ABYDOS

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And Maritime Transport
Alexandria, Egypt

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MATE

ABYDOS ROV Co.

Notions

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I. Abstract

The ocean has hidden as many secrets for as long as it has existed. On its bed, those secrets have lied dormant for millenniums, waiting patiently to be discovered. **ABYDOS** had emerged in 2015 for a unique purpose: to serve the ocean, and help uncover its secrets, discover all that was once unseen by human eyes. Within the pages of this technical report. **ABYDOS** unravels its history, with all the hard work that has led to our newest pride and joy, **Anubis**.

Anubis is designed specifically to suit the requirements of this year's mission, packing eight thrusters placed in different angles and a body of *High-density Polyethylene* (HDPE to provide our ROV with the agility required to navigate freely under the deep waters of Lake Washington, and fortified with a flexible 3D-printed gripper arm running on a speed-reduction gear DC motor to deliver the strength, precision, and consistency required to lift heavy Korean aircraft debris from crash areas.

ABYDOS, a company of ten engineers, was founded three years ago with the goal of building the ultimate balanced ROV that can serve any purpose and adapt to any given environmental conditions. The company uses up-to-date technology including the company's own CNC machine and 3D printer, and a wide range of other specialized equipment. The development process has been in an efficient manner and split up into a number of tasks assigned amongst the four teams: the electronics, the mechanical engineering, the software development, and the logistics & management teams.

Members from back to front, left to right: Mohammed Ali, Mohammed Ibrahim, Wagdy El-Mogy, Mahmoud El-Mogy, Ahmed Mohammed, Loay Akram, Hania Badr, Nancy Fareed, Alieldin Ayman, Amro Magdy

II. Design Rationale

A. Design Process

In order to develop an extraordinary customized ROV that suits all MATE's specifications and Lake Washington’s atmosphere and terrain environmental conditions, as well as being compatible with ABYDOS’ standards. The production process of Anubis went through several stages of reviewing, editing and refining to ensure reaching the maximum possible production quality and vehicle efficiency. The designing process began with brainstorming and conceptualizing sessions that lead to numerous creative and innovative ideas. Ideas were then filtered, merged then sketched onto a whiteboard creating several possible designs (fig-1). Each design had been analysed and reviewed individually, and all mechanical aspects were carefully discussed. The primarily-approved designs were chosen according to several factors such as size, weight, easy maintenance, strength, efficiency, availability, machinability, and safety.

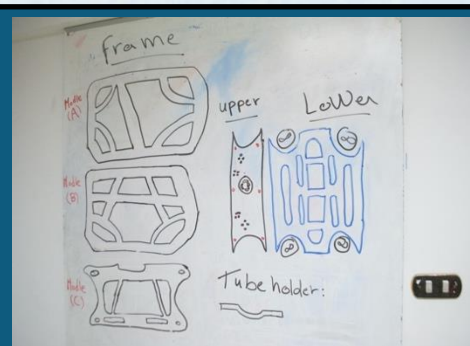

Figure-1 : Whiteboard Sketches

Prototypes were made using 3mm PVC panel (fig-2) and analysed carefully to prove the concept of designs. The next step was to convert the final approved designs and sketches into *Computer Aided Design* (CAD) files via SolidWorks which was done by Nancy Fareed and Autodesk Inventor. To ensure the durability of Anubis, the CAD model was tested under extreme conditions that outweigh the missions' conditions around two times via ANSYS and SolidWorks Simulation. The final CAD model would then be modified to suit the new circumstances according to the output data.

Figure-2 : Prototype for Model (C).

Frame, Control Tube holder, PCB holder CAD files were then converted from *SolidWorks Part* files (SLPRT) into *Drawing Exchange Format* (DXF) files to be machined using a laser-cutting machine. Floating parts, thruster’s stator base, thruster's motor adapter, and the wire organizer CAD files were converted into *Stereolithography* (STL) files to be printed using our 3D printer ABYDOS-V3 (fig-3). End cups’ files were converted into a *Computer Aided Manufacturing* (CAM) format to be machined using our *Computer Numeric Control* (CNC) milling machine. The light system chassis CAD files were then converted into detailed sketches to be manufactured manually.

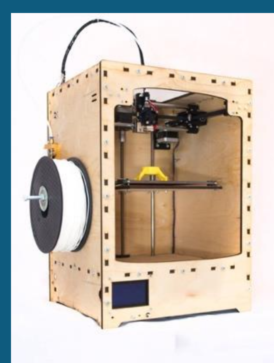

Figure-3: ABYDOS’ Printer

B. Design Evolution

Last year, the *Marine Advanced Technology Education* (MATE) organization declared very specific curtailments regarding the design. These restrictions were made with the required mission in mind. Most of which were design-related leading to feasible manufacturability, compatible cost and performing the mission. And although the situation had become very challenging to not only our company but most of the other ROV companies, it has become very rewarding to the field in general. Although this year's design restrictions might be less exigent, our company is aiming to face the biggest challenge we've ever had. Our goal is to design an ROV that could be perfect all-around, and not just for the missions ahead.

The company's experience and research these past two years has presented Anubis. A new vehicle for a new era in various fields including offshore construction. Anubis does include other company's original designs for some of the key components –such as: propellers -which are to be specified in the following sections in details. However, as our original ROV ❝Mantaray❞ was a bedrock in our designs, our company used some of its components to achieve the optimum cost and efficiency. Components as the nozzles and propellers remained the same and were carried out in the process to be reused for Anubis.

As our company believes in the utilization of all the available resources aiming towards effective cost, it was important to consider the number of external purchases. Although acquiring the learning and management process of its members, some of the domestic components were at a reduced cost when designed and manufactured at hand.

Figure-4: The Complete ❝Anubis❞ ROV of 2018

C. Mechanical System

Frame

The design of Anubis' frame was customized and edited by Mohamed Ali to be appropriate for operating at Lake Washington's environment. Our aim in ABYDOS was to develop a lightweight, rigid, suitable size, cost effective, chemical resistance and durable ROV chassis that can operate under any extreme condition. The limitation and constraints of weight and size (the total weight of the ROV must not exceed 17 kilograms, and the ROV largest face must fit through a 58 cm diameter circle) were kept in mind during the designing, material selection, and production processes. In order to produce the minimal drag force, the shape of the frame was controlled by the drag force equation ($F_D = \frac{1}{2}\rho u^2 C_D A$). The main parameters that control the value of the drag force (F_D) are the Drag coefficient (C_D) and the reference area (A), where the other parameters are almost unchangeable. The drag coefficient is a dimensionless quantity that is used to calculate the drag force exerted on an object in a fluid environment such as water in our case. According to Barnes W. McCormick, ❝The drag coefficient is always associated with a particular surface area❞[1] (fig-4). On that matter, our main efforts were pointed towards achieving a design where the frame has the minimal achievable drag coefficient of C_D= 0.34.

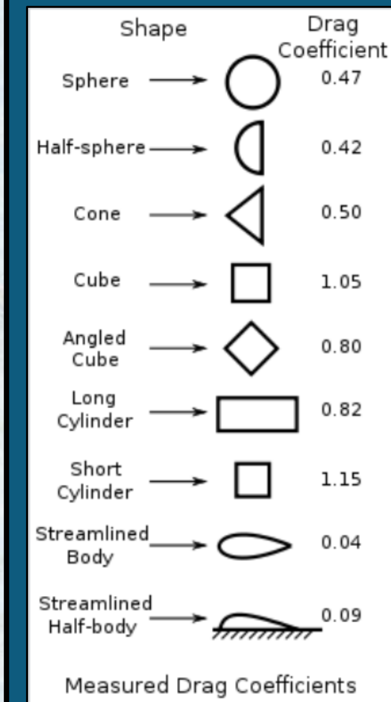

Figure-5: Drag coefficients in fluids with Reynolds number approximately 10^4

As an alternative to aluminium and stainless steel, *High-density Polyethylene* (HDPE) was chosen to be the building material for Anubis' frame as it has superior mechanical and physical properties; such as low density 0.95 g/cm^3 compared with aluminium 2.7 g/cm^3, low cost (approximately 0.45 of aluminium cost), easy machinability using the laser-cutting CNC machine, high chemical resistivity and high shock absorption.

