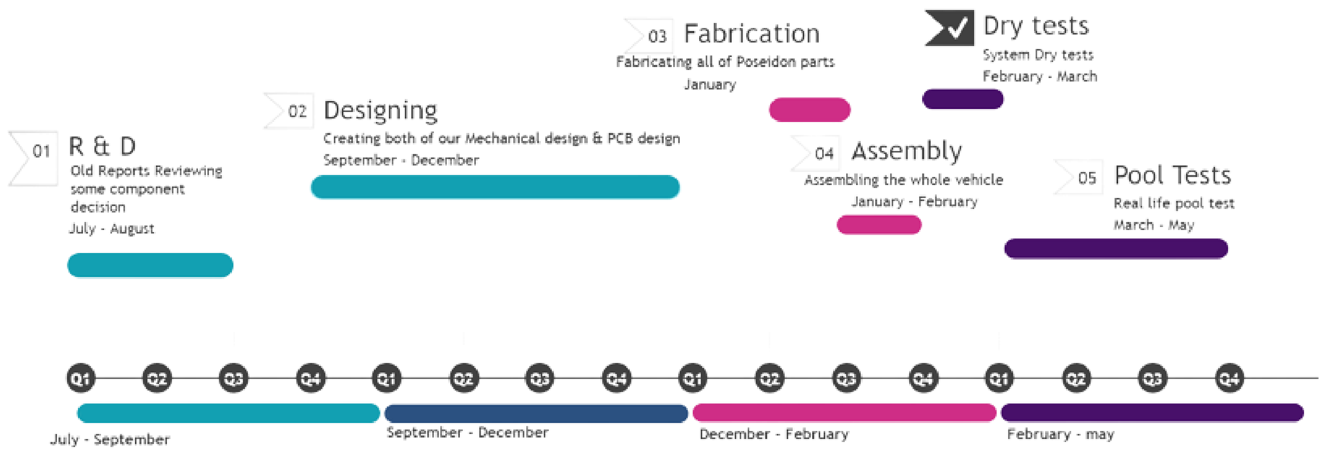

Figure 34 Gantt chart

information as possible with the most creativity. Then, now that they have collected their information, during our weekly meet up, everyone is provided a pen and paper to write down their ideas/solutions. After that, we would write everything that was we wrote on a board then we would vote out the most suitable solution/idea. We used the brain writing brainstorming method where everyone sit in a circle writes three ideas related to the topic and then passes it to the person on their right. Then, they build off the ideas that were written and repeat until the papers have gone all the way around. Furthermore, that is how we picked

Figure 35 Mind map

our choice of thrusters. At first we had 3 choices between Johnson bilge pumps, Seaflo bilge pumps and T200 thrusters, and we found that the T200 thrusters produce the highest thrust force and it uses the least electricity, so it was the best choice. Another brainstorming technique we used was "Mind Mapping" it is one of the best brainstorming techniques. Using this method, ideas and concepts are visually represented in order to organize thoughts and inspire creativity. A major idea or topic is usually the starting point of a mind map, which is subsequently developed through a number of branches and sub-branches. Each branch is a new thought or idea related to the main subject. A digital tool or pen and paper can be used to generate mind maps. The benefit of this approach is that it promotes non-linear thinking, which aids in the generation of a variety of ideas and the connections that can be made between them. Mind mapping is a fantastic tool for examining difficult issues or situations, as it allows individuals or teams to break down the problem into manageable parts and identify potential solutions.

5.3 Planning and scheduling

Coordination and planning were two of the company's main issues because its lofty goals required a significant time investment from each employee. In order to maintain high attendance at meetings and efficiency, communication between employees was crucial. To keep track of attendance and emphasize the value of attending as many meetings as possible, a reminder was sent to each one. The **WhatsApp** group was one tool utilized for this, allowing firm administrators to send out announcements to every employee and acting as a hub to connect the entire organization across devices. All staff members and parents may access the upcoming week's calendar of meetings thanks to the use of an Excel sheet Schedule that has been updated daily and sent to all company members for meeting scheduling. Trello was used to organize the work so that each department could see what needed to be done,

Figure 36 Planning for the timeline

what had already been done, and who was responsible for each task. Each task that was allocated to a team member had a deadline, and team leaders were accountable for checking in with every team member. We created a calendar so that we could adhere to it. We had five milestones in mind when planning the entire season: R&D, designing, fabrication, assembly, dry tests, and pool tests. We separated up each milestone into its own time period and scheduled the entire area.

