mia robotics

MATE ROV 2022
TECHNICAL DOCUMENTATION

MEGATRON

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Alexandria,Egypt

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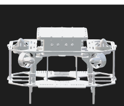

1. Introduction

A. Abstract

M.I.A. is blessed to be founded in a region that possesses coastal diversity, the variance of offshore operations, and a desire to reach sustainable renewable energy solutions. A large set of fish species and a multitude of fish farms characterize this area bounded by the Mediterranean. Unfortunately, marine life is suffering due to climate change while the offshore operations needed to maintain it are costly. In consequence, for M.I.A. to better protect sea life, industrial solutions to help with the sustainability of our aquaculture and energy are needed. We hereby introduce our new remotely operated vehicle (ROV), **Megatron**. M.I.A. Robotics is a 30-person company of interdisciplinary students from Alexandria University which was originally founded in 2011. This being its **8th** year at the MATE ROV Competition, the company has accumulated expertise in the field of underwater robotics over the years. With a steady pace towards improving the performance of each ROV, the company devised innovative solutions to accomplish this year's tasks. In response to **MATE Organization's** request for proposals, M.I.A. designed **Megatron** with the **17 United Nations Sustainable Development Goals** in mind. The following technical documentation records the process of designing Megatron from the blueprint to finishing along with the challenges, lessons learned, and reflections from the company's seniors and mentors.

Figure(1) : M.I.A. Members

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2. Design Rationale

A. Design Evolution

We started the year by studying previous designs to draw from our long experience participating in the MATE ROV Competition. Extrapolating their advantages and limitations allowed us to create the best version of Megatron to offer high performance. Our main goal was to manufacture a multi-functional ROV with advanced features.

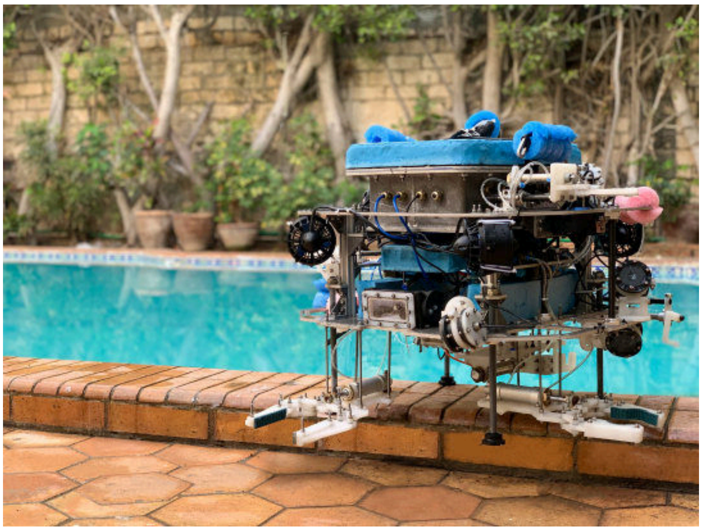
Figure(2) : Rendered Megatron

Mechanical System Design Evolution

- **The Octagonal Frame:**
  The embodiment design of the frame is based on the synthesis of an extruded octagon shape. The mechanical team decided that it is the best geometry related to the thrusters' configuration and provides a wider area for mounting equipment compared to other designs. This geometry was achieved by the presence of two aluminum plates connected by carbon fiber rods which create a sturdy lightweight, and homogeneous structure. The chosen geometry of the frame, especially the thrusters' mount plate, aids the propulsion system in expanding the operating area in front of each thruster's throttle to overcome the drag force on Megatron and exclude any obstructions within the perimeter of the thruster's operation to get maximum thrust force.

- **The Electronics Enclosure:**
  The design evolution of the electrical housing is reflected mainly on its geometry. M.I.A. selected the "Cuboid" shape because of its features compared to a cylindrical one. The cuboid volume corresponds with the electronics components inside. That act as scaled elements for the same geometry, reducing volumetric losses. It provides well-organized wiring and creates a central gap at the frame that serves the hydrodynamics.

- **Mechanisms:**
  Multi-purpose mechanisms were mounted on Megatron providing flexibility, high performance and increasing missions' success rate.



Figure(3) : Megatron

Electrical System Design Evolution

- **Vision System:**
  Eight digital cameras are the main feed for the ROV (unlike last year's analog cameras), using digital cameras enabled the use of a stereo camera.

- **Communication System:**
  Robot Operating System (ROS) is an open-source robotics project, it is used for providing a modular design, and implementation following ROS architecture and node hierarchy, compared to our previous implementation of our own communication schema.

- **Power distribution:**
  Isolated power for each thruster, using DC-DC buck converters in a bus structure to maximize efficiency over the previous year's combination of buck converters and linear regulators.

- **Enclosure and wiring:**
A new enclosure design method, with a box shaped enclosure and cables access from the front, back, and the sides. PCBs were designed to accommodate less space inside the electronics enclosure and to facilitate troubleshooting. This enclosure provides a great distribution and easy access for internal elements while isolating the power boards from sensitive electronics, achieving a more stable, reliable, and easy maintained ROV.
- **Custom-fabricated Sensors:**
This year, the Research and Development (R&D) team designed and fabricated the leakage sensor. They have also isolated an air-pressure sensor which was selected for its high resolution.

Software System Design Evolution

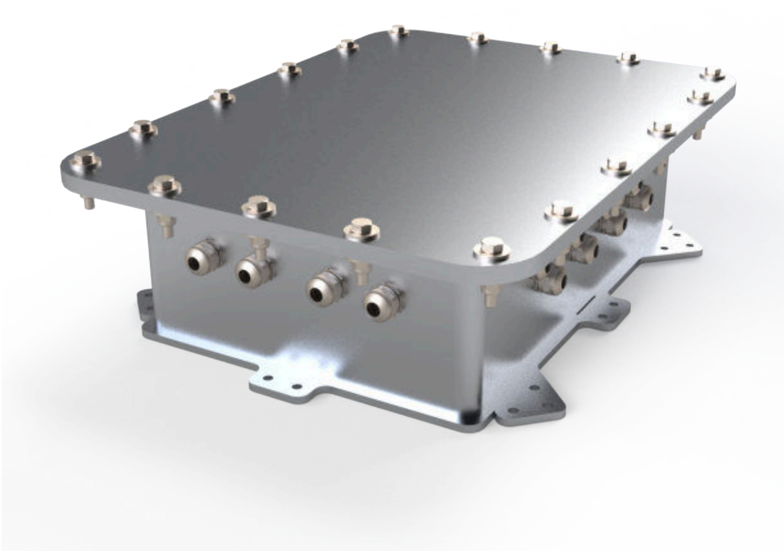
- **Top Side GUIs:**
A modular Model-View-Controller (MVC) based Python written Control and Missions graphical-user interfaces (GUIs) with user-friendly interface and features for the pilot, as a continuum of the previous versions of GUIs.
- **Machine learning and Image Processing:**
A continuation of using the You Only Look Once (YOLO) algorithms, in addition to standard image processing methods.
- **Debugger logic:**
A custom debugging logic built over ROS enables low-level troubleshooting at interfacing with sensors and solves them when possible.
- **Navigation system:**
Using a more scientific approach on understanding the matrix mathematics upon the ROV movement, it was decided to pertain the previous years vector mechanics for their computational efficiency, allowing the ROV to operate on 5 degrees of freedom using a 6-dimensional basis vector for each axial movement.

B. Mechanical Design

Frame

Megatron's Octagonal bolt-based frame consists of two functional parallel plates in addition to the electronics enclosure

- **Electronics enclosure**
The enclosure is made of 5mm 5083 aluminum sheets shaped by metal forming technology and welded together in a gas tungsten Arc-welding manner to create a (316 x 216 x 100) mm^3 internal volume housing. Enclosure firm sealing depends on double-layer O-rings squeezed by a 5038 cover and that provides sealing up to 8 bar pressure head. The extensions from the enclosure base are required for the proper fixation.

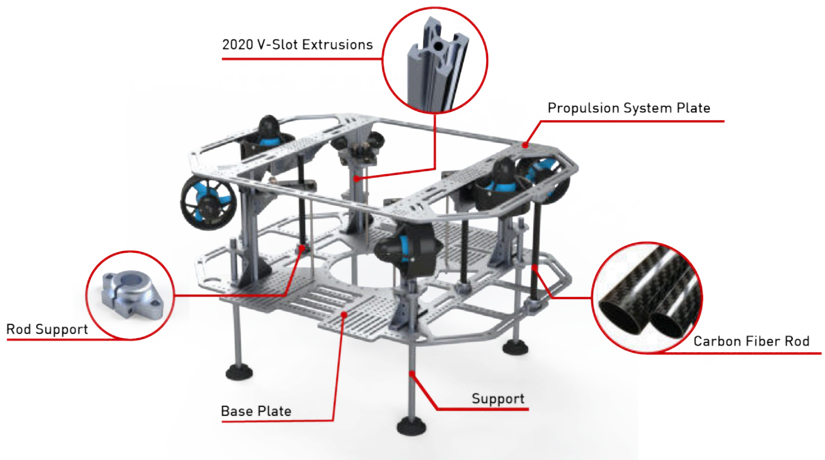


Figure(4) : Electronics enclosure

- **The Octagonal Structure** The existence of the base plate and propulsion system plate creates more available spaces to mount mechanisms and cameras on the frame. They also have multi-array cavity points to allow water to penetrate easily and avoid rapid corrosion.
    - **Propulsion System Plate**
    The propulsion system plate is responsible for mounting the six T-200 thrusters to eliminate their vibration and noise, allow all thrusters to contribute to the total propulsion in all cardinal directions, and prevent flow interference with other components. A 5mm 5083-aluminum

sheet is selected to build the propulsion system plate.

- **Base plate**
  The base plate has multiple fixation points; it is considered the main chassis of Megatron's frame. Thus, a 6mm 5083-aluminum sheet is selected to build the base plate to be strong enough to withstand stresses. 5083-aluminum alloy is known as marine-grade aluminum, it is characterized by high strength, rigidity, and corrosion resistance in marine environments.



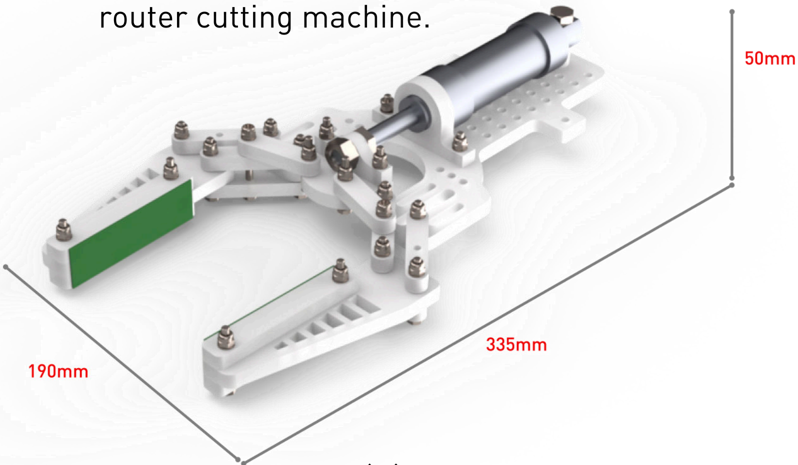
Figure(5) : Frame Skeleton

- **Enforcing Supports** The two parallel plates are connected and supported together by carbon fiber hollow rods and 2020 V-Slot aluminum extrusion bars made of 6061 aluminum alloy. The mix utilization of carbon-fiber rods with aluminum extrusions as the enforcing members based on their features such as high strength-to-weight ratio, corrosion resistance, and rigidity. In addition to the fixation flexibility of a V-slot due to its extensions.

Mechanisms

Megatron is equipped with multi-functional mechanisms (manipulators, double layer-cable mechanism, mandibular) by transforming input pneumatic power into the desired output movement to accomplish specific missions in the competition. This variety of mechanisms provides the ability of multitasking, better time utilization, and a backup solution for unexpected cases. They are made of HDPE (High-Density Polyethylene) with 8mm thickness. The material selection fell on using HDPE material because of its features which are cost-effectiveness, high machinability, non-corrosiveness, and high strength compared to other polymers. It is also distinguished by its density (970 kg/m3) which yields better stability and buoyancy effects. In addition to HDPE, PLA+ is used with the assistance of 3D printing technology to create complex geometry lightweight parts, which provides good toughness, corrosion resistance, and suitable bearing to physical impacts , making it ideal for underwater conditions.