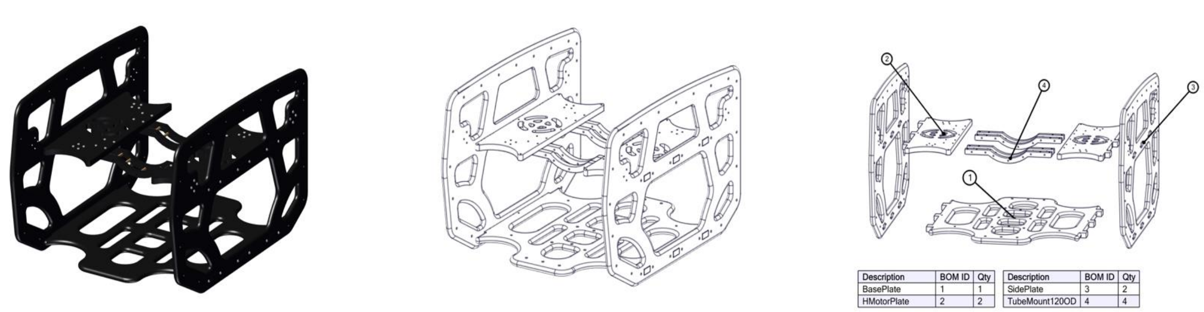

Figure-6: Render of Anubis' frame and bill of materials (BOM)

[1] Barnes W. McCormick. Aerodynamics, Aeronautics, and Flight Mechanics (1979). P.24.

The frame of Anubis consists of nine parts: two vertical plates placed on each side connected by three horizontal plates (fig-5). The upper two plates are jointed together using four connectors in a U shape to mount the control tube and secured with M3 bolts. The frame is jointed using M6 self-tapped screws, which were selected according to the stress analysis results with a safety factor of 2.

The results of stress analysis under the worst case showed that the frame's joints are exposed to 4 different kinds of stresses. Two normal stresses (Tension and bending) and two shear stresses (direct shear and shear due to torsion), which result in, frame separation after long time of operation. Therefore, after the calculation regarding the frame jointed with bolts we needed to strengthen the frame to reduce the effects of stress to a minimum. We designed the frame as to be connected in a puzzle-like joint. Extensions from the horizontal planes intersected with the outside frame in unison. Proved by calculations, it was shown the effectiveness of this design. Thus, it was reused this year for its reliability.

Propulsion

Anubis is powered by eight ❝Nyke❞ thrusters. A Nyke thruster is a customized version of the Blue Robotics ❝T200❞ thruster that is developed and manufactured by our company (fig-7), and supplies a maximum power of 250 Watts and draws 20 Amperes under full load. The stator base, cone and motor adaptor are designed and developed by our *Research and Development* (R&D) team members, then printed in 3D and attached with the original T200 propeller and the Kort nozzle.

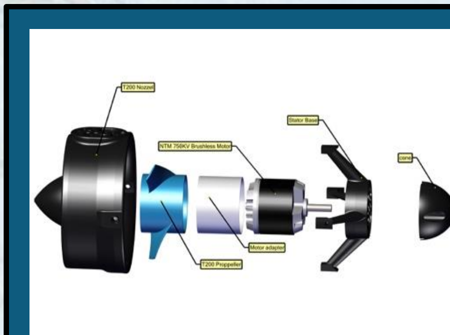

Figure-7: Nyke Thruster in Exploded-View

Thrusters' configuration (figure-9) was chosen by both Nancy Fareed and Mohamed Ali to achieve six degrees of freedom (heave, sway, surge, pitch, roll and yaw). Four vertical thrusters are placed at the top four corners of the ROV which are responsible for vertical control, pith and roll movements. The other four thrusters are installed horizontally at 45° with respect to the front of the ROV, and opposing each other, these thrusters are mounted at the corners of the ROV to provide stable control. The orientation of the horizontal thrusters is specifically estimated according to our design aspect of providing a forward thrust that equals the sideways thrust, that can be calculated using the formula: $[thrust * \cos(45) \cong 0.707\, thrust = thrust * \sin(45) \cong 0.707\, thrust]$.

	Dry Weight	Wet Weight	Power	Forward Thrust	Reverse Thrust	Thruster Cost
Nyke	270 g	90 g	250 W	2.52 kgf	2.05 kgf	55 $
T200	334 g	156 g	350 W	3.55 kgf	3.0 kgf	194$
T100	295 g	120 g	135 W	2.36 kgf	1.85kgf	150$
Bilge Manta 200	305 g	147g	120 W	1.2 kgf	0.9 kgf	65 $

Figure-8: Comparison of specification of BlueRobotics and ABYDOS thrusters (12v)

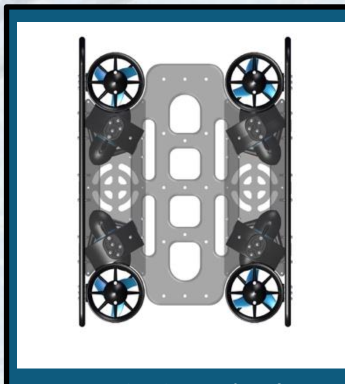
Figure-9: Anubis Thrusters' Configurations

Each Nyke thruster weighs around 270 grams above water and 95 grams under water, and produces a maximum forward thrust of 24.71N and a reverse thrust of 20.1N. The Nyke thruster has an operation voltage of 12V. The estimated lifetime of a Nyke thruster rounds about 2,500 working hours with added lubrication every 100 hours.

Stability

According to Archimedes' principle, our company designed a vehicle with a slightly positive buoyancy which was Aly Mohamed' idea. The reason for that is to ensure that Anubis could be operated at any point across the water column and to ensure that it manages to return to the surface if a voltage drop occurs without any risk of damage. The mechanical team at ABYDOS used the SolidWorks software to perform accurate buoyancy calculations. According to the results, the team was able to estimate the required volume of the floating material (Rigid Polyurethane foam with density of 36 Kg/m^3). The floating material was cut in a rectangular shape and placed above the horizontal motors' plates then covered by the floating 3-D printed parts.

D. Electrical System

Electronics

Previous ABYDOS vehicles had a wide range of different voltages, communication protocols, and expensive pieces of equipment. This meant that troubleshooting was a very complex task with the potential of high-cost replacements. Anubis' all new onboard electronics system marks a great achievement for the company, as commercial components were researched extensively to find solutions which were much better budget-wise, easy to integrate, and extremely reliable. While coping with the user-centered design philosophy, the system was optimized for the simplicity of understanding and troubleshooting.

To achieve this, the electronics in Anubis were organized along two copper boards, with the power in one board (figure-10) and the communication system within the other (figure-11). The power board consists of eight *Electric Speed Controllers* (ESC's) which were used from last year due to their lack of production in the industry, and DC-DC converters which lower the 48V input voltage from the tether to 12V for the optimum system usage. It does so at a high efficiency, which exceeds 95% under normal operating conditions. By providing the ESC's with the voltage needed, and by fetching them together in one board, this design has allowed us to provide electronic noise isolation to the ROV and this board was implemented by Mohamed Ibrahim,. As for the communication system in the other board, it consists of an Arduino that controls the incoming and outgoing signals of the sensors and the ESC's. The Arduino was chosen for its relatively small size and programming feasibility.