5.4 Meeting organization

Trello, Zoom, and WhatsApp were the most frequently used business communication tools in terms of resources. Depending on the intended sort of communication—a team database, a company-wide statement, or an individual communication—each had a certain purpose and function. This made it possible for staff members to consult data from several departments when troubleshooting systems. In terms of business practices, each meeting day would adhere to a consistent steps approach that would efficiently guide us through each task that needed to be completed as well as any potential complications. The entire team would first gather to review the day's objectives for each group, as well as to make any other significant announcements or pose any queries. Second, each team would divide into smaller groups to finish the day's assigned duties. During the meeting, someone would be identified who could be contacted for assistance. In order to review their progress, whether they accomplished their daily aim, and any problems they encountered, the team would finally reassemble. Each employee was expected to follow certain procedures, such as maintaining a peaceful workplace, refraining from unexpected movements, and concentrating on their task throughout the entire meeting. We hanged an objectives board that was updated weekly based on weekly objectives for company work. Throughout the working period, all the team members were thinking about how to exploit all our resources and tools to achieve the mission's maximum points. The main tools we used like motors, cameras, and manipulators were the main resources, which helped us to test our ROV. This design functionality was inspired by the human body, so the motors were like the legs of the ROV, which help it to move freely. Second, the manipulators were like the human hands to catch the mission needs such as the Eco mooring connector mission, lastly, the cameras act as the eyes of the ROV that helps it to see all missions needed underwater.

5.5 Testing and troubleshooting

The main focus of Overflow' engineers is testing and troubleshooting, from the tiniest mechanical component to the largest functional code. Prior to attempting mission runs, a four-step verification and validation method is used for vehicle testing in accordance with our safety protocol and the use of the V model.

Phase One – Unit testing: For mechanical systems, 3D printed models were used to prototype design ideas in order to understand the nature of their assembly in the actual world. This phase is known as unit testing. Before any electrical components are installed, all sealed enclosures go through a water test that lasts a different number of hours to assure water sealing. In terms of electrical systems, simulators like SPICE analysis were utilized to test our electrical components for any voltage spikes and confirm that the input values that were theorized to produce the intended output actually do so .Additionally, to prevent any significant accidents, they are tested separately in a private setting in the real world. For software, "Statement Coverage" and "Decision Coverage" techniques are used to test algorithms, with all statements in particular decision-based ones are tested.

Phase Two – Integration testing: A new unit is integrated with the pertinent system after passing its unit test subsystem. The subsystem is tested by feeding it certain inputs obtained through boundary values approaches, equivalence partition, and truth tables, and then watching the related outputs to make sure it functions as intended expected. The ROV is equipped with debugging LED lights, each of which is placed in a different area to signal a problem with a particular component of the system.

Phase Three – System testing: The ROV is tested in the actual world after being extensively tested in simulation and after being constructed mechanically and electrically. It undergoes a dry run phase test where it is evaluated in a secure and useful setting on land. Phase four of Overflow' testing methodology, which involves testing the ROV in water, starts once the dry run is finished.

Phase Four – Acceptance Testing: For many days straight, the ROV is put through a stress test underwater to make sure it can perform to its maximum potential. Analysis is performed to identify the problem in the event of any underwater malfunctions. Once it has been found, all department personnel come up with remedies, which are then put to the test using the same four steps to make sure they work well. The pilot utilizes the ROV to complete all tasks if there are no faults. The results of each mission are used to confirm that the acceptance test satisfies the standards established by the request for proposals issued by the international community.

5.6 Safety

“Tomorrow: your reward for working safely today.” Attributed to Robert Pelton. This motto serves as the inspiration for our business since it drives us to prioritize employee safety above everything else. The commitment of employees to provide a safer working environment to prevent workplace injuries, safeguard instruments, and boost overall productivity. Comply with all MATE rules. The organization provides training, operating guidelines, safety procedures, and safety checklists to enable staff to take the right action in an emergency and avert potential mishaps.

Safety training: Past team members decide to introduce the new hires to Overflow Robotics since they are motivated by their dedication to the group. During their trial time, every trainee receives a briefing on the workshop protocols. Then, new hires receive in-depth safety training. Each new hire receives one-on-one instruction to make sure they thoroughly understand the workshop safety rules. Before doing the duties themselves, new employees must first watch an experienced team member complete each step numerous times.

