ISTANBUL TECHNICAL UNIVERSITY

Istanbul, Turkey

2018 Technical Documentation

Jet City: Aircraft Earthquakes and Energy

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ITU ROV TEAM

Supervisor: Bilge TUTAK & Mehmet Ozan ŞERİFOĞLU

TABLE OF CONTENTS

I. Introduction

1. Abstract

ITU ROV Team has developed its own remotely operated vehicle (ROV) in order to carry out the ROV project given by University of Washington's (UW) Applied Physics Laboratory (APL). ITU ROV Team, has completed the production of its ROV with enthusiasm. ITU's ROV has been produced for the purpose of; determining a aircraft debris, surfacing the motor, assembling a seismometer and installing various instrumentation. Our ROV has been designed and produced to successfully execute the missions given by APL.
ITU ROV Team, has different subteams (mechanical, electronical, software and organization) to focus on different areas. Subteams with different disciplines are created for manufacturing the most suitable ROV and make our ROV more usable. At the same time, ITU ROV Team has focused well on safety while producing its own ROV.
Our ROV has been produced within the minimum size and weight limits. Our ROV's design has began with idea of making a successful, and superior vehicle. ROV has designed as an aluminum tube for protecting electronical device, two plates for adding speacialized equipments for tasks and aluminum connections between plates. For reducing the cost of our ROV, we have decided to use third party thrusters and most other elements of the ROV has been designed by us as much as possible to be produced in our workshop.
Another point that we want to mention about is ITU ROV Team is a completely open source team. As we keep learning from the big open source community, we have decided that it is now our turn to contribute and give back to this community. Our full software and hardware designs can be found at our project's GitHub page, https://github.com/iturov

2. Team Structure

ITU ROV Team is formed by students from Electrical Engineering, Control and Automation Engineering, Mechanical Engineering, Naval Architecture and Ocean Engineering, Management Engineering and Mining Engineering departments of Istanbul Technical University. As a team consisting of different departments, we tried to keep in-team communication high so that we could take advantage of the unity of different disciplines. While performing weekly team meetings and sub-team meetings to ensure team and project management, we did our planning with trello to help project management.