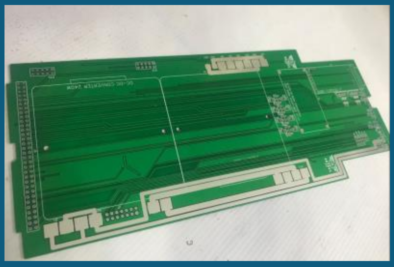

Figure-10: Power Board

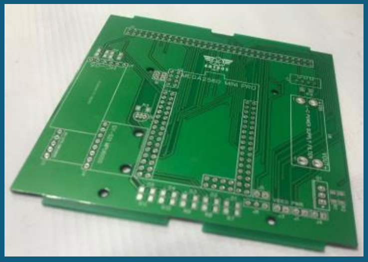

Figure-11: Control Board

The main camera is mounted on the front control tube dome of Anubis connected to a laptop at offshore via an USB converter that allows us to view live video feed from Anubis, to further improve the user experience, Anubis features a wide variety of onboard diagnostics which comes from different sensors that was implemented by Amro Magdy and instrumentation that goes with the safety standards which is a group of sensors that gives the operator a specific live feed of how Anubis is doing which is discussed more thoroughly in the safety part, Internal and external pressure and temperature, voltages and currents, and onboard computer performance are some of the metrics used to ensure vehicle performance.

Tether

Anubis' tether uses a construction proven method that relies on previous products. The tether shelters multiple communication cables within a single flexible sheathing to prevent tangles and keep the cables organized and protected. The tether used was provided by the VideoRay™ Company at a reduced price. The tether has a length of 18m, a diameter of 12mm, and weighs 1.5 kg. It houses four 20-gauge power wires connected from the ROV to the station, a 24-gauge twisted pair used for video communication with a passive balun, two-28 gauge twisted pairs used for data communication which transmits the data between the ROV and the station and contains one Category 5 Ethernet (Cat5e), Cat5e was chosen over alternatives such as Coaxial, Cat4, or Cat6a cables due to its ability to resist interference, low cost, and flexibility. The tether was reused from last year due to the very expensive cost of acquiring a new one, and due to its proven efficiency in last year's competition.

Figure-12: Tether

Electronics Enclosure

All electronics this year are placed on two copper boards that are held in place with our custom-made PCB holder that consists of two rings that hold 8 ESC's, three rings holding the boards together, and a special 3D-printed part that holds the CCTV camera. This setup makes it easier to insert and remove the electronics and do any maintenance required.

In order to ensure a perfect isolation for Anubis' electronics while maintaining high flexibility, Acrylic was chosen as the material for building the control tube body that houses the electronics. The tube has dimensions of (11in cm x 12od cm), and is transparent to allow for easier maintenance and inspection. It is built in a cylindrical shape to decrease the drag coefficient of the vehicle, allowing for much smoother exploration under water. The cylinder is held in place by a smooth Valcro strap for easier installation and removal of the tube and overall protection from scratches.

Figure-13: Electronics Enclosure

The two end caps enclosing the cylinder are made of Artylon due to its high machinability and cheap manufacturing price compared to Aluminum. The end caps merge with the control tube using a rubber O-ring, which attains a larger diameter than that of the tube when connected to the end caps. This connection applies enough pressure on the tube's ends to secure it from water leaks at any depths. To reduce the air pressure inside the control tube, a vacuum vent were used. This vacuum permits the air to go out of the acrylic tube in order to ensure perfect close and sealed caps.

The dome end cap holds the CCTV navigation camera on a special 3D-printed mechanism that was designed by Hania Badr that allows for rotation. One laser-beam source is held beside the camera on the same mechanism. The housed electronics connect to the rest of the ROV through cables coming from the tether and passing through the penetrations made through the Artylon end caps, and are held on a PCB holder inside the tube for safety measures.

E. Software System

Anubis' software can be classified into bottom-side and topside code. The topside code relates to everything that has to do with data science, calculating equations, estimating distances, and making an analogy of the different sensors statuses under-water. The topside code runs on the co-pilot's laptop, while the bottom side code is the heart of Anubis, it includes all the software that operates, maps all the motors and internal infrastructure and controls all its functions, and runs on the Arduino micro-controller housed on the control board.

Bottom-side

The Bottom-side software is the code that allows Anubis to run on the Arduino Mega micro-controller, which receives the *User Datagram Protocol* (UDP) packets that control the eight thrusters, camera servos, flashlights laser-sources, and maps all their functionalities together. The micro-controller also receives packet readings from the temperature, pressure, humidity, water and gyroscope sensors to act accordingly. Most of the ROV functions were optimized and rewritten to work on the topside instead to decrease the processing overhead, which lead to a significant increase in performance and response time in Anubis this year due to Mahmoud El Mogy exceptional effort in designing and implementing this year's bottom-side.

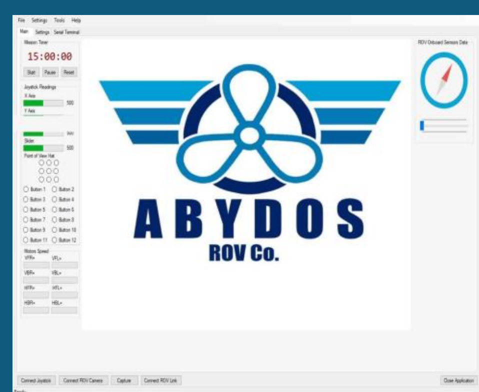

Figure-14: ANUI's Interface

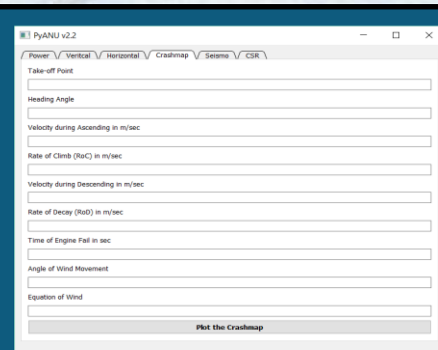

Figure-15: PyANU's GUI

Topside

The Topside which was designed and tested by Ali Eldin primarily consists of two software programs: the Anubis' piloting interface software *Anubis User Interface* "ANUI" which is written in C# and uses the Windows Forms Application for the GUI and runs on the pilot's laptop during navigation, and the co-piloting terminal *Python Anubis* "PyANU" which is written in Python and uses PyQt5 for the GUI which is used by the co-pilot to process all the data and do all the calculations required for the tasks ahead.

ANUI consists of four tabs: the "Main" tab displays the movements, buttons pressed and commands sent from the joystick, it also shows the feedback from the CCTV camera, and finally displays a compass for helping the pilot during navigation. The "Settings" tab is responsible for all the ROV connections, and for initializing the connection between the USR TCP Ethernet module connected to the Arduino microcontroller with the co-pilot's laptop via Ethernet. Finally, the "Serial Terminal" tab monitors the sensors and displays all their readings in real-time. There's also a warning screen that flashes red if any water leak was detected by the water sensor during underwater exploration.

PyANU consists of six tabs: the "Power" tab which is used for calculating the power generated from the array of tidal turbines in the area where the maximum tidal current of the day is observed. The "Vertical" tab which is used to calculate the vertical distance between two distances by converting the difference between their respective pressures to distance. The "Horizontal" tab which is used to calculate the horizontal distance between two points by using two laser beams as a reference and calculating the unknown distance using a pixel-to-distance conversion algorithm. The "Crashmap" tab which is used to estimate the coordinates of where exactly an aircraft crashed into the sea given the various flight data, a visual graph is then plotted on a map to show the precise crash position. The "Seismo" tab which is used to receive the earthquake data continuously from the Wi-Fi module of the OBS under-water and assign it to a sorted array, a plot of the coordinates is then made forming a Seismograph of the given earthquake. Finally, the "CSR" –*Color & Shape Recognition*– tab which is used to recognize geometrical shapes and their colors, it takes control of any chosen camera connected to the DVR and scans its video stream in real-time, drawing contours around detected objects and displaying the shape and colors detected.