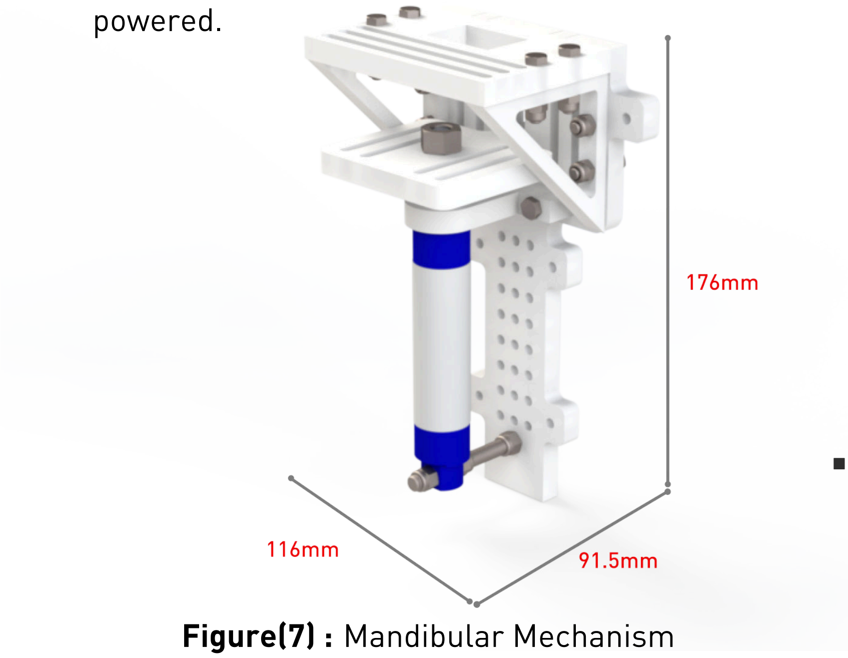
- **Manipulator**
  A four-bar mechanism-based manipulator is a multi-functional mechanism that allows the ROV to clamp objects underwater. It acts as an essential hand of the ROV. Pneumatically-actuated 25 mm-diameter piston is used to energize the mechanism, which applies a force in a range between (110 and 135 N) forward and backward respectively at 40 psi pressure. The end effectors were designed to deal with various cross-sectional shapes objects and with a capacity to hold up to 100 mm in diameter. The mechanism design - based on the kinetics - allows the parallel motion of end effectors during the piston action, and provides a large contact area (along with the end effector). The attached spacers to the end effectors increase the contact area in the vertical direction in addition to rubber, which provides higher friction to properly grip the objects. Slots at the base plate are used for pilot assistance, providing various positions of the gripper. The gripper was fabricated out of 8mm high-density polyethylene (HDPE) using a CNC router cutting machine.



Figure(6) : Manipulator

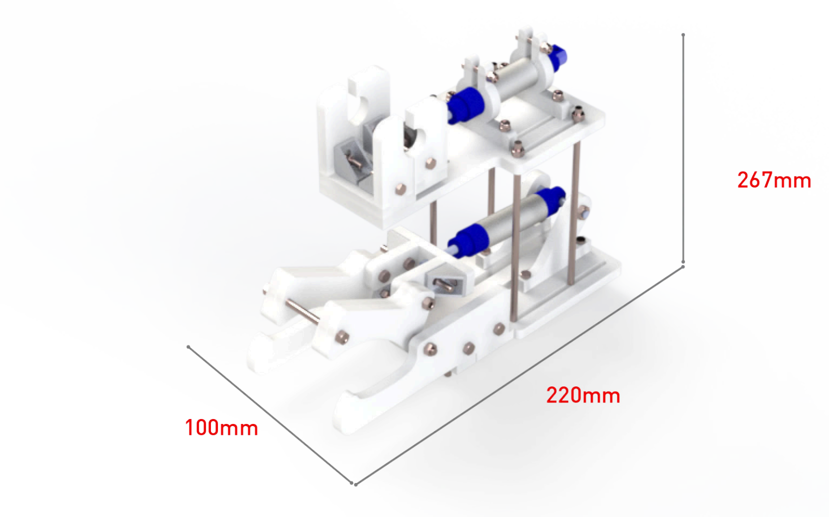
- **Mandibular mechanism**
  For repairing the damaged section of the netting mission, the attached U-bolt in the PVC pipe is grabbed and then released to cover the entire damaged region by the mandibular mechanism,

which is made from HDPE and is pneumatically powered.



Figure(7) : Mandibular Mechanism

- **Cable Mechanism**
  In the inter-array power cable mission, our company sought to replace the damaged cable section with the new one, rapidly and easily; we designed a double-layered mechanism pneumatically actuated with four pistons, the lower side is responsible for picking up the damaged cable section, while the upper side is responsible for placing the new cable section and connecting the wet-mateable connectors to the rest of the cable array by using two-terminal actuators that produce motion in two reverse directions.

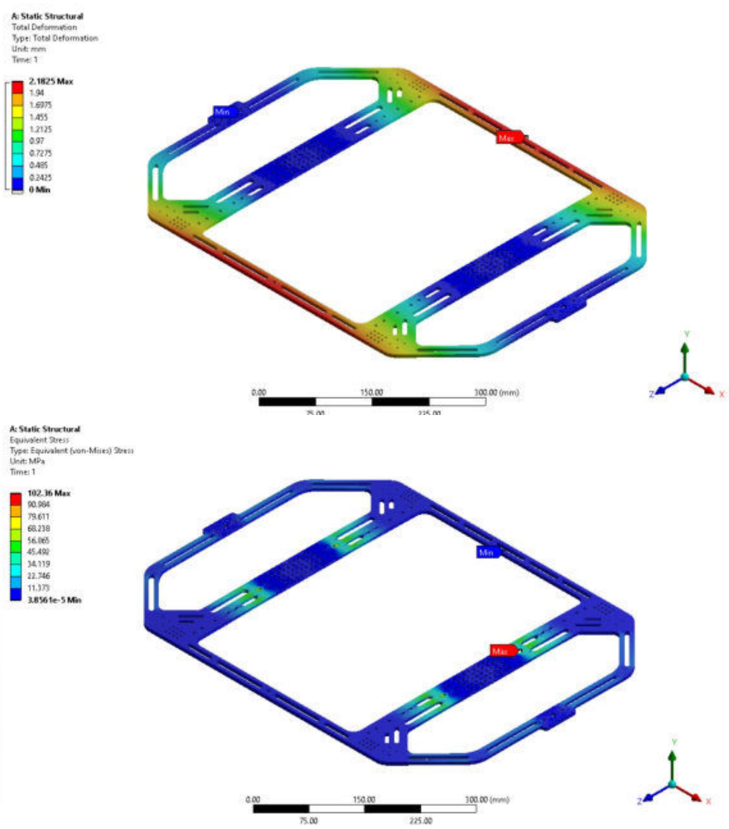


Figure(8) : Cable Mechanism

Stress Analysis

Stress analysis study is a vital phase in material selection to measure the material's ability to withstand the loads applied to it, allowing it to overcome unexpected bending deformation or material failure. The stress analysis process is done using the software program ANSYS by simulating real loads, fixations, and material specifications. The mechanical team decides that 5083-aluminum alloy is the optimal choice for the marine environment.

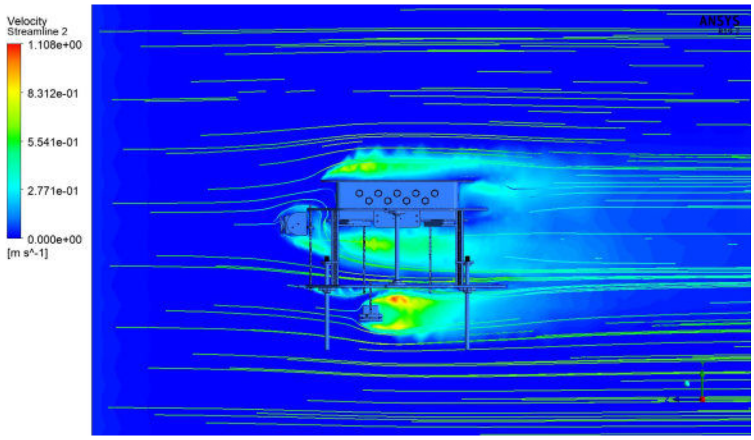
- **5083-aluminum alloy simulation loads**
  The simulation was performed on the propulsion system with all applied loads and support points while Megatron is being lifted by the handles. (Figure 9.a) shows that the maximum negative deformation is approximately 2mm, and the maximum applied stress is 102.36 MPa as shown in (figure 9.b). This aluminum alloy has tensile strength of 350Mpa and Brinell hardness of 75HB for a 5mm sheet. Using the results shown in the previously mentioned figures, this aluminum alloy was suitable for all applied loads. Also, the alloy has a melting point of 570 °C and is a machinable material that can be easily shaped using CNC machines.



Figure(9) : Stress analysis on Megatron plate

CFD

A computational fluid dynamics (CFD) study has been applied to the ROV for visual examination of the flow field features along the domain enclosing the body of the ROV, test the endurance of the vehicle to the pressure forces acting on the body due to the sudden conversion of kinetic energy into pressure energy, and to estimate the drag force. (Figure 10) shows the streamlines along Megatron's that illustrates the advantage of two separate plates containing multiple cavity points that allow water to flow uninterrupted during the motion of Megatron. This decreases the drag drastically since the streamlines flow smoothly through the ROV's frame. The solution computed shows that the drag force is (25 Newtons) (The case is solved for the ROV moving with (0.75 m/sec)).



Figure(10) : CFD of Megatron

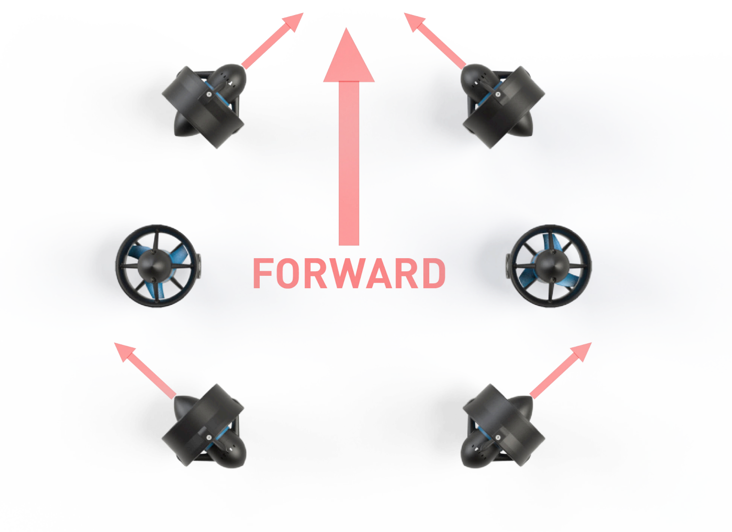
Propulsion

The ROV is equipped with six T200 Blue Robotics thrusters. T200 thrusters have proven their efficiency due to their high thrust force, high speed, and performance. The T200 thrusters have one deficiency which is their high-power consumption, yet this is only considered at high-speed operations as shown in the drag equation:

$$F_D = \frac{1}{2} \rho \, u^2 \, C_D A$$

$where:$
$F_D : drag\ force\ (N)$
$\rho : density\ of\ the\ fluid\ \left(\frac{\text{kg}}{m^3}\right)$
$u : relative\ speed\ \left(\frac{m^2}{s^2}\right)$
$C_D : drag\ coefficient$
$A : cross\ sectional\ area\ (m^2)$

The above equation shows that drag force is directly proportional to the square of the velocity; and hence, does not hinder Megatron's operation. Achieving better maneuverability and introducing lateral translation, four T200 thrusters are mounted at 45° angles at the corners of the propulsion system plate. Two vertical thrusters are mounted on either side of the plate. Thus, the vehicle can achieve 5 degrees of freedom: surge, sway, heave, yaw, and roll. The center of thrust is aligned with the center of mass of the ROV to maximize ROV stability, facilitate maneuvering and obtain a stable vector drive.