Figure-1 : Safety Cautions

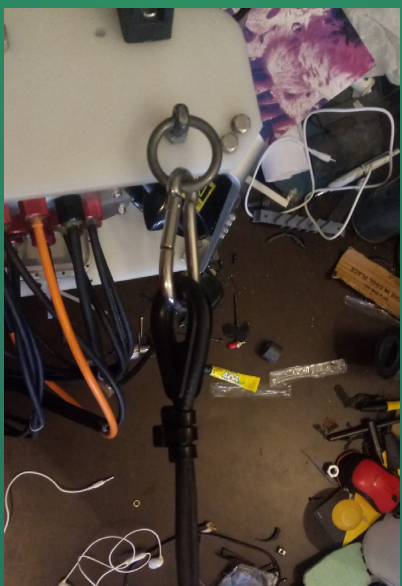


Figure-2 : Thimble and eye-bolt

II. Safety

1. Work Safety Philosophy

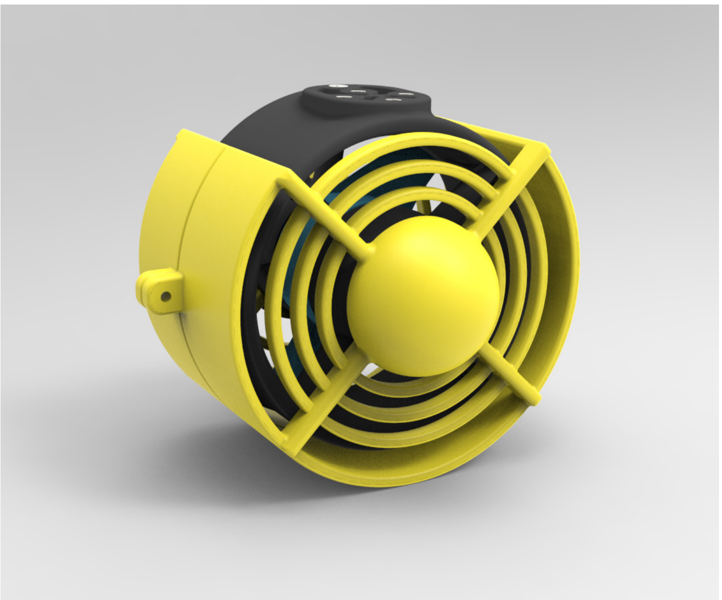
This year, as ITU ROV Team, we gave our priority to job security before designing and manufacturing the vehicle. During the tests, working on the vehicle and out of the workplace, we always attached importance to job security and worker's safety in all conditions. As a team, we did not avoid taking security precautions which protect the team members' health and increase comfort of team members. Therefore, we applied all job security protocols and needs in the right place, at the right time. Besides we assigmed one of our team members to study for work safety.

2. Safety Level

As team members, we have not missed any security practice during ROV's production. In our workshops, besides using personal protective equipments such as glasses, gloves, masks, ear plugs, we also have an emergency eye wash and first aid kit in our workshop. We used warning labels and stickers in all our work areas. In addition to these, experienced team members applied the rules that should be followed in the workshop without skipping them.
A brief training was given to our team before the start of the workshop, with the support of the Society of Occupational Health and Safety at our school about the rules required for occupational safety and workshop compliance. Team members are also required to have a toolkit for both testing and other workspaces; vertical drilling machine, milling machine, sanding machine they have tried to create suitable and comfortable work environment for themselves and others by following these rules. Personal protective equipment (PPE) such as goggles and gloves have been used for eye protection when using equipment that can cause accidents. Electrical technicians have also tried to prevent risks by determining necessary controls.

3. Safety Precautions in Vehicle

While paying attention to the technical properties of our vehicle, we did not ignore the security precautions. The position of the six motors on the vehicle is determined so that it will not be damaged from the outside. In short, it has been installed so as not to interfere with the use of the operators.
While paying attention to the technical properties of our vehicle, we did not ignore the security precautions. During tests and in and out of water we worked properly according to safety checklist. For example the positioning of six thrusters were made according to that.
Horizontal thrusters being positioned inside of legs and vertical thrusters not sticking out from the bottom plate. With this thruster placement, we planned to avoid the risk of contact from outside. All thrusters on the vehicle are equipped with meshes for covering front and back sides of the thrusters. Also, there are warning stickers on every thruster. In addition, all the plastic clamps on the vehicle are shaved so as not to damage the user. No sharp surfaces were left on the vehicle that could damage the user. If there is any problem during operation of the vehicle in underwater, there is a possibility to stop the vehicle quickly thanks to the emergency stop button located in the control center that hosts on the land. Furthermore, during the operation of the manipulators on the vehicle, it is possible to cut off the power of the manipulators on the vehicle by the pilot control center. Our vehicle's tether's thimble is connected to an eye bolt which mounted on the upper plate of ROV. In this way we are able to pull the ROV without harming tether.
Also there are electronical and software safety measures on the ROV. There is a 25 amp fuse on the exit of the 48 volt DC power supply. The power from the 48 volt DC main power supply is also switched from the groundstation for added security and for the capability of turning on and off the ROV. The current and voltage that goes through ground station is checked by a current and voltage meter with display and gives instant information.
All of the electronic cabling both inside and on the ground station are covered with heat shrink tubing to avoid any short circuits, cables are also secured tightly. Also non-ROV devices' power supply was placed in to its own cases and conserved same way. In this way we have avoided any contact from outside. Any communication breakdown can be identified on ground station thanks to software measurements. This allows our pilot and co-pilot to warn other team members and let us intervene the problem as soon as possible.