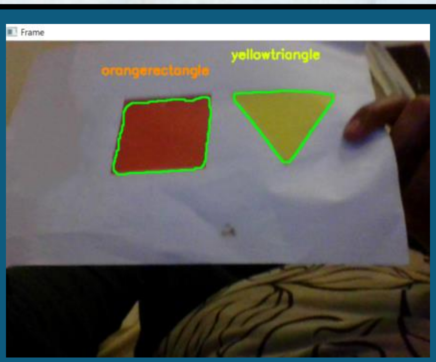

Figure-16: CSR Software Sample

F. Payload Tools

The electronics engineering team has decided after thorough analysis of this year's mission to use the following sensors which have proven to be enough to get the mission done:

Pressure Sensor

Anubis is equipped with a barometric pressure sensor. Previous ABYDOS products have used pressure sensors with a resolution up to 10cm, the high-resolution pressure sensor will resolve pressure to 20 Pa, which translates to a depth resolution of 0.2 cm. The pressure sensor is calibrated by comparing it to a known barometric pressure when the ROV is out of the water. The pressure sensor is mainly used for calculating the distance between two points vertically for this year’s mission.

Compass

One of the major electronic components installed on the Anubis’ board, it is used to minimize the deviation as much as possible. Anubis wouldn’t function properly under water without the use of the compass.

Bluetooth Module

This module is used to facilitate the reprogramming of the Arduino without the need of any physical interference on Anubis. Used this year as the primary lift bag release mechanism.

Wi-Fi Module

A module implemented specifically this year in order to fetch and parse earthquake data from the OBS at seafloor.

Camera Filter

This filter is used for clearing all the noise and ripples in the voltage that could be found from other components before sending the input image signal to the camera. Mainly used this year for getting a clear image for identifying the aircraft model through shape and color recognition.

Gripper and Rotator Arms

Two major components of Anubis, widely used in most operations that include pulling and moving objects around. Anubis uses two DC arms running on two DC motors, where one is used as a gripper for the opening and closing procedures for holding objects, while the other is used as a rotator which will be specifically used this year for leveling the OBS In this year's mission. The motor is supported with a speed-reduction gear to increase the torque and sustain the strength of the arms under-water.

Figure-17 : Left – Gripper Arm, Right – Rotator Arm

CCTV Camera

Being considered the most important tool in any ROV, the pilot does all the actions according to the image stream received from the camera, and all the tasks done by the ROV are fulfilled accordingly.

DVR

A *Digital Video Recorder* (DVR) was used to connect all the cameras to work simultaneously neglecting the delay of switching between different cameras. Both the laptops of the pilot and copilot are connected to the topside DVR in order to allow navigation and running the image recognition software respectively.

Lift-bag

A non-ROV component used in this year's mission to the debris followed by the engine of an aircraft underwater, the engine with the larger weight of around 60N, this weight was used as the reference upon which we calculated our Lift-bag dimensions. Along with the volume and depth of the engine, we used "Divestock" to make an estimation of the Lift-bag capacity and amount of air it can contain inside, which amounts to 26Kg and 76L of air respectively.

Inductive Coupling

Another non-ROV tool used specifically for this year's mission in order to power up the OBS with the 5v required. It consists of an inductive coil, a battery, a reed switch, and a small PVC cylinder with two end caps housing the components. The battery starts transmitting power once a magnet comes in contact with the tube, thus adding a mechanism to avoid wasting power when the battery is not in use. Finally, the end caps open freely when the pressure on the tube reaches a maximum level, as not cause any damage to the ROV.

G. Troubleshooting and Techniques

During the development of Anubis, the Company implemented vehicle systems in stages. This allowed the various teams to focus on one aspect of the vehicle at a time before moving on to additional features. The vehicle's first bench test was completed in January 2017 which established the functionality of the thrusters and cameras, the core systems of the vehicle. Following this, features were implemented sequentially based on priority. This continual system integration allowed the vehicle to be used for practice while newer features were developed and implemented, ultimately leading to a more effective use of personnel resources and time and finally on March 2017 was the time for the complete Anubis test, where all the features were implemented and we started the test by trying out the different tasks Anubis were designed for which led to a few adjustments and by the end of March Anubis was fully tested and ready to sail.

ABYDOS' approach to troubleshooting is a 'one thing at a time' type of approach. This follows the traditional scientific method whereby only one variable is changed while all others are kept constant. Following this concept, the company was able to quickly focus on the source of the problem and work on resolving it. One example was facing the problem of the huge amount of current passing through the tracks in the board, which was an issue we solved by adding overlapping layers of tin on top of the copper, and running tests after the addition of each layer, and eventually it was adjusted to handle the 30A for this year's design scheme.

H. Product Demonstration

Anubis was designed specifically to cope with this year's mission. Thus, finding optimum solutions for every task was a priority we had to design Anubis around. Below are our own implementations for the tasks ahead:

Task 1: Aircraft

We designed Anubis' gripper arm with a significant amount of strength all while maintaining high precision, so that the arm is able to lift the heaviest of debris attached to the Korean aircraft's engines, as well as ensure the proper attachment of the inflated lift bag to them. A lamplight-based light system was implemented in Anubis specifically for exploring deep underwater crash areas where sunlight isn't abundant and the water might be contaminated with plane fuel causing a lot of pollution to the surrounding environment causing the line of sight to be shallow. Anubis has also been supplied with a Wi-Fi module as well as a Bluetooth module set up to act as a release mechanism for the lift bag, and also be used for receiving data underwater (see task 2). The ❝PyANU❞ topside software has been supplied with numerous tools in order to estimate the exact aircraft crash site on the map of Lake Washington, and identify the aircraft's type through the color and shape of the figure on the aircraft's tail.

Task 2: Earthquakes

Anubis' second arm was designed as a rotator placed at the bottom of the ROV. Designed specifically for this task, the arm was given the ability to rotate in 360° in order to be able to level the OBS by rotating the leveling mechanism on two corners of the OBS by 1080° as quickly as possible, allowing for a quick reliable estimation and prediction of any natural disasters before their occurrence. Combined with the strength of the arm, this has shown magnificent results in a very efficient manner of time. Anubis has been supplied with a Wi-Fi module that acts as a slave to catch and parse the earthquake data provided by the internal OBS' master Wi-Fi module, the data is then sent to the station through the tether to be processed and visualized into a Seismograph by the topside code at the station.

Task 3: Energy

We designed the gripper arm to be able to hold the thinnest and lightest of objects with extreme precision, that in order to efficiently place the turbine props, and installing the *Intelligent Adaptable Monitoring Package* (I-AMP) into their respective bases. The gripper is also able to deploy the mooring line prop accurately and attaching an *Acoustic Doppler Velocimeter* (ADV) to it mid-water. We also designed a system for measuring the distance between any two horizontal points by projecting two laser points of known fixed width between

them, a picture of the object of unknown width along with the laser points is then taken and sent to the topside software, this width is then converted to pixels on the shot taken and used as a reference to measure the unknown distance. Finally, another technique is also implemented to measure the vertical distance which makes use of the pressure sensor by converting the difference of pressure between two vertical points from sea-level into actual distance.

III. Safety

A. Company Safety Philosophy

Our company's safety motto:

❝Accident Prevention is Our No. 1 Intention❞

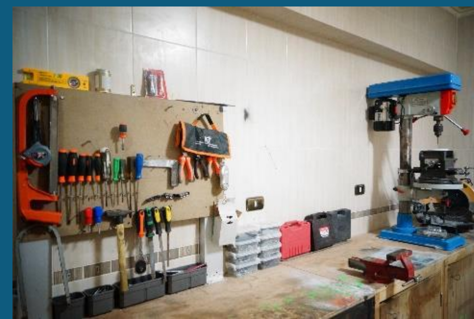
Figure-18: ABYDOS' Lab

Safety is a top priority in ABYDOS, we aim towards keeping our employees safe, protected and satisfied in order to produce the top-quality products and be able to master their crafts without the fear of exploring further technical depths within their skill ranges.