Figure(11) : Thrusters Configuration

Buoyancy and stability

One of the major challenges that faced the mechanical team was the stability configurations. To solve this, our goals were summarized in the following points: achieving smooth suspension of the vehicle in water for better navigation, obtaining neutral buoyancy underwater, and making the buoyancy force slightly higher than the weight of the vehicle as it will directly affect safety and maintenance issues. Taking into consideration that the vehicle has to be slightly floating. After the assembly operation, the final weight of the ROV was bigger than the weight of the displaced water (which causes the negative buoyancy effect). This sort of variation in components of the vertical forces tends

Item	Quantity	Mass (Kg)	Volume (m^3)	Displacement mass (Kg)	Total Buoyant Force (N)
Main base	1	2.408	0.0009054	0.9054	-14.729
Thrusters plate	1	0.91827	0.000345	0.345	-5.618046
Thrusters	6	2.064	0.00099101	0.99101	-11.0544
Electronics enclosure	1	8.39299	0.01056688	10.566	21.3041
V-slot beams	4	0.15723	0.00023293	0.2329	-3.8806
Carbon fiber	4	0.0125	0.000006911	0.006911	-0.05486
Camera casing	8	1.08528	0.00256	2.560	14.4522
Gripper	2	1.3236	0.000712	0.712	-5.99368
Hook mechanism	1	0.3924	0.0002403	0.2403	-0.1521
Cable mechanism	1	1.0674	0.00079383	0.7938	-2.6809
Total buoyant	**Negative Buoyancy**				-5.4071

Table(1) : Buoyancy Calculation

to counteract the buoyancy effect; hence, it shall cause the vehicle to sink. Different solutions were devised, and the company employed several fixed buoyancy aids and constructed a ballast system. The flotation material should maintain its form and resistance to water pressure at the anticipated operating depth. A spreadsheet (Table 1) was made to record the displacement mass of some of the main parts of the ROV. These parts tend to affect the buoyancy but their effect is countered by other denser materials in the ROV such as nuts and bolts. This data was used in calculating ROV's weight in both air and water. After comparing the weight and the buoyant force we make a floatation system (foam) to achieve the static stability of the ROV that keep the center of buoyancy (CB) above the center of gravity (CG).

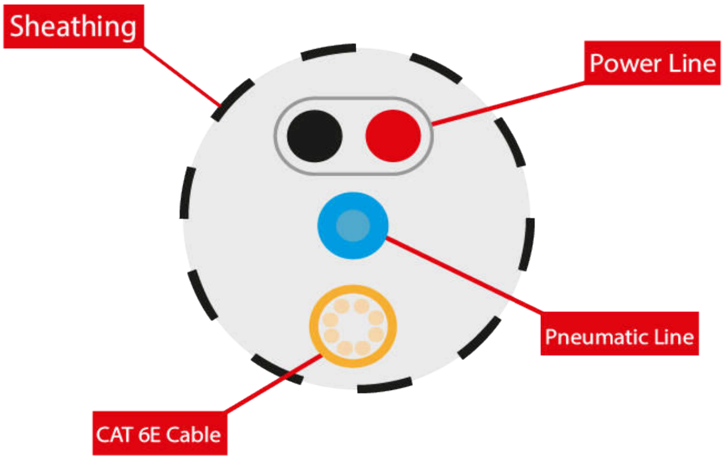
Tether

The neutrally-buoyant tether is ideal for almost all ROV operations. Floats with a specific size were used to decrease drag on the tether. The number of floats required to make the tether neutrally-buoyant was calculated and then divided over the length of the tether. Tether management could be done using a system consisting of a pulley where the tether is wrapped around it, where the length of the supplied tether could be controlled by extending and wrapping the tether around it. In addition to being lightweight; the pulley is provided with a handle and holder to ease the tether management process.

C. Electrical Design

Tether:

The tether consists of a CAT6E Ethernet cable, an AWG-12 DC power cable, and one pneumatic cable. The tether is wrapped inside a flexible sheathing to protect the lines housed within. The CAT6E cable connects the top-side control unit and the Raspberry Pi 4 inside the ROV. CAT6E is chosen over other alternatives such as CAT5 or CAT4 cables due to its bandwidth (1 Gbps) and higher signal-to-noise-ratio. The usage of our one but fast speed CAT6E cable led to a smaller and lighter tether, with the ability to be extended well beyond its original length of 30 meters without losing the signal. The AWG-12 cable choice came due to its low resistivity, which means a lower voltage drop across the transmission line. The AWG-12 cable is a tinned copper cable used in marine applications as it resists moisture and rust.

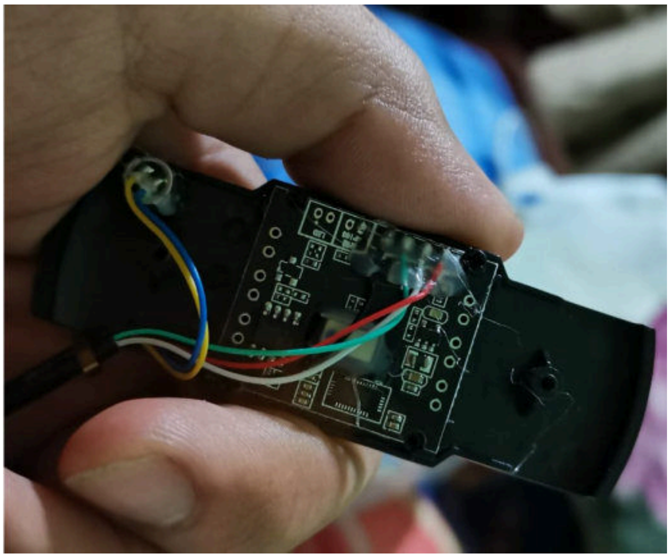


Figure(12) : Cross-Sectional View of Tether

Imaging System

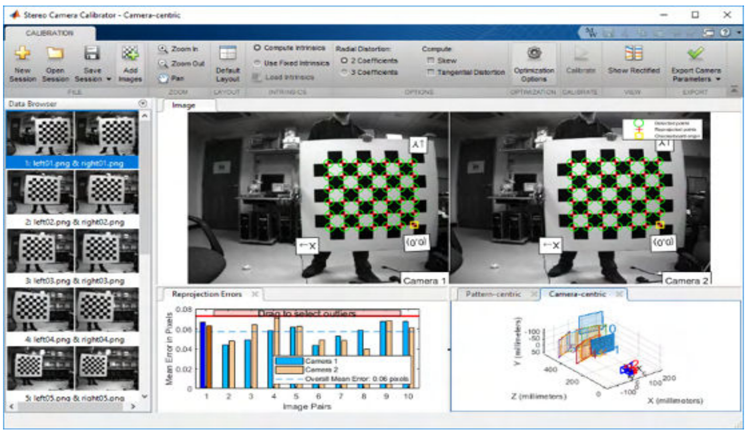
- **Transition To Digital Cameras**
  Our imaging system consists of 8 USB digital cameras, one stereo camera, six commercially available webcams, and one 100 degrees wide-angle camera. Most of them are modified to have wide-angle lenses. We can receive camera feed

over a computer network rather than using a Digital Video Recorder (DVR) as last year. Digital cameras have the advantage of digitizing the signal from the source. Hence, digital signals are very immune to noise and reliable for real-time processing.



Figure(13) : Used Camera

- **Streaming**
  Digital cameras are connected to the Raspberry-pi via USB and then streamed over Ethernet using Gstreamer with RTSP protocol.
- **Stereo Camera**
  Our R&D team accomplished a paradigm shift this year when deploying the stereo vision camera in Megatron. The stereo vision system is a computer vision system based on triangulation and stereoscopic ranging techniques, providing actual depth estimation, thus we can measure absolute distances in the real world. This paradigm shift will be the stepping stone for a new era of localization and mapping of underwater objects.

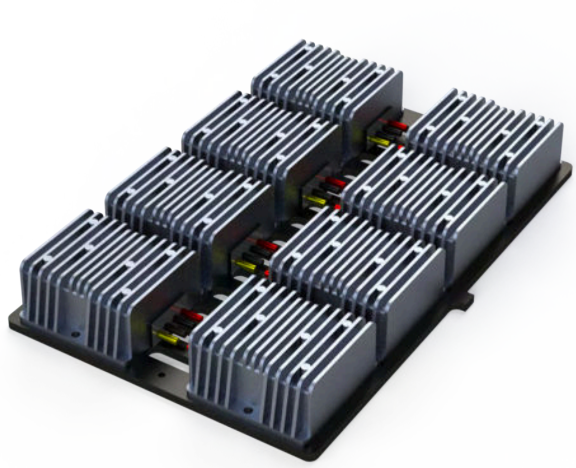


Figure(14) : Stereo Vision

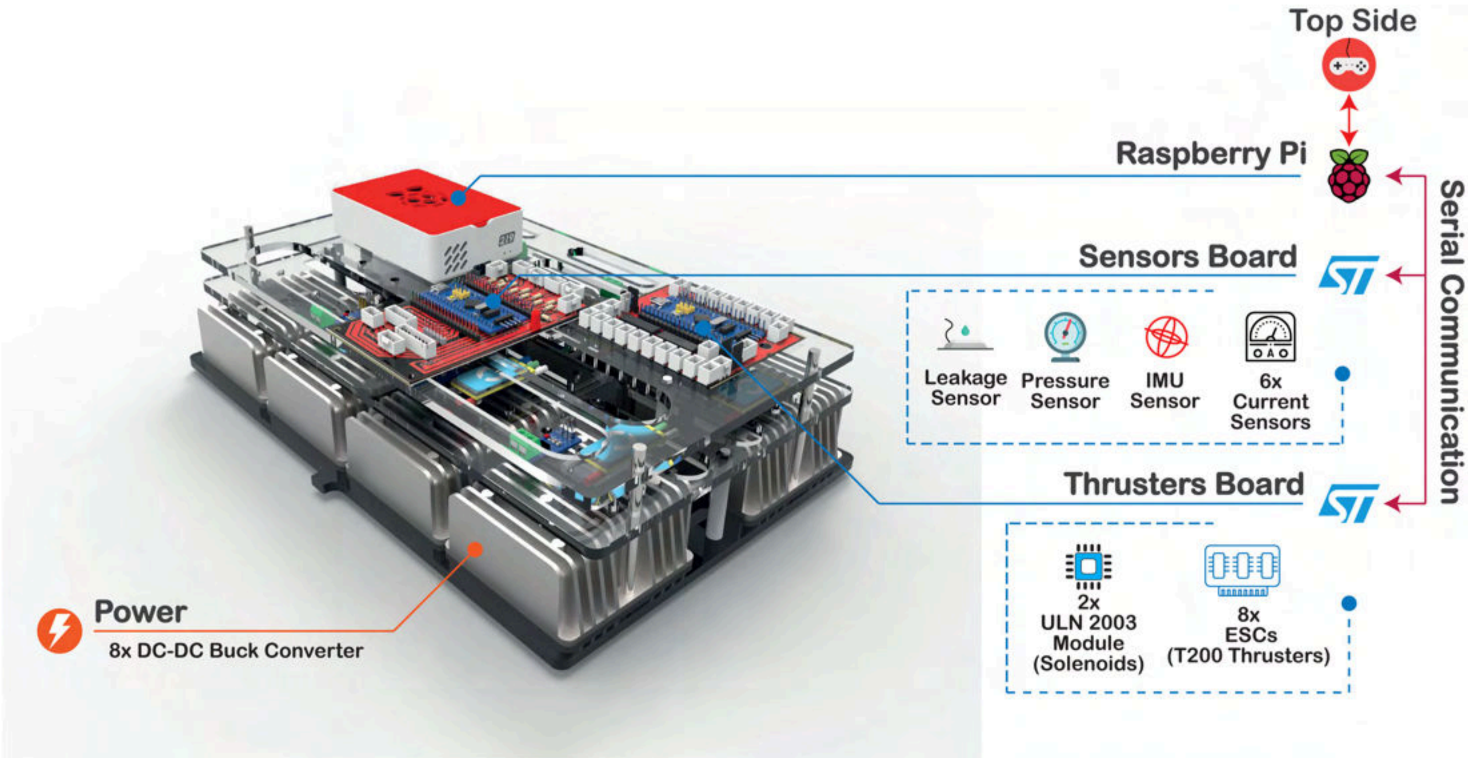
Electronic Housing

Previously, M.I.A. used cylindrical housing to contain the ROV's electronics. This year and after reviewing designs performed in previous years, it was found that the cuboidal housings are used for industrial counterparts and have more surface area for our electronics. The cuboidal shape of the housing made it easy for tracing and cable management. The electronic housing is divided into three layers ??. These layers are as follows:

- **Layer 1: Converters and power distribution**
  This layer contains eight DC-DC buck converters fused for safety, characterized by reliability, efficiency, and performance. Their safety features include over-current, over-voltage, under-voltage shutdown, and short circuit protection. With a power input of 48 Volts, six converters are used to power six thrusters at 12V, one used to energize the solenoids at 12V, and one used to power Raspberry Pi and digital cameras at 5V. The aluminum housing of the electrical enclosure acts as an additional heat sink for the converters, positioned at the bottom to transfer thermal energy to the water. The input power from the tether is distributed among the eight converters, using a bus with ring connectors and tinned copper wire AWG 12. This bus facilitates the power distribution among the converters as their positions are four on each side.