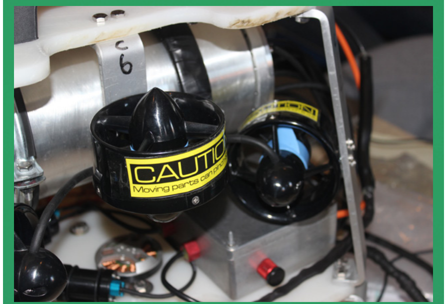


Figure-3 :Thruster Safety Cautions

Figure-4: Emergency Stop Button

III. Mechanical Design Rationale

1. Mechanical Overview

As the mechanical team, our first duty was to gather together and decide on the best possible design of our ROV. While designing the ROV, we made sure that the design was: mission oriented, cost effective and efficient. After several ideas and sketches our current design was selected for its cost effectiveness, its ability of modularity and expandability which made it extremely easy for the team to further develop the ROV down the road. After the final selected design's sketches our ideas was carried on to the SolidWorks CAD software to be improved on. All of the manufacturing work done on the ROV are done by our team members apart from complex manufacturing techniques that require special mastership such as CNC mill work and CNC router laser cutting.

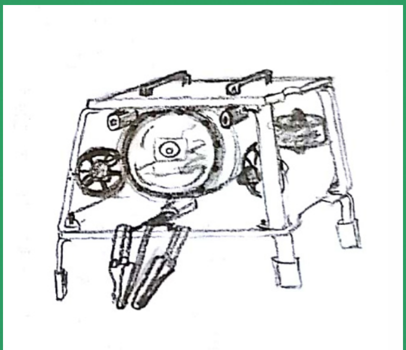


Figure-5 : First Draft of Our ROV

2. Frame

ROV's final design incorporate four main vertical legs that support two horizontal plates one on the upper and one on the lower portion of the ROV. This design made it extremely easy for us to fasten all kinds of components ranging from thrusters to handles, from DC-DC converters to grippers without the need of adapter plates. The fastening between the legs and the plates are done by hexagonal head screws, washers and fibered nuts, that are all stainless steel. Initial shapes and the holes on horizontal plates were laser cut first, from 10mm foggy white acrylic glass plates, acrylic was chosen for its adequate strength [mek1] and ease of production, however as more and more components were added to the ROV, eating away from our buoyancy budget, acrylic glass was proven to be too heavy. Instead of the acrylic glass, HDPE which is durable enough for our application and more lighter than acrylic glass because of its lower density (1.18 g/cm^3 vs 0.93 to 0.97 g/cm^3) [mek2] was chosen instead. The lower and the upper legs as well as the brackets which are holding vertical thrusters were manufactured from 6mm plate 6061 aluminium alloy. Firstly, the plate was cut on a bandsaw according to parts dimensions, parts were later deburred manually with a flap disc on an angle grinder, holes were drilled, bends on required locations was made and then finally anodic oxidation was applied on the parts in order to prevent corrosion.

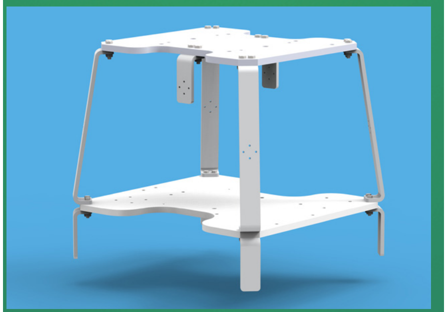
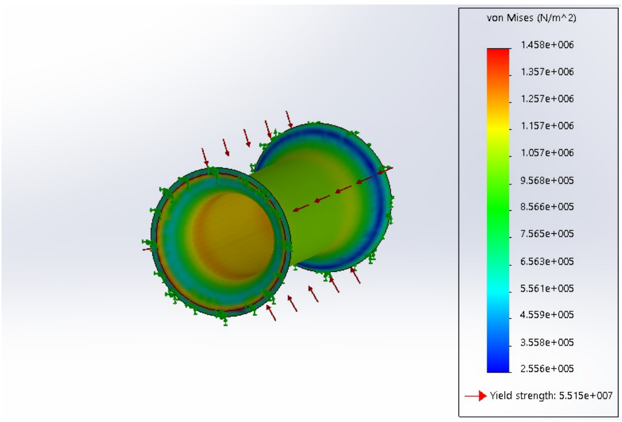