Therefore, health and safety come first. And so our safety standards are mainly inspired by the internationally-applied British Standard for *Occupational Health and Safety Assessment Series* **(OHSAS 18001)[2].**

B. Operational Safety Protocols

Our company makes sure to follow the Job Safety Analysis (JSA) in the launch, recovery, operation and waterside safety before and after the deployment of Anubis underwater. Safety checklists are prepared by the safety managers of the company, and are regularly checked along every step of the way to avoid potential hazards. Instructional guides are printed with every product used in the ABYDOS' labs (figure-17), which include the safest and most efficient ways to use the product and perform all its available operations.

The ABYDOS' labs follows a strict practice of maintaining safety for its workers and thus is provided with multiple vents for keeping the air clean from any harmful fumes produced as a result of welding or performing any other hazardous operation.


Figure- 19: An ABYDOS team member training with safety equipment on

Our employees must first undergo the company's safety checklist mentioned below which ensures that they are fully protected and properly equipped to keep them from any harm while still maintaining an organized attractive work-ground.

C. Training

We created a sustainable training process for the continuous growth of our company. Newly appointed employees are not allowed to operate tools and machinery unsupervised. The training process starts with the observation period where the new trainees are given tasks and get supervised in action by the highly experienced employees. The process then continues with supervised pointed trials following through with the required task where the trainees are required to give a presentation about their understanding of their positions, given tasks and how each of the products used operates. On an extended period of trial and error, we can sure that the trainees finally develop the mentality for solving any challenge introduced to them in the field.

D. Vehicle Safety Features

The ABYDOS' staff has considered safety a prime factor during the design of Anubis in order to keep the employees, workplace, ROV and the surrounding environment safe prior to and during operation. And for that reason the company maintained a number of safety factors for every major component of the ROV including:

Mechanical

The frame has its fillets designed to avoid sharp edges, and all bolts and connectors were properly covered to avoid any issues with the electronics under-water. The thrusters, where all the ones used in Anubis were shrouded by surrounding every propeller by a T200 Kort nozzle, and a thruster guard used which completely encircles the propeller, and has a mesh size that meets the IP-20 standards[3] which equates to a mesh size of >12.5mm. All the electronics in Anubis were waterproofed by inserting all the electronics inside a tube made from polyethylene which is a non-conducting material and is and capable of taking pressure up to a depth of 5.5 meters. Cables were connected to the control tube through the end cap's rubber O-ring to provide the strain relief, preventing the cables from breaking, and sealing the control tube to prevent water leakage.

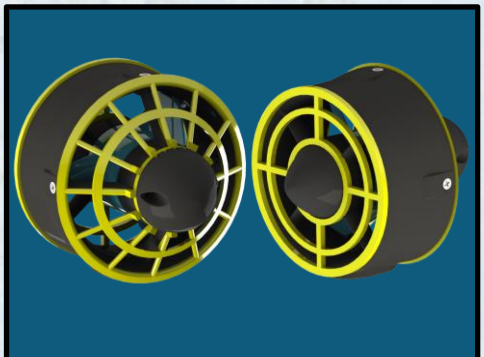

Figure-20: Thruster Guards

Electrical

As for the electrical safety, a water detection sensor module was also installed inside the tube, which would alert the pilot to shut down the system in the case of occurrence of any water leakage, a temperature sensor for getting constant reading of the temperature internally and externally, a gyro and accelerometer to identify whether Anubis is out of balance, and constantly adjust its level under-water, a compass to minimize the deviation as much as possible, a humidity sensor to measure the condensation inside the Acrylic tube and notify the pilot when it reaches a critical level so that they can decide their course of action accordingly and a current regulator to supply all the LEDS in Anubis with a constant current supply and prevent any sudden current changes that may lead to any malfunction or hazardous damage.

The Tether's length was designed to be around 18 meters to be able to operate all tasks with flexibility, and go through depths of over 5.5 meters. The ROV electrical system runs on 12v which feeds off the power provided

[3] *International Protection Marking (IP Code)* - https://en.m.wikipedia.org/wiki/IP_Code

by a power supply with a nominal voltage of 48v through the Tether, then scales it down to 12v to be used in Anubis. All the power provided to Anubis must first pass through the single inline fuse of 30 amp before being used to operate our ROV. Finally, for the power used to operate the Non-ROV devices, 9V alkaline batteries were mounted on the PVC cylinder's end caps and O-rings, in which they freely open if pressure developed inside the housing.

E. Operational and Safety Checklists

Pre-Power

□ Inline fuse exists □ Area is clear & hazard-free □ Power switches verified

□ Power source connected □ Tether is kinks-free □ Tether securely connected to the ROV & TMS

□ Electronics housings sealed □ Visual inspection of damaged parts □ Visual inspection of loose bolts and nuts

□ Vacuum test Anubis' housing □ Vacuum port is securely capped □ Operating crew present on deck

Vacuum Test Procedure

□ Connect vacuum hand pump to ROV □ Pump electronics housing to -50kpa vacuum

□ Verify electronics chamber holds -50kpa □ Remove vacuum

Power-Up

□ TCU receiving 48 Volts nominal □ Power on TCU □ Control computers up and running

□ Thruster test verified □ Thrusters respond to joystick

□ Arms test verified □ Gripper & rotator respond to joystick

□ Camera positions & angles checked □ Video transmission stutter-free □ Anubis' lights are green

Pre-water

□ Wires are securely fastened and sealed □ End caps of the battery enclosure are freely open

In Water

□ Visual inspection of any water leaks through the readings of the water sensor

ROV Retrieval

□ ROV lights indicate green "Safe Mode" □ Operation Technician (OT) powers down TCU

Communication Loss

□ ROV powered off □ ROV retrieved via tether □ ROV free from any leakage or damaged parts

IV. Logistics

A. Project Management

To manage this project, we needed to accomplish each specific objective through a set of interrelated tasks through setting a clearly defined objective stated in terms of scope, schedule, and cost. The responsibility of the CEO was to make sure that the project objective is accomplished and that the work scope is achieved in a quality manner, within budget, and on time.

The first phase of the project's life-cycle states that the executives should define all the project's needs and set the goals which should be accomplished. The second phase defined the goals of the members of the company and includes the archiving of all notes and proposals, and choosing the most suitable proposal. This phase is considered the starting point of the implementation of the project. The company has a fixed meeting day set every week, which includes reviewing what every branch of the team has recently achieved and set each branch's next goals to start working on, this meeting was quite important because it made us clear on where we are in the timeline that we set for ourselves and whether anyone is lacking behind.

Motivation inside the team was quite abundant as we have learned from the previous two years that a motivated team has the strongest base. Motivation appeared the most when mistakes were made by any team member, where the whole team worked on addressing the problem rather than blaming a certain individual, which had led to the formation of a much stronger bond between team members, one of our biggest problems where motivation was the key when our Acrylic Tube broke down before the Regionals, with only two days to but with a motivated, non-blaming, strong bonded team a problem that huge was solved in just a matter of two days.

To facilitate the communications between the members, the company utilized "Trello"; an online project management tool, which made things a lot easier, and allowed access to files anywhere and anytime wherever the team members were, whether it be in the university or outdoors, they could still get a hold of all the latest project schedules, as there was no need to copy files onto any external memory hardware which could get lost. The ability of chatting also meant that your whole discussions are recorded and can be archived for future analysis, utilizing Trello in the right way was one of the reasons of achieving our schedule easily because we always knew exactly where we are and what we needed and whether things is going good or not.