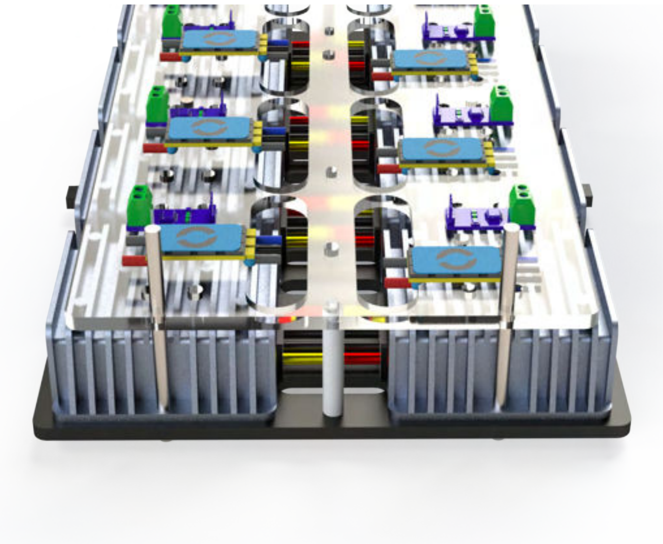


Figure(15) : Converters Layer



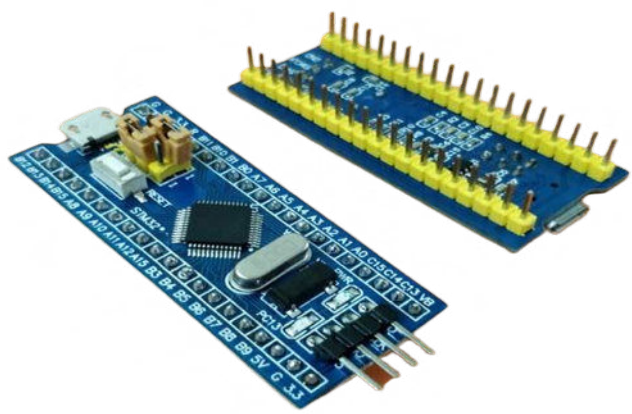
Figure(16) : Electrical Structure

- **Layer 2: ESCs and current sensors**
  In this layer, six 30-Ampere ACS712 current sensor modules replace the validation board used last year, giving continuous readings of the drawn current from each thruster, providing high protection and quick fault diagnosis. Each current sensor is in series with the converter below it and the electronic speed controller (ESC) that controls the thruster speed.



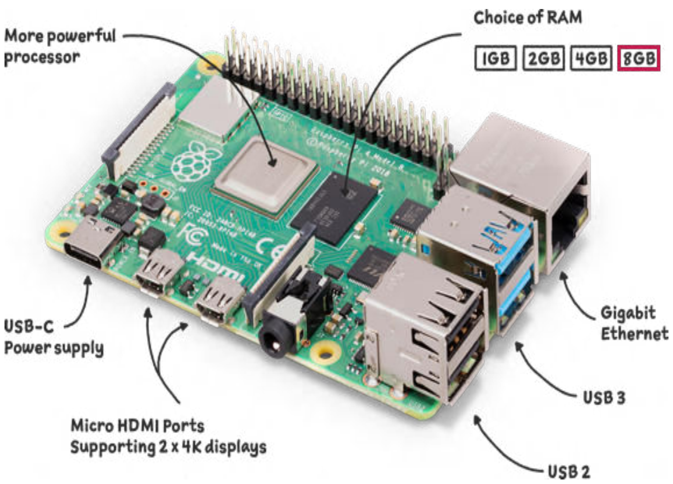
Figure(17) : ESC and Current sensor over each Converter

- **Layer 3: Boards**
  This layer contains the used microcontroller, the Raspberry Pi 4, two USB3.0 hubs, the thrusters' board, and the sensors' board. see Appendix D.2
- **ARM Cortex Microcontroller**
  Unlike previous years, M.I.A. replaced the Arduino Nano microcontrollers with STM32F103. This Arm-cortex μC enhanced the overall system speed and performance as it has larger memory, faster clock speed, better interfaces, and lower cost. It worked seamlessly with ROS. Two of them are used, one for the thrusters' board and one for the sensors' board.



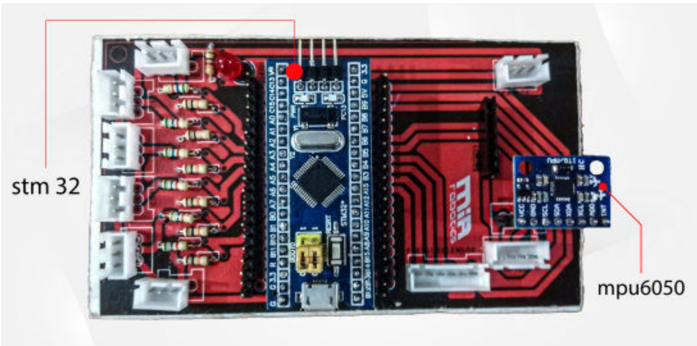
Figure(18) : ARM Cortex stm32 μC

- **Raspberry PI**
  We replaced our master microcontroller with a Raspberry Pi4, unlocking an unprecedented performance in terms of speed and variety of options supported. Raspberry Pi is used for real-time video streaming of our imaging system of eight cameras. It is connected to the digital cameras through two USB3.0 hubs, it also acts as an open channel of communication with the microcontrollers. This configuration has lowered the tether weight significantly; using one instead of three Ethernet cables.



Figure(19) : Raspberry Pi

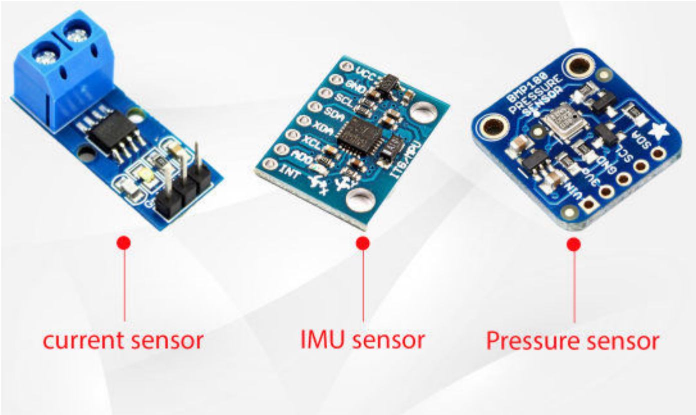
- **Thrusters board**
  The thrusters board is connected to the six ESCs and the solenoids. It controls the speed of the thrusters by transmitting the signal from the microcontroller to ESCs by communicating with Raspberry Pi. It contains two ULN2003 ICs to control the solenoids.
- **Sensors board**
  The sensors board consists of a pressure sensor, IMU sensor, leakage sensor, and current sensors.



Figure(20) : PCB sensors

Sensors

- **Pressure Sensor** The pressure sensor is used for vertical position localization. The usage of an air pressure sensor was more convenient in terms of performance and cost relative to the available water pressure. We used the BMP-180 barometric pressure sensor. We isolated the sensor in a flexible air-filled bladder, achieving an impressive resolution of 0.0.03hPa making it a thousand times more accurate in water (around 0.3 millimeters) compared to last year's MS5540C water pressure sensor with a resolution of 0.1 cm.
- **Leakage Sensor** A simple, yet effective, water detector probes are installed. Four probes at the corners of the box at the very bottom for early detection of any leakage and alerting the pilot.
- **IMU**
  MPU6050 sensor module with 6-axis Motion combining 3-axis gyroscope and 3-axis accelerometer to detect rotational angles. We implemented a Kalman filter on the built-in DMP chip to achieve a highly-accurate low-noise readings.
- **Current Sensor**
  Six ACS712 current sensors connected in series with each converter for monitoring and getting feedback of the drawn thrusters' current. They constantly update the GUI with live current consumption to ensure that every thruster is running within the rated range, and detect possible failures.



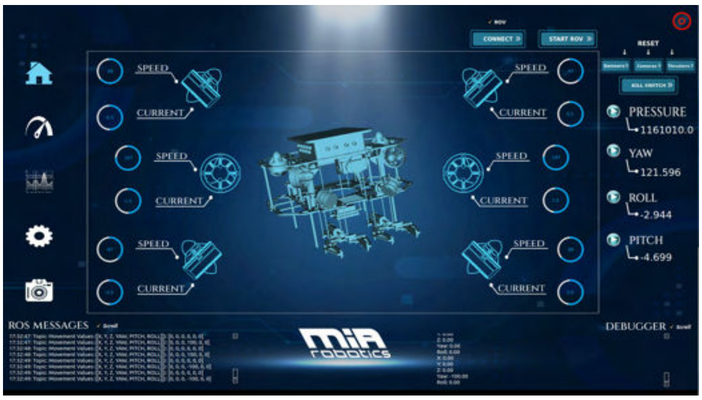
Figure(21) : Megatron Sensors

D. Software

Top-Side Control Unit(TCU)

This year the company's TCU has raised the bar in terms of features, performance, and user experience. The TCU mainly consists of the monitor, 2 Graphical User Interfaces (GUI) on the laptop, and the joystick. The monitor is used to display cameras attached to the ROV, and a status bar shows (sensors, connection status, etc., are vital information.) Megatron is controlled with our most advanced GUI; the control GUI gives the necessary features to help the pilot execute underwater actions efficiently. These features include real-time feedback from sensors and thrusters with interactive widgets, modern UI design, plotting various data of sensors and Proportional Integral Derivative (PID) control system response, and simple interfaces for setting speed values and PID constants. Additionally, this year, the GUI team included a real-time 3D model for the ROV that changes according to the movement and position of Megatron.

The GUI is developed in python using PySide2. MVC design pattern is used, where the units are divided into separate modules and classes, making the GUI robust in error handling and debugging. M.I.A. robotics utilizes ROS for intercommunication between the GUI, and Megatron.



Figure(22) : 3D model of Megatron in Control GUI

Missions GUI is designed to be malleable with ROV missions (floating, mapping, and line follower); supporting manual and autonomous solutions. The station includes an Xbox Series X controller which helps the pilot to control the movement and mechanisms of the ROV. The implementation of the joystick is flexible. It allows the pilot to choose different layouts for controlling the ROV.

Navigation Logic

Vector-based navigation has been selected for our ROV to ensure the alignment of the motion along the axis of a specific camera view.

- **Soft start:**
  It is based on the idea that thruster force changes step by step until it reaches the required value. This method not only avoids the rush current from the ESCs (Electronic Speed Control), but also gives us more smoothness and stability for the movement.