Figure 37 Mechanical team member using safety gloves while working

Workspace Safety: Lab safety procedures are important since even the smallest error could result in a fatal tragedy. Personal Protection Equipment (PPE) is provided to each Overflow employee and must be worn at all times when working in the lab. Also, each employee must complete a sign-in page before entering the lab. On this sign-in sheet, it is noted. Who was using the machine, when, and where this is done in order to maintain a record of all active personnel, which will be useful in determining how accidents were caused.

Figure 38 Thruster Shrouds

Rov safety features: ***Poseidon*** has some different safety features having no sharp edges, shrouded thruster, 2 strain relieves and also overprotection on each thruster made ***Poseidon*** different.

5.7 History

Overflow didn't happen overnight; it required the perseverance and hard effort of a few motivated students who wanted to make a difference in the maritime technology field. We have been in business since August 2021, growing and improving every day. Both of the events we organized—one at "Robokid" and the other at "Jupiter Academy"—were focused at educating the next generation about robotics and ROVs. Our goal has always been to educate people about robotics, thus we set up a Facebook page where we share news and information.

Figure 39 Alexandria TV show

We were asked to a TV show on the "Alexandria channel" to share our tale. We also discussed how to manufacture ROVs and where to find information about them.

Figure 40 Jupiter orientation session

We also shared some of our information throughout courses we created both online and offline courses as fund-raising and also to spread robotics knowledge in the Egyptian culture.

5.8 Reflections

Ahmed Amr: The vibe here is different you work with people that make you feel as you are in your home, you develop every day more and more.

Ahmed Salah: Since I joined these people I gained a lot of knowledge and improved my software skills a lot. The work environment is different and that makes these people special.

Youssef Wael: Throughout the year the team chose me to manage the financial situation since that I have learnt responsibility and dedication.

Eyad Ahmed: ROV knowledge came out to be so valuable and working with overflow was one of the best life time experiences ever.

5.9 Future Plans

We want to add some enhancements to the next iteration of our vehicle because ***Poseidon*** was a significant improvement over Arsenik. In order to boost efficiency, we are considering developing the grippers and putting DC motorized grippers. We are also considering installing an underwater distance sensor, which will allow us to write an underwater autopilot code. Additionally. We considered integrating a GPS to map the entire underwater area, which would improve the characteristics of our vehicle. We are also thinking of creating a hybrid mode which can change all of our vehicle directions since we have grippers in front and back so it can be easy to control our vehicle.

Figure 41 Sealed Ultrasonic

5.10 Challenges Faced

We faced 2 challenges, firstly rush current this event occurred due to the sudden Increase in current consumption due to high consumption of thrusters at a sudden so we decided to create a soft start software code which makes our speed of thrusters Increase until it reaches the required speed. The second challenge we faced was the unavailability of most of the required components so we needed to build most of the components except the high level and quality components.

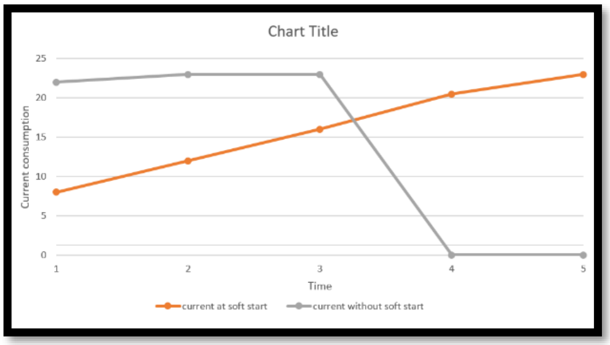

Figure 42 Current consumption for 2 options draft

5.11 R&D

Since the beginning of the season, we've focused on one of the most crucial phases: research and development. We've assigned two engineers to oversee all of our investigations and developments, and we've allotted a specific budget for R&D so that we can conduct tests on particular components in order to choose the one with the greatest functionality. The R&D team in an ROV team is responsible for identifying new opportunities, addressing challenges, and continuously improving the ROVs' performance and functionality. An efficient R&D framework fosters creativity, teamwork, and ongoing development within a ROV team. By creating new researches and developments, enhancing old ones, and catering to consumers' shifting needs, the team is able to keep one step ahead of the competition. In general, an R&D system is essential to a ROV team's success. As an illustration, when looking for the best water pumps for our Go-BGC float, we had three options with various specifications. Our R&D team tested each pump in a variety of settings before selecting the best one.