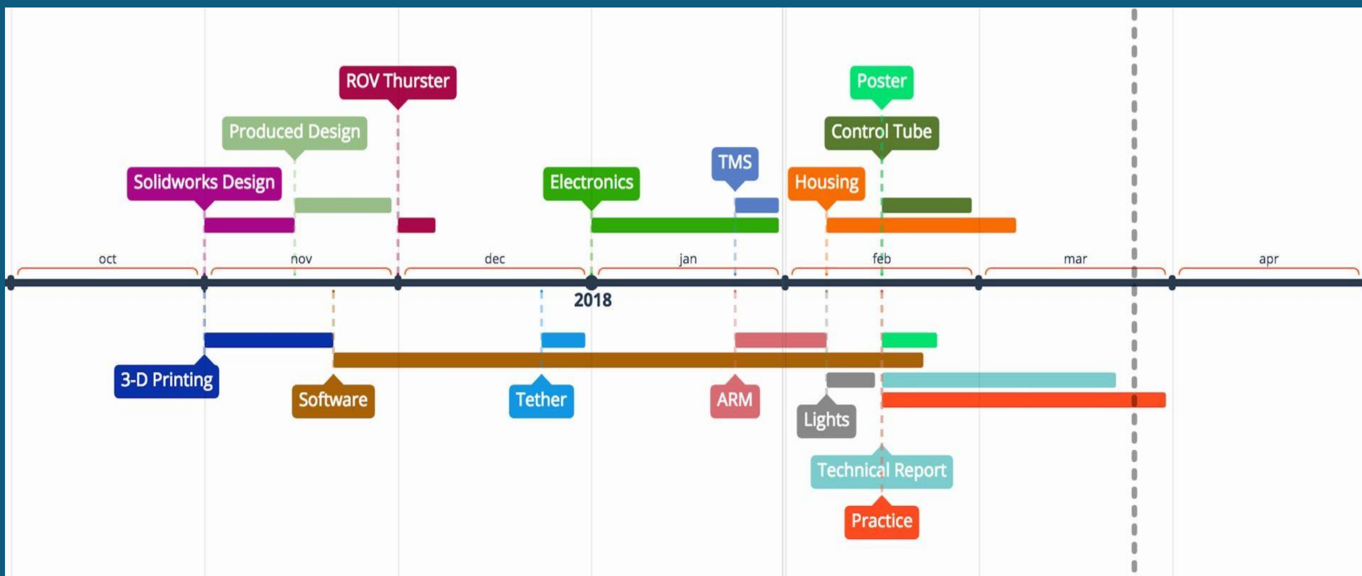

Figure-21: Workflow Timeline

B. Team Organization and Assignments

ABYDOS is organized into four primary teams, each team has two members responsible for innovating new ideas resembling the *Research and Design* (R&D) factor; Mechanical Engineering, Electronics, Software Development, and Logistics and Management to produce the final ROV product. Reporting directly to the CEO, the functional leads are responsible for implementing their assigned deliverables according to the project schedule.

Several key deliverables produced by these departments include the integrated buoyancy designed by Mohamed Ali, the lightweight *High-Density Polyethylene* (HDPE) platforms for the frame built by Nancy Fareed, the proportional thruster control software implemented by Mahmoud El-Mogy, The ANUI piloting software implemented by Loay Akram, the PyANU co-pilot software written by Alieldin Ayman, the CSR image recognition software designed by Wagdy El-Mogy, the custom Arduino shields developed by Mohammed Ibrahim, circuit board designing and assembly by Amro Magdy.

Finally, the trainees Aly Mohammed, Ahmed Mohammed, and Hania Badr were all given a general extended training on all the ROV tasks and field, they also were assigned tasks that ensured they practiced what they had learnt during their training period.

C. Budget and Project Costing

Date	Category	Item Description/Use	Unit price $	Quantity	Total	Fund by
	Electronics/Wire/Connector/Sensors					
12/6/2016	ESCs	30A , Voltage 2.4S Lipo	$12.00	8	$96.00	Re-used
12/6/2016	Arduino	Mega 2560 pro mini	$16.00	1	$16.00	Re-used
12/6/2016	Raising Motor	NTM Prop Drive Series 25-35 750Kv / 260W	$10.00	10	$100.00	Re-used
12/6/2016	DC-DC power convert 12V	used to convert 48V to 12V	$20.00	4	$80.00	Re-used
12/6/2016	DC-DC power convert 5V	used to convert 12V to 5V	$2.00	2	$4.00	Re-used
12/6/2016	Joystick	Logitech extreme 3d pro	$45.00	1	$45.00	Re-used
12/6/2016	Monitor		$120.00	1	$120.00	Donated
5/5/2016	Ethernet Module	USR TCP232 15/07	$9.00	1	$9.00	Re-used
12/2/2017	PCB Double layer 1	Control PCB have Sensors and Arduino	$0.2	10	$20	Purchased
12/2/2017	PCB Double layer 2	Power PCB have DC/ DC Converter 48V to 12V	$3.94	5	$19.70	Purchased
12/2/2017	DVR		$50.00	1	$50.00	Donated
5/5/2016	Thruster Cable	with 3 conductors , 8M	$7.00	1	$7.00	Re-used
5/5/2016	High power Cable		$12.00	1	$12.00	Re-used
5/5/2016	Lumen Cable	With 3 conductors , 8M	$7.00	1	$7.00	Re-used
5/5/2016	Voltammeter	inside the tube to check the volt	$4.00	1	$4.00	Re-used
12/2/2017	WIFI Module	Esp8266 WIFI module	$3.30	1	$3.30	purchased
5/5/2016	Bluetooth Module	HC-05 Bluetooth module	$3.00	2	$6.00	Re-used
5/5/2016	USB DVR	4-Channels	$22.00	1	$22.00	Re-used
12/2/2017	Battery 9V	Powers the lifting bag release mechanism	$2.56	1	$2.56	Purchased
12/2/2017	Inductive Coupling Coil	5V,1.5amps	$8.00	2	$16.00	Purchased
5/25/2016	Fuse	3A fuse for batteries	$0.15	1	$0.15	Re-used
5/25/2016	Camera	Analog CCTV camera	$45.00	2	$90.00	Re-used
5/25/2016	Pressure Sensor	Analog pressure	$6.00	1	$6.00	Re-used
5/25/2016	Temperature Sensor	waterproof DS18B20 Digital temperature	$5.00	1	$5.00	Re-used
5/25/2016	Water Sensor	used for Safety inside the control tube	$4.00	1	$4.00	Re-used
	Consumables					
12/25/2016	Drill bit	3mm and 2.5mm	$0.25	2	$0.5	Donated
12/25/2016	Marine Epoxy	For wire sealing terminals	$14.00	4	$54.00	Donated
12/2/2017	Silicone Grease	For sealing	$3.00	3	$9.00	purchased
12/2/2017	Super glue	For sealing	$5.00	3	$15.00	Purchased
12/25/2016	Thermal Conductive Epoxy	For brushless motor coils sealing	$160	2	$320	Donated
	Manufacturing					
12/25/2016	3D Printing	ABS printing filament	$0.12/g	2000g	$240	Donated
12/2/2017	Laser Cut	Acrylic cutting	$50.00	1	$50.00	purchased
12/2/2017	Milling and turning	For Caps	$20.00	2	$40.00	Purchased
	Misc.					
12/2/2017	O-ring	For sealing	$1.00	4	$4.00	Purchased
12/2/2017	Bolts and nuts	For fixations	$0.25	100	$25.00	Purchased
12/2/2017	Pneumatics	8mm pneumatic hose 40meter	$0.6/meter	40meter	$24.00	Purchased
	Actuators					
12/25/2016	Brushless Motor	For Thrusters	$20.00	8	$160.00	Re-used
12/25/2016	DC-motor	For manipulator	$12.00	1	$12.00	Re-used
	Other					
12/25/2016	Safety Equipment				$160.00	Donated
2/2/2018	Employee T-shirts		$5.00	11	$55.00	Donated
3/1/2018	Fluid Quiz fees				$15.00	Donated
2/3/2018	MATE fees				$300.00	Donated

Total Purchased	$208.56
Total Re-used	$685.15
Total Donated	$1314.5
Total ROV cost	$2208.21
Travel Cost	$11000
Accommodation	$5000

V. Conclusion

A. Challenges

Technical Challenges:

Electrical:

One of the main challenges that faced the electronics team was the occurring of a power surge that damaged the tracks of the power board one week before the competition which meant another board had to be made and tested in just 3 days so that the team could train with Anubis, but due to our team's experience and our new method of solving problems in the team, a new board was made, components were implemented and the board was tested in just a matter of 2 days which is something which could not have happened in previous years.