- **Vector mechanics:**
  Using four thrusters with 45° at the (X-Y) plane and two vertical thrusters at the (Z) plane give us more options and directions to work with. This orientation helps us get 5 degrees of freedom and to perform the tasks efficiently and accurately. As for the mathematical analysis, we take an input matrix of 5 degrees of freedom, then we calculate the forces that will result in this net speed. Then we distribute the values on the thrusters according to each axis and orientation. A generalization is used with 5 dimensional vectors, and a basis vector for each direction of movement.

$$A_{\text{TC}} = \begin{bmatrix} FL_{DX} & FL_{DY} & FL_{DZ} & FL_{TX} & FL_{TY} & FL_{TZ} \\ FR_{DX} & FR_{Y} & FR_{DZ} & FR_{TX} & FR_{TY} & FR_{TZ} \\ BL_{DX} & BL_{DY} & BL_{DZ} & BL_{TX} & BL_{TY} & BL_{TZ} \\ BR_{DX} & BR_{Y} & BR_{DZ} & BR_{TX} & BR_{TY} & BR_{TZ} \\ UL_{DX} & UL_{DY} & UL_{DZ} & UL_{TX} & UL_{TY} & UL_{TZ} \\ UR_{DX} & UR_{Y} & UR_{DZ} & UR_{TX} & UR_{TY} & UR_{TZ} \end{bmatrix}$$

$$B_{\text{required motion}} = \begin{bmatrix} X - motion \\ Y - motion \\ Z - motion \\ Yaw \\ Roll \\ Pitch^{*} \end{bmatrix}$$

- The input signal of each thruster(c) is calculated using matrix multiplication (generalizing the dot product rule on Megatron kinematics system) as follows:

$\mathbf{AC} = \mathbf{B}$

$\mathbf{A}^T\mathbf{AC} = \mathbf{A}^T\mathbf{B}$

$\mathbf{C} = \mathbf{A}^T\mathbf{B}$

where :

A_{TC} : *Thrusters Configuration Matrix*

$B_{\text{required motion}}$: *Required motion Matrix*

C : *Thrusters input signal matrix*

FL : *Front left thruster.*

FR : *Front Right thruster.*

BL : *Back left thruster.*

BR : *Back Right thruster.*

UL : *Up left thruster.*

UR : *Up Right thruster.*

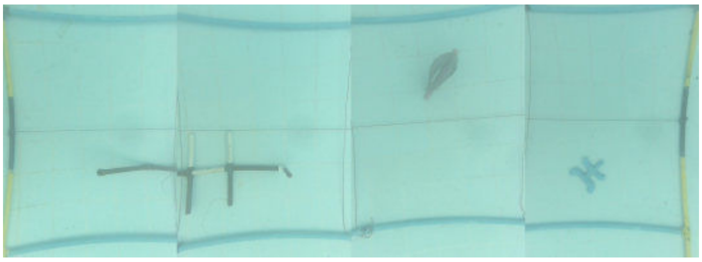
* Pitch is set alawys to 0.

- **Stability mode:**
  The ESCs have a limit for their minimum force. For the low speeds, after the analysis and mapping of the thruster forces, the ESC signal value may be less than the minimum. So we used a zero net force, moment, and position basis and added it to the forces of the thrusters to get higher forces for the thrusters, and with the same net speed Which also ensures faster thruster responses and transition between speeds.

E. Computer Vision

Stitching

This task works on warping eight input pictures in the stitching-domain space by developing the following procedure:



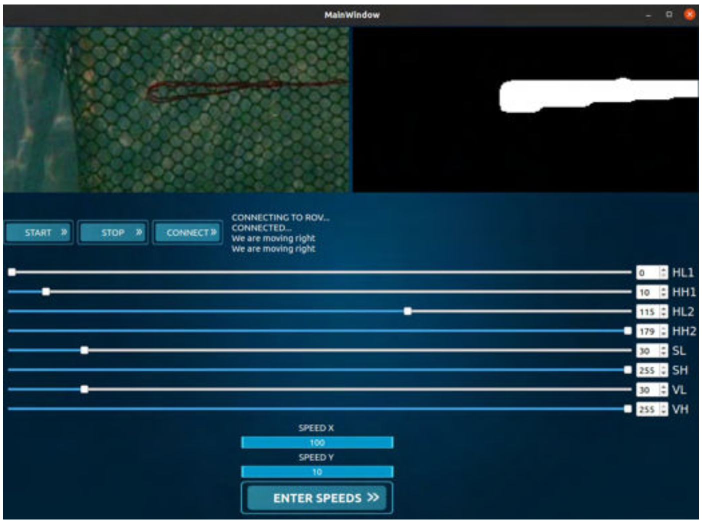
Figure(23) : Stitching

1. **Images capturing**
   The ROV autonomously starts its movement from the yellow line, capturing each of the eight grids then feeds it into a software program for placing each in its actual position.

2. **Image stitching**
   To collectively group down images into a single stitched image, different approaches were tried. Feature matching with popular descriptors was unreliable in underwater tests even after fine-tuning. AI aided feature extraction relied on having a multitude of objects on the map to match reliably. A solution of using our other givens, like location estimation through the transect, and engineered features were the most reliable throughout the underwater tests.

Autonomous Line Follow

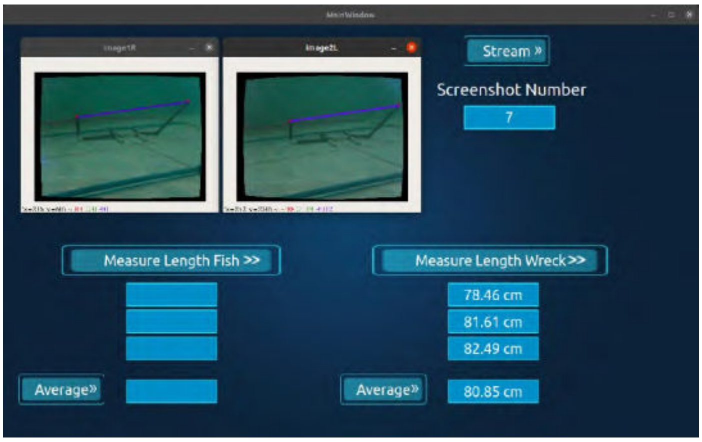
For the autonomous inspection of the fish pen netting, we utilized OpenCV as the helper library. To isolate the red transect line, we implemented an adaptive red filter based on ensemble algorithms of dark channel prior and static saliency mapping together with HSV colorspace filtering, reaching a seamless white straight line or a clean right angle (Figure 24). The detection algorithm is immune against color shifts and ambient noise. The control logic is based on detecting changes in movement when a right angle is encountered. Algorithms based on spotting areas of pixel concentration are used to determine whether or not the vehicle should redirect. Once the correct direction is identified, the correct values are then calculated and sent to the thrusters. Moreover, our algorithms used the sensors' data to remain in a plane parallel to the board. This closed-loop feedback guarantees a smooth movement of the ROV.



Figure(24) : Line Follower GUI

Length estimation

We used the stereo camera for both wreck and fish length tasks. The stereo camera was calibrated extensively until reaching a resolution of 0.2 cm. Once the pilot has located the item needed to be measured, the copilot only specifies the endpoints of the object and the length is then obtained.



Figure(25) : Length estimation

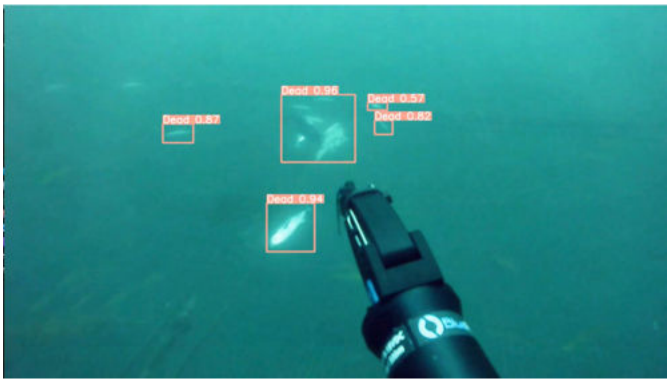
Float

In this task, the distance reached by the float is determined using the speed and time supplied using the formula D=V/T. The distance traveled in the horizontal and vertical directions is computed using trigonometry. Since each square in the grid is 2 cm^2, the number of squares covered is computed. Pygame is used to draw the grid and the position where the float will surface.

Morts Detection

After studying and deploying several approaches to tackle this task, we have reached a conclusion that using a Yolo v5 is the best model architecture. Our current model detects not only the dead but also the alive fish. Its development can be divided into three phases:

1. **Data acquisition**
   We have developed a data preprocessing pipeline consisting of a video subsampler script, followed by an image denoiser algorithm and model data loader. We ended up with 590 pictures gathered from 8 videos which were divided into a ratio of 70% for training and 30% for evaluation. Each of the 590 pictures were subjected to the labeling process where the alive and dead fish were manually identified.
2. **Model Training**
   We trained the model by dividing the data into batches of size 12 and the whole dataset was trained for 200 epochs.
3. **Testing and Evaluation**
   The remaining two videos which are not used in the training phase were used for testing and evaluation. The model reached an F1-measure of about 90%.



Figure(26) : Morts detection

F. Features

PID Controller

Megatron's PID system achieved outstanding performance in terms of robustness and flexibility of control since last year. However, last year's method (manual tuning) was based on finding the constants by trial and error which was a tedious and time-consuming procedure. This year we focused on auto-tuning the PID constants, by simulating the ROV kinematics and interpolating its transfer function. This gives us a much wider perspective of the system response and characteristics before going to test.

Figure(27) : PID Controller GUI

ROS

This year we took a step further, by incorporating ROS as our communication architecture handler. The Robot Operating System (ROS) is an open-source framework that helps researchers and developers build and reuse code between robotics applications. Ros serial is a protocol for wrapping standard ROS serialized messages and multiplexing multiple topics and services over a character device such as a serial port or network socket.

- **Communication between boards**
  ROS is built upon the subscriber/publisher principle; a nodal architecture to facilitate the communication between hosts. The sensors board sends rotational angles from the IMU, vertical depth from the BMP, converters currents measurements, and leakage sensor state to ROS topics for each sensor. The thrusters board subscribes to sensors topics and sends feedback from the speeds of the thrusters. Topside sends communication commands to initialize the ROV, restart the board, stop the PID, kill the thrusters and initialize the cameras.
- **Debugging schema**
  We get feedback from every single value of data we send, so we can troubleshoot if we encountered any problem. (e.g corrupted data from sensors) The built-in debugging of the ROS system checks if every node is initialized and connected, topics are published,...etc.

Automation scripts

To automate cameras streaming and running, ROS nodes startup services are configured to do just that, so at every power-up everything is running, as services can run automatically at system startup.

Dockerization

This year, we introduce our very first Docker image for the GUI. the image incorporates all of the dependencies needed to run the application. Now, our GUI is platform-independent and can run on any machine.

G. Testing and Troubleshooting

Troubleshooting Megatron effectively and efficiently needed well-thought-out steps that were put in place before subjecting the ROV to any dry or underwater testing conditions. Our main philosophy in troubleshooting was to isolate, divide, and conquer. Once an issue was encountered, using deductive reasoning, each department started attempting to isolate the problem by first figuring out whether the issue was a mechanical, electrical, or software issue. The issue was then analyzed and classified into subsystems and dealt with accordingly.

Electrical Testing and Troubleshooting:

Electrical testing was thorough and conducted gradually and steadily as Megatron's electrical system was being assembled. Before fabrication, circuit simulators were used to analyze voltage and current for every circuit wire and electronic component, and many prototypes were fabricated and tested. During the fabrication of each PCB, components were constantly tested to identify any faulty device. Additionally, theoretical calculations regarding each device's power consumption were compared with readings in practice, to make sure that the voltage converters can supply stable power to the system even under full load.
Once an electrical problem was encountered during full-system testing, the team resorted to intelligent trial and error replacement. This process was conducted by reducing the number of suspected circuit boards, and then more specifically, reducing the number of suspected components or devices then using intelligent substitution to identify the faulty device.

Mechanical Testing and Troubleshooting:

- **Sealing Test**
  This test aims to ensure that the electronic enclosure sealing is perfect even in a very high-pressure head range compared to the

maximum pressure head the ROV can may reach in the competition. The test starts by filling the electronics enclosure with water and increasing pressure gradually using a hydrostatic pressure test unit until 8 bars of pressure is reached. Since this pressure is the maximum pressure our unit can supply as it means that our ROV could operate in a pressure head of 80 meters of water - 8 times higher pressure head compared to the competition's standard of 5 meters.

- **Pneumatic test**
  The team put great attention into ensuring proper connectivity regarding pneumatic circuits by visual inspection of all joints and testing them several times to enhance the safety and performance of the pneumatic system.

Software Testing and Troubleshooting:

Testing of algorithms was fairly straightforward, due in part to the implementation of ROS-based communication between the ROV and the control software. The software team was adamant about developing flexible, clean, commented code that accommodates constant change. Added code was continually tested for whether it breaks existing use cases or not.

Full-System Testing and Troubleshooting:

After Megatron's assembly, it was important to assess its performance in dedicated test environments.
A dry test checking basic functionalities was our starting point. After the success of the initial dry test, Megatron began being thoroughly examined during underwater tests in a practice pool. The two most important metrics during underwater tests were ROV stability and performance.
Later, the ROV was tested to perform all required missions within a reasonable time.
Underwater tests are thorough and lengthy; the main advantage of these long-duration tests is the ability to discover hidden problems that would not emerge otherwise.
Any issues encountered during the final underwater testing process were solved using our Isolate, Divide, Conquer approach was explained previously.