Figure 43 Water pump

5.12 Acknowledgments

Overflow wouldn’t be founded without the help of:

- Mate rov Egypt organization who helped us with any problems we faced
- Mate rov Egypt organization which helped us with all the registration steps
- Mechanism fabrication center which helped us with all the fabrication process and provided us with all the machines needed
- Moazz Mahmoud & Abdelwahab Adam & Ehab Abdel Rahman & Ahmed Amin & Abo-Bakr Mohamed all of our mentors helped and encouraged us to achieve higher and higher goals in the niche
- PCB way & Blue robotics for allowing us use their services at low costs with discounts.

Figure 44 Blue robotics, PCBWay and mechanism

5.13 Fundraising

After determining that a total budget of approximately $3700 was required, we began preparing a strategy for how to collect these payments. Each member was required $280 at the beginning of the season to join Overflow and utilize the components. In addition, we held some offline and online robotics courses and generated a total revenue of 520 $ that barely covered our budget. We created a go get fund campaign to help in our travel expenses but it didn't go so well.

5.14 Safety Checklist

Pre-Run Safety

- All nuts and bolts and attachments are secured.
- Thruster shrouds are secured and tight.
- Thrusters are clear no contact with any object - no foreign objects inside thruster shrouds.
- All wires are secure and in good condition.
- there are no sharp edges and/or corners on the ROV.
- Station table set up is clean and organized.
- All members of the station team are in a "ready position"

Product Demonstration Safety Checklist

- the tether manager is the only person handling the tether (other team members cannot step over the tether).
- the power connection is secure and not near water.
- Control station equipment is securely placed on the table (away from the edges of the table surface) in a clean and organized fashion. Demonstration).

5.15 References

https://bluerobotics.com/
https://courses.lumenlearning.com/suny-physics/chapter/5-2-drag-forces/

5.16 Strategy

Our vertical profiling float allowed us to obtain our first 60 points towards our goal of over 200 points in the underwater product demonstration. Also, our vehicle weighed less than 15 kg, which would add another 10 points. We began with positioning the solar panel, moving on to the fry release area and completing all necessary tasks, inspecting the buoy rope, and finally inspecting the Antarctica Lake and installing the long-term camera. As we complete all of these tasks, we collect images for the coral head model. Our rov then returns to the side of pool to be fully loaded again holding the tent, the syringe and the eco mooring connector. We go to place the tent over the diseased coral and then we install the eco-mooring connector and inspect the seagrass habitat, lastly we insert the syringe in its place. Our vehicle return to the side of pool so we can connect our airbag to lift the heavy container and retrieve it back after that we go to the docking station to auto dock.

6.0 Cost & Budget

We estimated that our total cost would come out to 3700 $ moreover we managed to cover over 4100 $ in budget from multiple income sources. We have laid out an estimated travel expenses and found out we needed in total a 17340 $ to cover all expenses from Alexandria to Longmont, Colorado covering flight, hotel, domestic transportation and registration, we started planning out how would we cover this costs.

INCOME	MONTHLY	BUDGET	MONTHS
OPERATING INCOME			
SELF FUND	-	$ 520.00	8 MONTHS
employee dues	$ 440.00	$ 3,520.00	8 MONTHS
PCB Way sponsorship	-	$ 110.00	2 MONTHS
TOTAL		**$ 4,150.00**	**8 MONTHS**

Figure 45 Budget Plan

TRAVEL			
TRANSPORTATION	$ 11,000.00	$ -	$ (11,000.00)
HOTEL	$ 3,480.00	$ -	$ (3,480.00)
Visa	$ 2,400.00	$ -	$ (2,400.00)
REGISTRATION	$ 250.00	$ -	$ (250.00)
T-SHIRTS	$ 200.00	$ -	$ (200.00)
MAREKTING THOUGHOUT EVENT	$ 10.00	$ -	$ (10.00)
	$ 17,340.00	**$ -**	