Mechanical:

Stress accumulations on the screws was a big problem during the designing of Anubis. The team had to deal with a very similar problem last year, so this year a new idea was introduced in the design. New custom-made parts that have the capability to connect to each other were added in the design to allow for holding the design together without screws. Instead, screws were then added to fix the parts in the design and thus the stress accumulations were reduced in a major way.

Software:

One of the most significant challenges this year was the introduction of the problem of detecting the blue color under water, where our software wouldn't draw the contours around the blue color properly. Instead, it would cover the whole image of the pool as one unidentified blue object as their color ranges were very close. We adapted a fix to this problem by adjusting the blue color ranges through closer HSV and RGB analysis of the ranges and dividing the blue color of the pool and that of the mission props into two different ranges. Another problem that faced us was our software detecting only one object a time, which resulted in its scope usually being focused on the wrong objects, and not identifying the required ones. We fixed this by implementing multi-object detecting in real-time rather than taking and analyzing a screenshot of the pool. Finally, making a GUI for our ❝PyANU❞ software was a huge issue as Python is a script-based language that is mainly used to run snippets of code on the console. Rather, we used an external module called ❝PyQT5❞ allowing the usage the GUI-designing language ❝QT❞ in Python, which was no easy task.

Non-Technical Challenges:

A major challenge that faced us was finding space for testing Anubis such as a swimming pool due to the lack of abundance of open water spaces in the city. The *Arab Academy for Science and Technology* (AAST) eventually provided us with a swimming pool where we could dive once a month to test Anubis, and train on the piloting process. Another challenge was finding a workplace for designing and building Anubis. Notions Academy provided us with the privilege of having a place with a wide range of services to work on Anubis any time needed.

B. Lessons Learned and Skills Gained

ABYDOS is constantly improving through trial and error. Every day, all team members train and experiment with new mechanics to figure out the best possible way to improve our ROV.

The biggest leap we've made was our upgrade from our original ROV, "Mantaray", which was a huge reinvention of the wheel as we started designing and building Anubis from scratch using our newly gained knowledge and experience to make every aspect better. All of the company members has improved tremendously through the last two years where Mechanical team became more unique and fast with their design ideas, Electrical team became more and more comfortable with designing PCBs and implementing them in a short time while keeping the quality of work off the charts and finally the software team has become much in better in thinking outside the box and solving problems easier and faster and most importantly team work has increased thoroughly in the Company and it has become one of our exceptional features

C. Future Improvements

For our future improvements, we're aiming to implement a visual-reality (VR) system to pilot the ROV once the budget allows for affording one. The VR system would help the pilot be more accurate and precise during the piloting phase by separating them from any disturbances in the surrounding environment.

We're also planning to implement an embedded-system into our ROV instead of the Arduino as a micro-controller, which will allow for faster processing, better multi-tasking and a more lightweight hardware experience overall.

Upgrading our CCTV cameras to 4K HD cameras is also a very important goal we're aiming towards, which will give us a better vision of the ROV's situation under water, allowing for much more smoother piloting

D. Team Reflections

During this year and prior to the competition, the team has made a huge improvement. This improvement can be especially observed in the older members of the team who used to be contestants for last year's Explorer competition. The lessons learned were very efficiently applied this year and can be seen in the vast improvement from last year's vehicle "Mantaray" to this year's one "Anubis". Mistakes made last year were avoided, and overall team work has significantly improved and enhanced.

One of the old team members says: "This year, I feel like the team is more capable of going through the competition because of the improved techniques used." another one of the new team members said: "I am really glad that I finally got to put the subjects I learnt from my college courses into use and managed to implement theoretical science into the real working field."

The team believes that after all the hard work done this year, we will manage to achieve a higher ranking and top our previous record by levels.

E. Acknowledgments

ABYDOS would like to thank the following benefactors:

• ***Marine Advanced Technology Education*** **(MATE) Center and Marine Technology Society** – for sponsoring this year's competition.

• ***Arab Academy for Science & Technology & Maritime*** **Transport (AAST)** – for their generous funding of our ROV, providing the pool used for testing and training, and hosting this year's competition.

Telecom Egypt (WE) – for their generous funding to the team and providing the team with Airplane tickets and Accommodation in Seattle.

• **Notions Academy** – for providing us with the laboratories and all the required tools to operate the ROV.

• **VideoRay™** – for providing us with the tether at a reduced cost.

• **Mamdouh Azmy**, **Head Coach** – for his time, creativity, knowledge, and guidance for the last eleven years.

• ***Regional Informatics Centre*** **(RIC)** – Dr. Osama Ismail, Dr. Ahmed El-Shenawy, and all the volunteers for organizing the competition, constructing the playground, providing the mission props, and granting our team access to the AAST pool.

• **Our families and parents** for their consistent love and support.