3. Safety

A. Company Safety Philosophy

"Accidents hurt, safety doesn't."
At M.I.A. Robotics, we believe a safe workspace is crucial to producing a suitable environment to design, manufacture, and test. We always strive to meet MATE's safety requirements by ensuring all MIA personnel adhere to the safety protocol and warning labels. Our safety philosophy is centered around the welfare of the crew and always putting the employee's safety before the machine. To comply with MATE's safety regulations, a set of workplace guidelines and protocols are carried out during manufacturing and pre-launch. Appendix A.

B. Lab Protocols

To ensure a safe work environment, specific safety protocols are implemented while working in the lab. Every MIA employee is assigned Personal Protective Equipment (PPE) which is obligatory to use while working in the lab. All crew members are committed to following lab protocols set by senior team members. Wearing protective clothing, safety goggles, and appropriate non-slip shoes is essential during operation. In addition to this, periodic safety checks are performed before deploying the vehicle in the water.

C. Safety Protocols Standards

1. Assigning proper PPE and avoiding actions that carry a potential for injury.
2. Inspecting equipment before use
3. Using proper technique when using any sharp tools.
4. Using vice of proper size and capacity to hold work objects.

5. Using a barrier around a piece of equipment being pressure tested
6. Stop work when an unsafe condition or act could occur during operation; if in doubt stop the job.
7. Using insulated electrical tools including insulated fuse pullers, hand tools, and drills
8. Before working on any electrical equipment, it must be de-energized.
9. Systematic safety checks are performed before every test.

D. Safety Features

- **SBS-50 Anderson Connector**
  To comply with MATE safety standards, SBS-50 Anderson Power pole connectors are provided by the ROV. Anderson connectors secure the two power terminals in position to avoid any mishaps during connection.
- **Fuses**
  A suitable standard 30-A fuse is added to the power cable based on power budget calculations[C].
- **Power Supply**
  Megatron comes out with a power supply unit that can provide DC voltages of values from 5 to 48V. It is protected against overload currents and reversed polarity. A kill switch is present in case of an emergency shutdown.
- **Validation Currents Sensors**
  Each converter has its current sensor, which monitors the drawn current and allows the pilot to keep track of each to detect any issue and then, easily handle it.
- **Leakage Sensor**
  Monitoring any water leakage is a crucial issue in our design to prevent any irreversible damage to components and helps us to quickly detect and fix the sealing of electrical housing with no damage.
- **Shrouded Thrusters**
  The primary objective of workplace safety programs should be to help prevent workplace injuries, so shrouds are used which act as a cover to the intake and exhaust of the thrusters.
- **Sheathed Tether**
  Developing an anti-slipping poolside procedure is a must; thus the tether cables are all bound together and sheathed by ether-based polymers.
- **Strain-Relief**
  For the ROV and tether to tether connections, there is a strain relief system. It helps in reducing tension forces on the tether's end and securing wires in their position.
- **Deburred Edges**
  Sharp edges cause as many as a third of all accidents in some engineering workplaces thus, to guarantee a higher level of safety, all the edges and corners are smoothed out.

Figure(28) : Shrouds

4. Logistics

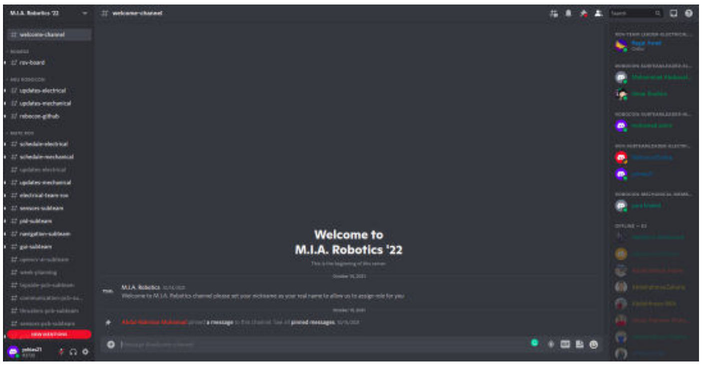
A. Company Management

For the sake of maintaining progress and further development, management at Made in Alexandria company is divided into three parts.
First, Supreme Council is headed by the CEO, electrical CTO, mechanical CTO, and CFO. Their responsibilities are setting up a proper plan, an estimated budget, and discussing the expected costs for this year's project. Recruiting the employees responsible for this project, discussing how to implement it with them, arranging company-wide meetings bi-weekly throughout the year to track progress and objectives, and talking about any resources needed to achieve these objectives.
Second, the project committee consists of an electrical leader, a mechanical leader, and there is a deputy leader for each. Their responsibility is to ensure that all team members follow the plan that has been set up previously to achieve all the agreed

goals.
Third, an advisory committee consists of a supervisor and mentors who give their advice and opinions to our company.

B. Collaborative Workspace and Code Management

In the aftermath of COVID-19, it was central to establish a hybrid work environment that allows employees to work both from home and offline, in the company's workshop. To increase productivity while still adhering to public safety guidelines, we were able to successfully build a system where employees worked in harmony no matter where they were working from.
On the one hand, regarding virtual collaboration, we believed that a crucial factor in a company's success lies in choosing the suitable platforms to manage employee communication, as well as for settling on a cloud-based option for file sharing to store company information and knowledge. Additionally, it's equally important to pick a Version Control System (VCS) that allows parallel code development, we opted to use GitHub as a VCS for several reasons. A critical need for the team leads was to monitor code changes and their documentation from several employees who were not necessarily working linearly. This was achieved through maintaining and updating the code on GitHub repositories in several branches. GitHub also allowed employees to access older versions of the updated code.
For file management in both the R&D process and the documentation process, we chose Google Drive and its services (the Google Docs Editors Suite) as both a creation medium and a storage medium. Mainly, this was because of its features that facilitate real-time collaboration, synchronization, adding commentary, and revision history.
As a communication platform, the company created its own Discord server to coordinate correspondence between each team. Not only was Discord a favorable choice for instant messaging and company announcements, but it was also a pleasant and suitable platform for immediate, on-the-go video conferencing.
Moreover, we opted to use GitHub as a VCS for several reasons. A critical need for the team leads was to monitor code changes and their documentation from several employees who were not necessarily working linearly. This was achieved through maintaining and updating the code on GitHub repositories in several branches. GitHub also allowed employees to access older versions of the updated code.
On the other hand, offline work occurred in the company's workshop which serves as the main headquarters for M.I.A. Robotics. It was routinely organized and inspected which permitted a productive workflow from all employees.



Figure(29) : M.I.A. Discord Server

C. Project Management and Scheduling

Prior to the start of the season, a detailed timeline (Appendix B) was created with the help of experienced company mentors to assign periodic milestones in three departments: Electrical, Mechanical, and Software. Roughly, around 6 weeks were allotted to (R&D) for each department at the start of the season to allow space for creativity and progress without exceeding the allowed time limit. Team leads during the following months discussed progress with each other and assigned tasks to employees with care, all while confirming the utmost impact of respecting deadlines.

D. Budget Planning

Drafting an estimated budget for the season is one of the first tasks, the company's board takes on to be able to correctly plan for the rest of the project. Since it is currently the company's eighth year participating in MATE ROV, each season's budget builds upon the previous one's expenses, coupled with projections for new expenses. A Google Sheets ledger is kept to document all outgoing payments and incoming funds and donations. The team is mostly self-funded, however, through deals with corporations and companies, we are able to receive discounts on selected items and software programs. Detailed and thorough budget analysis can be found in (Appendix E).

5. Conclusion

A. Challenges

One of the most limiting challenges we faced last season was working in the aftermath of the COVID-19 pandemic. Respecting restrictions meant fewer employees were able to work from the company's workshop and more remote work had to be scheduled and assigned. Although we were able to pull through with good planning, we believe it was a challenge maintaining company morale in the unpredictability of a post-COVID environment.
Additionally, the unavailability of electronic components was a prevalent issue. Several components needed to be imported from abroad, awaiting customs clearance, which caused delays in the schedule as well as an increase in expenses.
Moreover, since the company was mostly self-funded, finding sufficient financial backing and procuring the necessary funds to finance the company's activities was not always an easy task. To solve this, we routinely reached out to major companies and corporations for sponsorship and financial aid.
A technical challenge we faced was displaying all cameras' feeds simultaneously on our GUI without latency or any software crashes. This was solved by running each feed in a separate process, utilizing multiprocessing.

B. Lessons learned

As a result of the new technologies the company used in ROV development this year, the amount of experience and new skills gained by all M.I.A. robotics employees are invaluable. All members in different departments benefited from the development process. Mechanical members gained powerful skills in SolidWorks, 3D printing, and machining. Electrical team members now have a great understanding of PCB design, soldering, and low-level programming. Software members are now fluent in both Python and C++ and are aware of real-life skills and frameworks like Git, ROS, QT, and Linux. This year, all members had professional training for technical writing and presentation skills. Moreover, working as a team helped all the members to develop soft skills of teamwork, communication, and documentation.
This year, the company had time to work on the future improvements proposed last year. One of the improvements was improving our low-level control system. The PID team achieved this goal by implementing more reliable control systems which are easy to use and efficient.
Another important lesson learned is the use of an efficient communication system. The ROV team this year used ROS as the major communication tool for different parts of the ROV. ROS helped us to implement great features that would have been much harder to achieve using normal serial communication protocols.

C. Future Improvements

Virtual Reality

Simulating the experience of being an ROV and exploring new adventures is one of the most important targets that we want to achieve in the coming years.

HIGH-LEVEL CONTROL SYSTEM

The company achieved one of its targets which was PID Control implementation; however, it's considered a milestone. We aim to implement a higher level of control for path planning and the ability to dynamically load and execute a new mission scripts based upon commands.

LOCALIZATION

Using more powerful cameras and sensors like (Sonar, ZED Camera, 360-degree camera, etc..) Would help us in localization, in order to reach the goal of autonomous movement.

MORE EFFICIENT CONVERSION SYSTEM

Using DC-DC Buck converters with higher rated voltage and current at the output means using few of them. This reduction in converters number will lead to a smaller electronics enclosure, less weight as well as harnessing the full power of the T200 thrusters.

CARBON FIBER FRAME

The company is considering the possibility of using carbon fiber as the main material in the frame fabrication. Carbon fiber provides a great material choice in terms of strength-to-weight ratio.

D. Build vs. buy, new vs. used

Build vs Buy: We custom fabricated our leakage sensor, reducing the cost, and providing an easily replaceable alternative. For utter performance, we used an air pressure sensor. After, calculating and fabricating the best way to actuate an air-filled bladder to act upon it. We were able to have a depth sensor with better accuracy, at less than half the cost of alternatives. New vs Used: COVID-19 lockdown, customs, and import fees are the biggest hinders to getting all the necessary components. This year, we decided to reuse four thrusters from our old ROV and buy two vertical thrusters to withstand the load. Others are kept as spare parts, giving us the best combination between cost and reliability.

E. Acknowledgments

We're very grateful to all of these organizations and individuals for their help and support that enabled us to overcome all challenges that we've faced:

- MATE Center for sponsoring this year's competition and for their generous awards.
- Arab Academy for Science and Technology (AAST) for hosting and organizing the regional competition.
- The Suez Canal Authority for allowing the team to sail its ROV through the Suez Canal. We are extremely grateful for the opportunity to benefit our country through our research and its applications.
- SolidWorks, ANSYS, Proteus, Eagle for providing the team members with access to a premium version of their software.
- Blue Robotics for providing the team with discounted components (thrusters, etc.).
- Victoria College for permitting the team to use their on-campus pool for testing the ROV free of charge.
- LaserTech for allowing the team to use their workshop and machines at a discounted rate.
- Team supervisor: Prof. Dr. Hassan Warda for his constant efforts in supporting the team.