Figure 46 Estimated Travel Expenses

6.1 Expenses

EXPENSES	Estimated	Actual	Description	Status
MECHANICAL				
HDPE for sealing box	$ 72.00	$ 90.00	Material for our sealing box	New
HDPE for cameras	$ 25.00	$ 20.00	Material for our Camera enclosures	New
HDPE for frame	$ 60.00	$ 55.00	Material for our full frame	New
HDPE for grippers	$ 30.00	$ 35.00	Material for our Manipulators	New
Center lathe for sealing box	$ 40.00	$ 48.00	Machning cost of our sealing box	New
Center lathe for cameras	$ 28.00	$ 24.00	Machning cost of our Camera enclosure	New
Router for frame	$ 65.00	$ 60.00	Machning cost of our frame	New
Router for grippers	$ 30.00	$ 35.00	Machning cost of our Manipulators	New
	$ 350.00	**$ 367.00**		
ELECTRONIC				
Arduino nano	$ 20.00	$ 45.00	Arduino nano that operates the full system	New
RS-485	$ 5.00	$ 10.00	RS-485 used for communication between TCU and ROV	New
HC-12	$ 25.00	$ 50.00	Hc-12 for wireless communication for the Go-BGC float	New
RJ-45	$ 10.00	$ 10.00	RJ-45 backup communication system for ROV	New
Tether	$ 100.00	$ 110.00	Power and data cables	New
PCB components	$ 25.00	$ 22.00	All rossetas and usb ports in our PCB	New
Camera	$ 35.00	$ 48.00	All CCTV cameras used for Rov vision	New
Pilge Pump	$ 12.00	$ 20.00	Used for GO-BGC float	New
Video Ballon	$ 8.00	$ 10.00	Used for Camera signal	New
ESCs	$ 260.00	$ 240.00	Used to control the Thrusters	New
Water Pump	$ 28.00	$ 26.00	Used for the GO-BGC float	New
T200 Thrusters	$ 1,100.00	$ 1,250.00	Used for high levels of underwater speed	New
	$ 1,628.00	**$ 1,841.00**		
TOOLS				
Rent	$ 550.00	$ 500.00	Co-workspace rent	Donated
Mentor salary	$ 1,100.00	$ 950.00	Mentor salary for their work with us	New
E lectronic components	$ 220.00	$ 195.00	Tools used for electronic system for our ROV	New
PCBs	Sponsored	**Sponsored**	Sponsored pcb costs	Sponsored
Machining & Fabrication	$ 200.00	$ 180.00	fabrication and machining cost for our ROV	New
3D printing	$ 100.00	$ 80.00	All 3d printed parts in our ROV	New
Printing & Marketing	$ 30.00	$ 20.00	T-shirts and flyers costs	Donated
	$ 2,200.00	**$ 1,925.00**		
TOTAL	**$ 4,178.00**	**$ 4,133.00**		