VI. Appendix

A. Operational Flowcharts

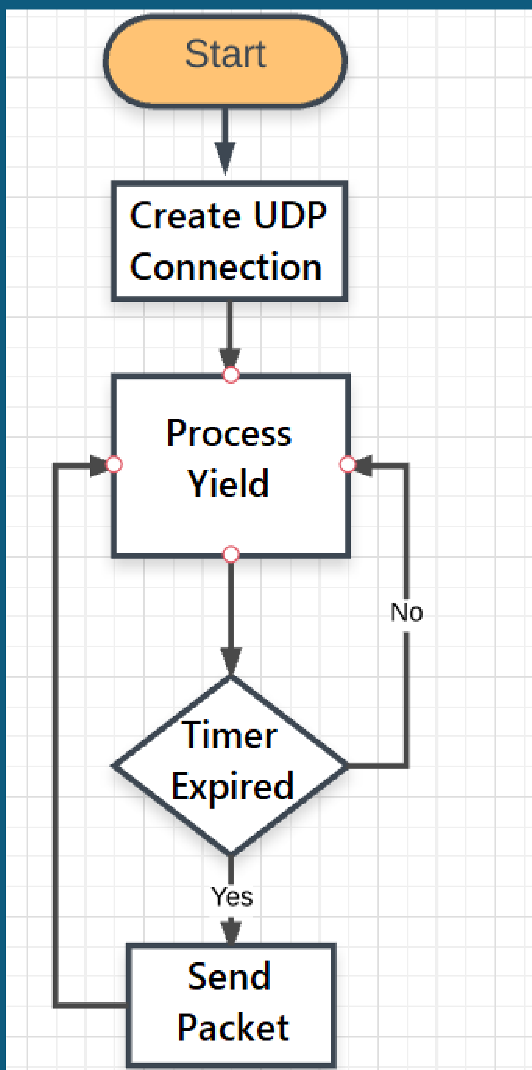

Figure-22: UDP Flowchart

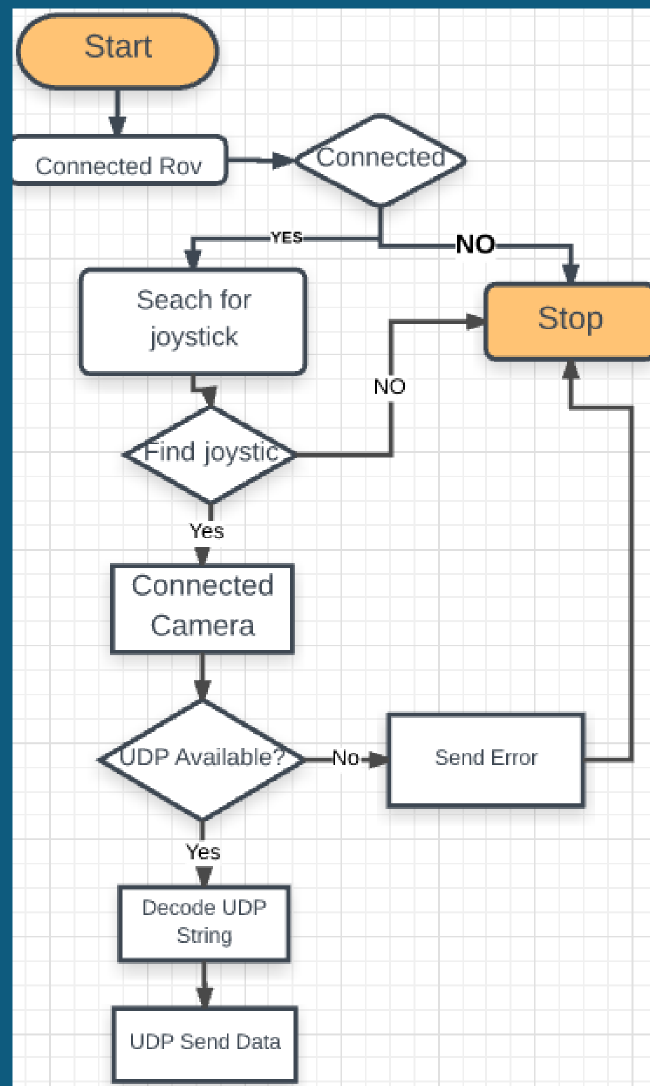

Figure-23: "ANUI" Software

B. *System Integration Diagram* (SID)

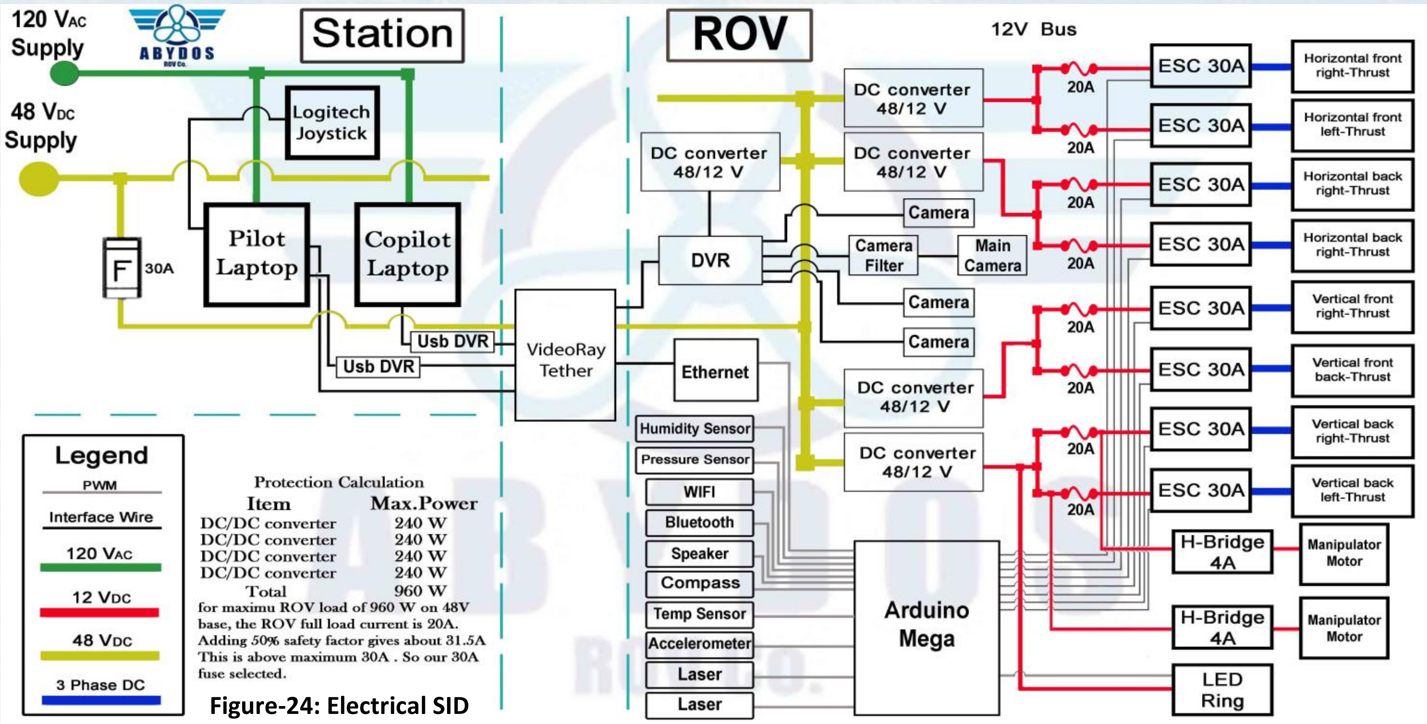

Figure-24: Electrical SID

C. *Computational Fluid Dynamic* (CFD) Diagram

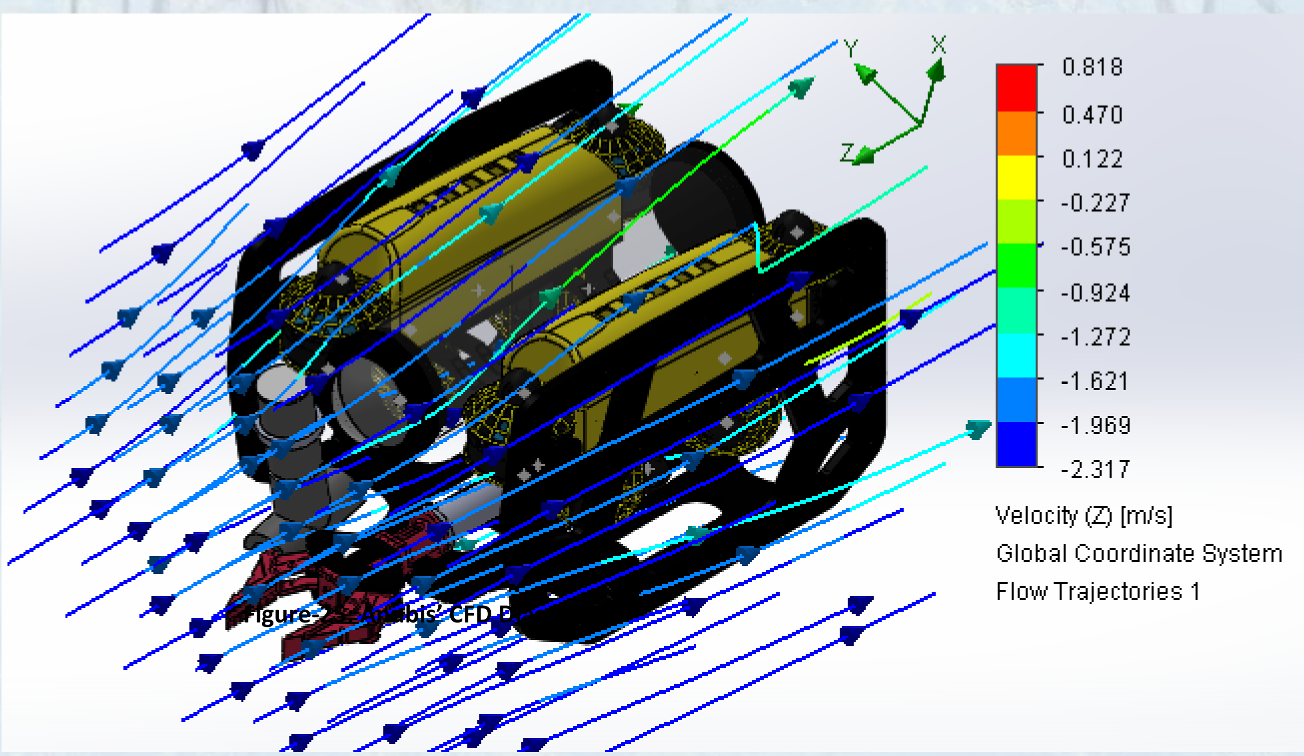

Figure-25: Anubis' CFD D