Figure(30) : Organizations' Logos

F. References

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- Docker Documentations:https://docs.docker.com/
- Ros documentation: https://wiki.ros.org/
- Blue Robotics store: www.bluerobotics.com

- Tensorflow documentation: `https://www.tensorflow.org/api_docs`
- Pyside Documentations: `https://pyside.github.io/docs/pyside/`
- OpenCV documentation: `https://docs.opencv.org/3.4.5/`
- Matlab documentation: `https://www.mathworks.com/help/matlab/`

6. Appendix

A. Safety Checklist

- **Pre-Power Test**

☐ Area clear/safe (no tripping hazards, items in the way).
☐ Verify power switches and circuit breakers on TCU are off.
☐ Tether flaked out on deck, connected to TCU and secured to ROV.
☐ strain relief connected to ROV.
☐ Electronics housing sealed.
☐ Visual inspection of electronics for damaged wires, loose connection.
☐ Nuts tight on electronics housing.
☐ Thrusters free from obstructions.
☐ Set compressor output to 2.75 bar. Power-Up
☐ Power source connected to TCU.
☐ TCU receiving 48 Volts nominal.
☐ Control computers up and running.
☐ Ensure deck crew members are attentive.
☐ Power on TCU.
☐ Perform thruster test/verify thrusters are working properly (joystick movements correspond with thruster activity).
☐ Verify video feeds.
☐ ROV lights indicate "Safe Mode" (green).

- **In Water**

☐ Check for bubbles, if large, pull to surface immediately.
☐ Visually inspect for water leaks.
☐ Engage thrusters and begin operations.

- **Loss of Communication**

☐ Cycle power on TCU to reboot ROV.
☐ If no communication, power down ROV, retrieve via tether.
☐ If communication restored, confirm there are no leaks, resume operations.

- **Pit Maintenance**

☐ Verify thrusters are free of foreign objects and spin freely.
☐ Visual inspection for any damage.
☐ All cables are neatly secured.
☐ Verify tether is free of kinks.
☐ Visual inspection for leaks.
☐ Test onboard tools.
☐ Verify camera positions.
☐ Washdown thrusters with deionized water.

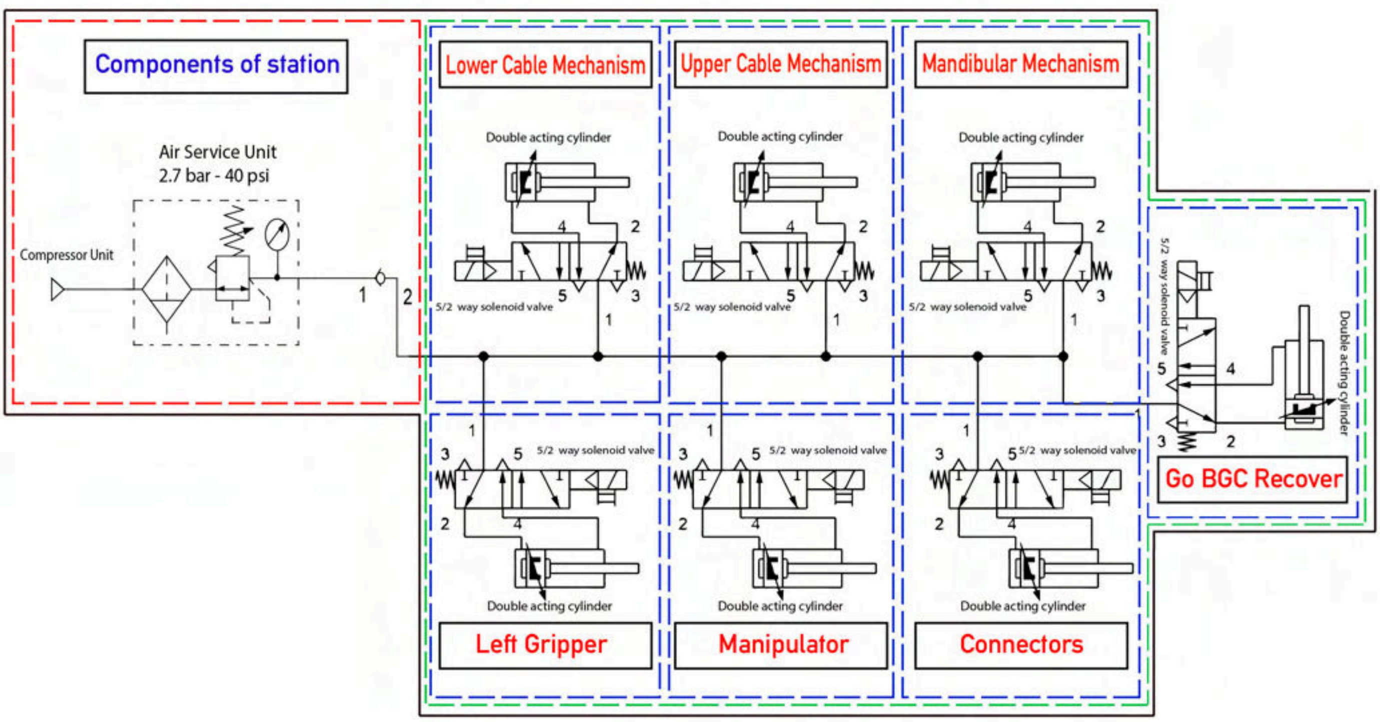
B. Power budget

Component	Quantity	Voltage(V)	Current(A)	Power/component(W)	Total power(W)
T200 thruster	6	12	12	144	864
Basic ESC	6	12	0.3	3.6	21.6
STM32	2	5	0.0127	0.0635	0.127
Solenoid	7	12	0.2	2.4	16.8
IMU sensor	1	5	0.01	0.05	0.05
Pressure sensor	1	5	0.01	0.05	0.05
Leakage sensor	1	5	0.01	0.05	0.05
Mechanisms cameras	6	5	0.3	1.5	9
Main camera	1	5	0.5	2.5	2.5
Stereo camera	1	5	0.8	4	4
Raspberry pi 4	1	5	0.8	4	4

Total Power Consumption = 922.177 W
Current drawn from MATE Power Supply = 922.177/48 = 19.212
Fuse value = (150%) x19.212= 28.818A ≈ 30 A

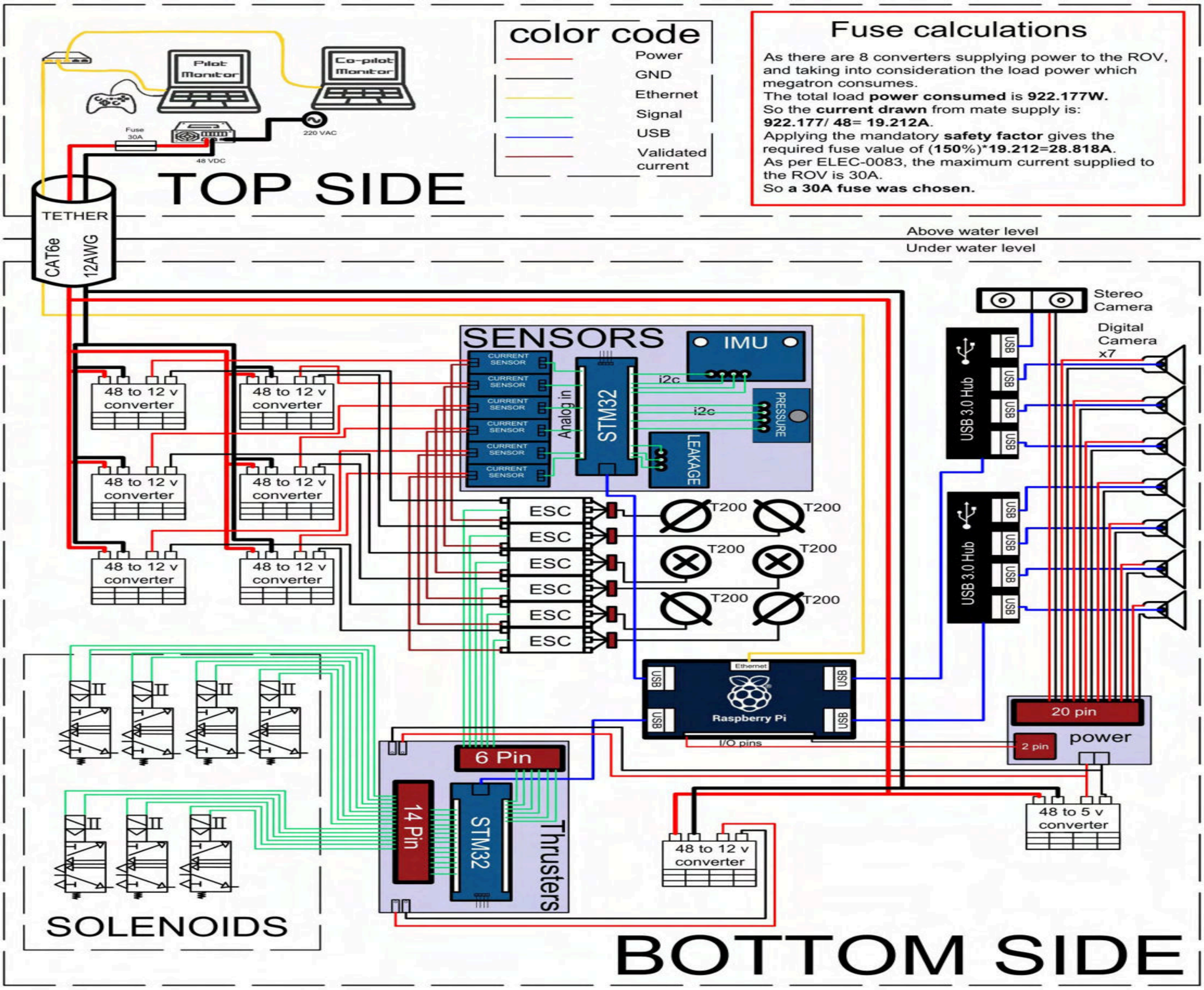
C. SIDs

Pneumatic SID



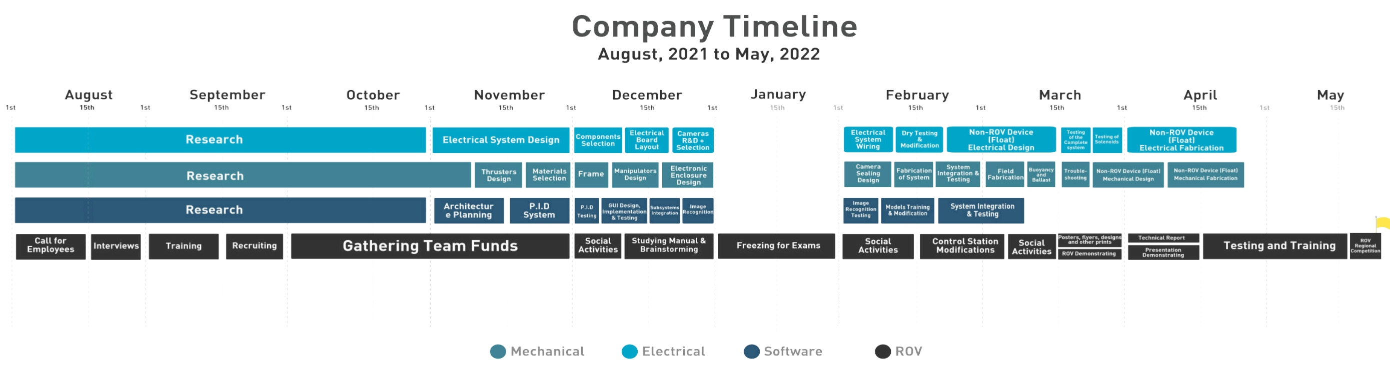
Figure(31) : Pneumatic SID

Electrical SID



Figure(32) : Electrical SID

D. Company Timeline



Figure(33) : Project Timeline

E. Budget Sheet and Project Costing

Budget sheet (MIA Robotics from 30/9/2021 to 26/5/2022)

	Category	Description	Amount in USD
Income	Self-Fund	Employee Dues	4100
	Mate Rov 2021 - Schmidt Ocean ROV	Prize	250