Figure 47 Total detailed expenses

7.0 Appendix

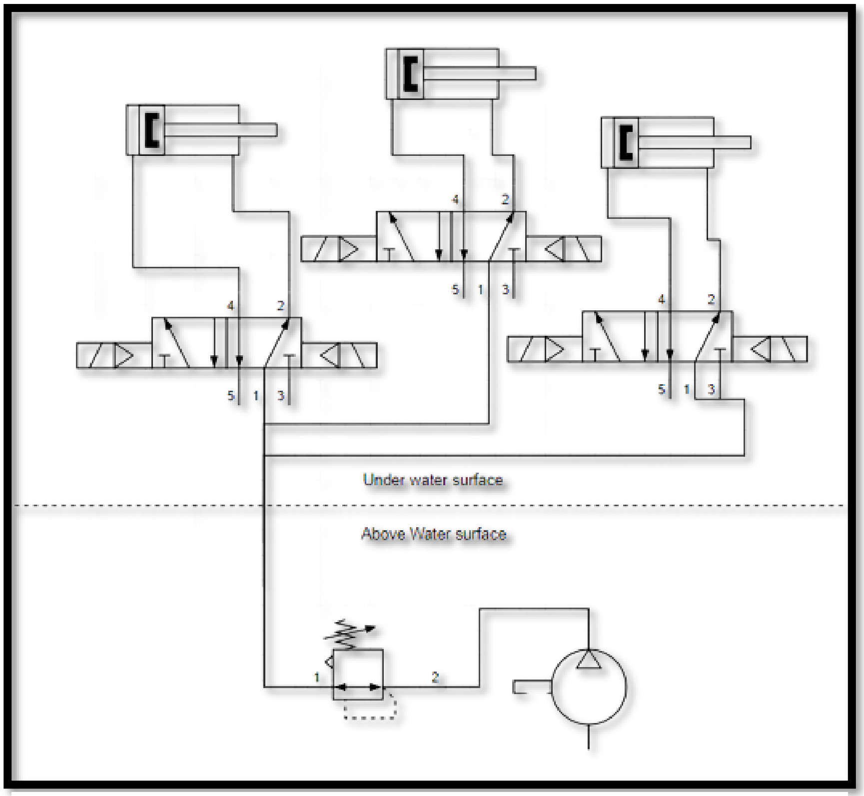

Figure 48 Pneumatic SID

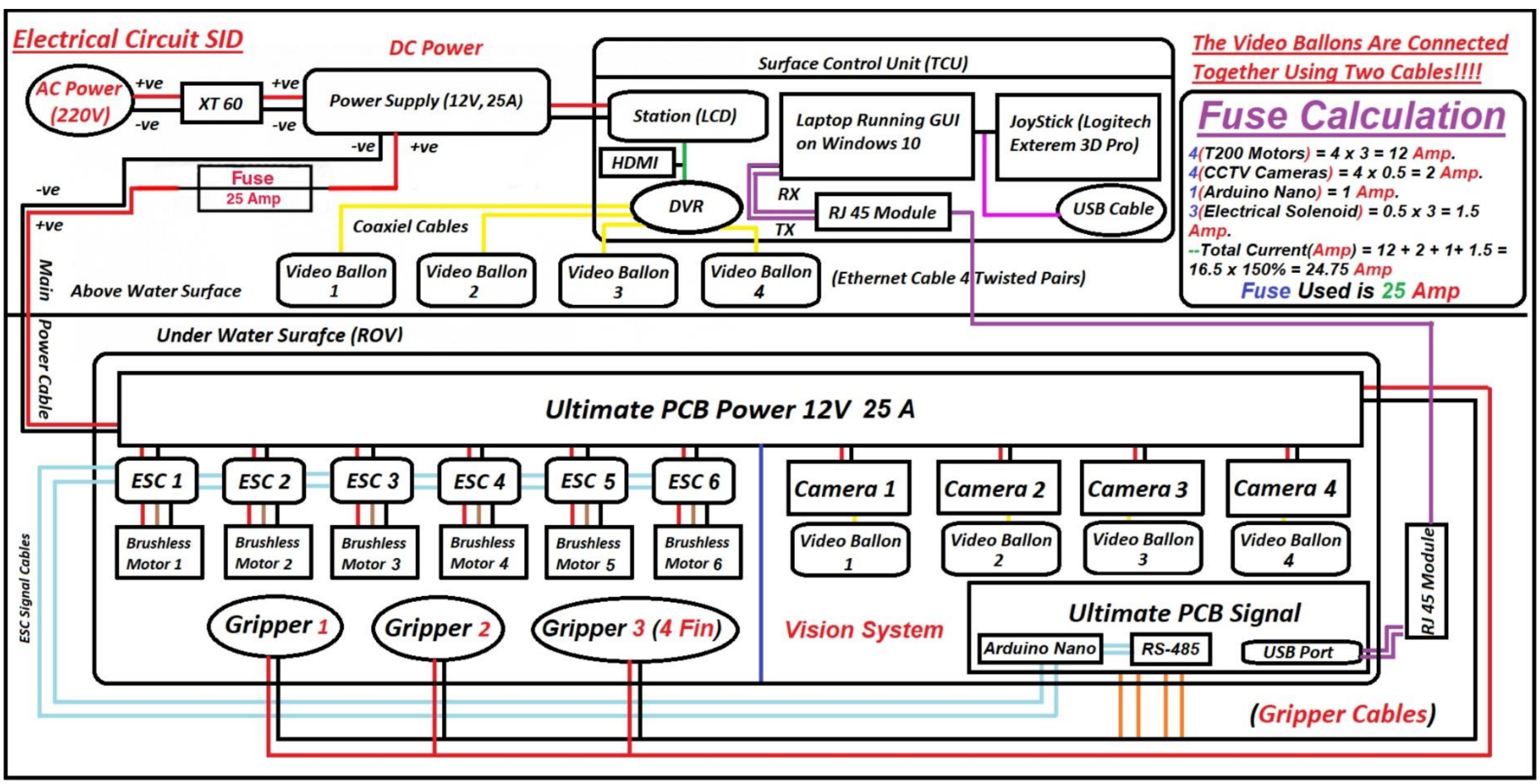

Figure 49 Electrical SID