Group	Section	Subcategory	Description	Type	Budget in USD	Total in USD per Category	Budget in USD per Category
Expenses	Mechanical	Raw Material	Aluminum alloy 5083 Sheets	Purchase	134.70	2188.95	2075.81
			2020 Aluminum Profiles	Purchase	5.39		
			Acrylic Sheet	Purchase	53.88		
			HDPE (Sheet & Rods)	Purchase	80.82		
			PLA+	Purchase	107.76		
		Fabrication	CNC Machines: Laser CNC	Purchase	256.47		
			CNC Machines: Milling	Purchase	168.10		
			CNC Machines: Lathe	Purchase	57.65		
			Welding	Purchase	39.49		
			3D Printing	Purchase	294.72		
		Sealing	Electrical Enclousre O-Rings	Purchase	8.08		
			Cameras casing O-Rings	Purchase	2.42		
			PG9 Glanda	Purchase	22.63		
			PG7 Glandea	Purchase	15.63		
		Pneumatic System	Air Compressor	Re-used	107.76		
			Pressure Regulator	Purchase	12.39		
			Pneumatic Fittings	Re-used	5.39		
			Pneumatic Lines	Purchase	0.54		
			Pneumatic Solonoid Valve	Purchase	47.95		
			Pneumatic Linear Actuators	Purchase	77.32		
		Miscellaneous	Aluminum Profiles Extensions	Purchase	43.10		
			Aluminum Supports	Purchase	21.55		
			Bolts	Purchase	93.97		
			Nuts	Purchase	45.26		
			Washers	Purchase	20.47		
		Tools	Screwdriver, Driller , Grinder, Tree Drill, Cutter, Clipper, Nylon Wires, Spanners, Strain Relief	Purchase	368.53		
		R&D	New Enclousre technique (electric enclosure box)	Purchase	43.10		
			New Sealing techniuqes	Purchase	53.88		
	Electrical	Vision System	Stereeo Camera	Purchase	129.31	764.14	762.80
			2X Digital Camera 1080p	Purchase	48.49		
			9X Digital Camera 720p	Purchase	91.59		
		Sensors	BMB Pressure Sensor	Purchase	4.04		
			MPU 6050 IMU	Purchase	4.31		
			6 current sensor 30A ASC712	Purchase	21.01		
			Leakage Sensor	Re-used	1.35		
		Electronic Components	7X DC-DC Converter 48V-12V	Purchase	23.90		
			DC-DC Converter 48V-5V	Purchase	21.50		
			Connectors, Data Headers, Data Base,Cables	Purchase	16.16		
			2X ULN	Purchase	1.08		
			2X USB HUB	Purchase	16.16		
			10X Micro-USB	Purchase	9.70		
		MicroControllers	Raspberry PI 4 8G Ram	Purchase	132.00		
			2X Stm32 F103C8	Purchase	16.16		
		Miscellaneous	PCB Fabrication	Purchase	13.47		
			Heatshrink	Purchase	5.39		
			OTG type C, Converter HDMI to VGA, 10 M CAT 6e internet cable	Purchase	6.47		
		Tools	Screwdriver, Cutter, Clipper, Nylon Wires, Tape, Hot Air Gun	Purchase	64.66		
		R&D	Microcontroller Research (Arduino Nano vs Stm32 F103C8)	Purchase	26.94		
			Pressure Sensor Research (Ms5540C vs BMB)	Purchase	16.16		
			Digital Cameras	Purchase	53.88		
			Local Hub vs Anker Hub	Purchase	40.41		
	General	Thrusters	Blue Robotics T200 Thrusters	Purchase	711.76	1275.66	860.14
			Blue Robotics T200 Thrusters	Re-used	355.88		
			Blue Robotics 30A ESC	Purchase	119.29		
			Blue Robotics 30A ESC	Re-used	59.64		
			Shrouds	Purchase	29.09		
		Tether	Cable Power - 2 AWG Cables	Purchase	107.76	167.03	167.03
			Ethernet Cable Cat 6e	Purchase	21.55		
			PE - Pneumatic Line	Purchase	16.16		
			Nylon Jacket	Purchase	21.55		
		TCU (Top Control Unit)	Station Box	Re-used	59.27	741.60	161.64
			2K Screen Monitor	Purchase	107.76		
			Xbox Series X Controller	Purchase	53.88		
			Power Supply	Re-used	484.91		
			Switch Connector	Re-used	12.93		
			Fuse Holder	Re-used	11.91		
			30-A Fuses	Re-used	10.94		
	Indirect Cost	Registration Fees	Regional Registration	Purchase	200.00	1074.72	929.90
			International Registration	Purchase	200.00		
		Probuilding	Playground (PVCs)	Purchase	118.53		
			Loftus International Gigantic Rubber Fish	Purchase	53.88		
		Tether Man safety	Life Jacket	Re-used	64.99		
			Water Shoes	Re-used	52.98		
			Safety Goggles	Re-used	14.99		
		Marketing	Poster	Purchase	14.82		
			Flayers	Purchase	59.27		
			Banner	Purchase	26.94		
			Business Cards	Purchase	5.39		
			ID Cards	Purchase	26.94		
			Flag	Re-used	11.85		
			T-Shirts	Purchase	224.14		
						Total	Total
						6212.10	4957.31

Total Cost	6212.10	Total cost of the project including re-used items
Total Re-used and Donation	1254.79	Donations and re-used items from last year's project
Total Budget allocated	4957.31	Expected budget in the beginning of the project
Cash Income	4350	Funds raised from employees, prizes, and donations
Funds Needed	607.31	Total budget allocated minus cash income
Travel expenses per person	1750.00	Travel expenses per person for travelling from Egypt to California,USA
Travel expenses for 15 persons	26250.00	Travel expenses for 15 persons travelling from Egypt to California,USA
Total Cost including Travel expenses	32462.10	Total Cost of the project including travel expenses for 15 persons

Project Costing (MIA Robotics 30/9/2021 to 26/5/2022)

Type	Expenses	Description	Amount in USD	Project Cost in USD	Running Balance in USD
Cash Raised	Employee Dues	Each member pays a certain ammount	4100	-	4100
Cash Donated	Prize from Schmidt Ocean ROV	-	250	-	250
Purchased	Aluminum alloy 5083 Sheets	Frame material	188.58	188.58	4161.42
Purchased	2020 Aluminum Profiles		5.39	193.97	4156.03
Purchased	Acrylic Sheet	Cameras Casing	52.80	246.77	4103.23
Purchased	HDPE (Sheet & Rods)	Mechanisms Material	80.82	327.59	4022.41
Purchased	PLA+	3D Printing Material	107.76	435.35	3914.66
Purchased	Laser CNC	For Manufacturing	172.41	607.76	3742.24
Donated	Laser CNC (Donated by Lasertech)		84.05	691.81	3742.24
Purchased	Milling		168.10	859.92	3574.14
Purchased	Lathe		57.65	917.57	3516.49
Purchased	Welding		39.49	957.06	3476.99
Purchased	3D Printing	For 3D Parts	294.72	1251.78	3182.27
Purchased	Cameras casing O-Rings	For Cameras Casing	2.42	1254.20	3179.85
Purchased	Electrical Enclousre O-Rings	For Control Box Sealing	5.39	1259.59	3174.46
Purchased	PG9 Glanda		22.63	1282.22	3151.83
Purchased	PG7 Glandea		16.16	1298.38	3135.67
Re-used	Air Compressor	For Pneumatic System	107.76	1406.14	3135.67
Purchased	Pressure Regulator		12.39	1418.54	3123.28
Re-used	Pneumatic Fittings		5.39	1423.92	3123.28
Purchased	Pneumatic Lines (inside ROV)		0.54	1424.46	3122.74
Purchased	Pneumatic Solonoid Valve		51.19	1475.65	3071.56
Purchased	Pneumatic Linear Actuators		77.32	1552.96	2994.24
Purchased	Aluminum Profiles Extensions	For Frame Structure	43.10	1596.07	2951.14
Purchased	Aluminum Supports		21.55	1617.62	2929.58
Purchased	Bolts	For Fixing	96.44	1714.06	2833.14
Purchased	Nuts		48.49	1762.55	2784.65
Purchased	Washers		20.47	1783.03	2764.17
Purchased	Screwdriver, Driller , Grinder, Tree Drill, Cutter, Clipper, Nylon Wires, Spanners, Strain Relief	For general use	350.22	2133.24	2413.96
Purchased	New Enclousre technique (Control Box)	For Sealing	40.41	2173.65	2373.55
Purchased	New Sealing techniuqes		53.88	2227.53	2319.67
Purchased	Stereeo Camera	For Vision System	107.76	2335.29	2211.91
Purchased	2X Digital Camera 1080p		45.80	2381.09	2166.11
Purchased	9X Digital Camera 720p		91.59	2472.68	2074.52
Purchased	BMB Pressure Sensor	For ROV's electrical enclosure	4.04	2476.72	2070.48
Purchased	MPU 6050 IMU		4.31	2481.04	2066.17
Purchased	6 current sensor 30A ASC712		21.01	2502.05	2045.16
Re-used	Leakage Sensor		1.35	2503.40	2045.16
Purchased	7X DC-DC Converter 48V-12V		23.71	2527.10	2021.45
Purchased	DC-DC Converter 48V-5V		21.50	2548.60	1999.96
Purchased	Connectors, Data Headers, Data Base,Cables		16.16	2564.76	1983.79
Purchased	2X ULN		1.08	2565.84	1982.71
Purchased	2X USB HUB		16.16	2582.00	1966.55
Purchased	10X Micro-USB		9.70	2591.70	1956.85
Purchased	Raspberry PI 4 8G Ram		134.70	2726.40	1822.15
Purchased	2X Stm32 F103C8		16.16	2742.57	1805.99
Purchased	PCB Fabrication		16.16	2758.73	1789.83
Purchased	Heatshrink		5.39	2764.12	1784.44
Purchased	OTG type C, Converter HDMI to VGA, 10 M CAT 6e internet cable		5.39	2769.50	1779.05
Purchased	Screwdriver, Cutter, Clipper, Nylon Wires, Tape, Hot Air Gun	For general use	64.66	2834.16	1714.39
Purchased	Microcontroller Research (Arduino Nano vs Stm32 F103C8)	R&D (Reasearch and Devlopment)	26.94	2861.10	1687.46
Purchased	Pressure Sensor Research (Ms5540C vs BMB)		16.16	2877.26	1671.29
Purchased	Digital Cameras		53.88	2931.14	1617.41
Purchased	Local Hub vs Anker Hub		40.41	2971.55	1577.00
Purchased	4x Blue Robotics T200 Thrusters	For Rov Movment	711.76	3683.31	865.25
Re-used	2x Blue Robotics T200 Thrusters		355.88	4039.19	865.25
Purchased	4x Blue Robotics 30A ESC	For Thruster control	119.29	4158.48	745.96
Re-used	2x Blue Robotics 30A ESC		59.64	4218.12	745.96
Purchased	Shrouds	For thrusters protection	29.09	4247.22	716.87
Cash Raised	UWRC	Winning AUV & ROV Challenges in UWRC	3232.7	-	3949.57
Purchased	Power Cable (Marine AWG 12)	For ROV Tether	107.76	4354.97	3841.81
Purchased	Ethernet Cable CAT 6e		21.55	4376.53	3820.26
Purchased	PE - Pneumatic Line		16.16	4392.69	3804.10
Purchased	Nylon Jacket		21.55	4414.24	3782.54
Re-used	Station Box	For TCU (Top Control Unit)	59.27	4473.51	3782.54
Purchased	2K Screen Monitor		161.64	4635.15	3620.90
Purchased	Xbox Series X Controller		51.19	4686.33	3569.72
Re-used	Power Supply		484.91	5171.25	3569.72
Re-used	Switch Connector		12.93	5184.18	3569.72
Re-used	Fuse Holder		11.91	5196.09	3569.72
Re-used	30-A Fuses		10.94	5207.03	3569.72
Purchased	Regional Registration	Regional Registration	200.00	5407.03	3369.72
Purchased	International Registration	International Registration	200.00	5607.03	3169.72
Purchased	PVCs	For Probuilding	118.53	5725.56	3051.19
Purchased	Gigantic Rubber Fish		47.95	5773.51	3003.23
Re-used	Life Jacket	For Tether Man safety	64.99	5838.50	3003.23
Re-used	Water Shoes		52.98	5891.48	3003.23
Re-used	Safety Goggles		14.99	5906.47	3003.23
Purchased	Poster	For Marketing Purposes	14.82	5921.29	2988.41
Purchased	Flayers		64.66	5985.95	2923.76
Purchased	Banner		26.40	6012.35	2897.36
Purchased	Business Cards		4.04	6016.39	2893.32
Purchased	ID Cards		26.94	6043.33	2866.38
Re-used	Flag		12.12	6055.45	2866.38
Purchased	T-Shirts		224.14	6279.59	2642.22

Project Cost in USD	6279.59
Project Cost - (Re-used & donations) in USD	4940.47
Total Income	4350.00
Total Raised	3232.70
Total Balance (used for next year's project)	2642.23
Travel expenses per person	2000.00
Travel expenses for 15 persons	30000.00
Total Cost including Travel expenses	36279.59

Figure(34) : Budget Sheet/Project Costing