Figure-6 : Chasis of Vehicle



3. Buoyancy and Ballast

For the buoyancy of our rov we calculated the total mass and the total buoyancy that is already present from the tubes and the box. We used our calculations to determine the needed BlueRobotics Subsea buoyancy foam. The foam pieces are secured with zip-ties to the legs and the upper main plate.

Figure-7 : Floating Foam

4. Network Box

A network box was decided to be made apart from the main electronics tube because of our ROV incorporating two IP cameras which makes use a network switch, us using the Blue Robotics Fathom X ethernet over powerlines adapter and us using a submersible potted DC-DC converter which is mounted on the outside of the electronic tube. All of these reasons made it sensible for us to design a seperate network box. The box is designed to incorporate six cable penetrators with o-ring seals and a rectangular "racetrack" style o-ring sealing the acrylic glass lid of the box, the lid is secured to the box with 22 evenly spaced stainless steel allen screws and washers. The box was manufactured from 6061 aluminium on a 3-axis CNC milling machine and the lid was laser cut from 10mm clear acrylic glass.

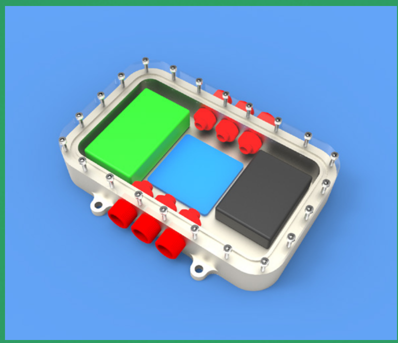


Figure-8 : Network Box

5. Main Electronics Tube

All of the main electronics such as the ESCs, computer boards, sensors and the main USB camera are housed in this tube. The tube has flanges that have two radial o-ring seals and one radial face o-ring seal, located on the front and the rear openings, on the front flange there is custom made acrylic glass dome, and on the back flange there is plate with penetrator holes. In addition to the tube, rear flange also holds the tray that is used to mount all of the electronics. The tray is designed for the ROV's electronics to be easily inserted and taken out of the tube and for easy development and troubleshooting. The tube itself, flanges and the rear plate are all manufactured from 6061 aluminium on a manual lathe. The tube is 250mm long, inner diameter is 124mm and the wall thickness is 2mm. The tray is laser cut from 5mm clear acrylic glass and joined to the flange by brass spacers.

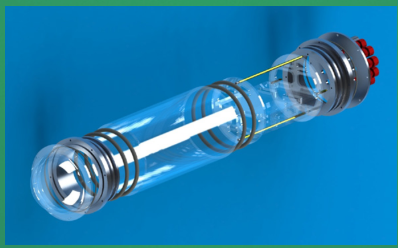


Figure-9 : Electronic's Tray

6. Cable Connections

For the waterproofing of cables. All of the cables entering and exiting the tubes and the box use penetrators with o-ring grooves. Furthermore the team used self-vulcanizing tape and designed and 3D printed our own cable potting mold and used 3M Scotchcast 2131 potting resin to pot the cable joints.

Figure-10 : Mold for Potting

7. Camera Tubes

We designed our camera tubes according to the IP cameras that we used, the tubes and the flanges are one separate part. On the front flange of the tube there is a laser cut 5mm straight acrylic glass for visibility and on the back flange there is a 5mm thick aluminium plate that has the hole for a single cable penetrator. The tube is manufactured from 6061 aluminium on a manual lathe.

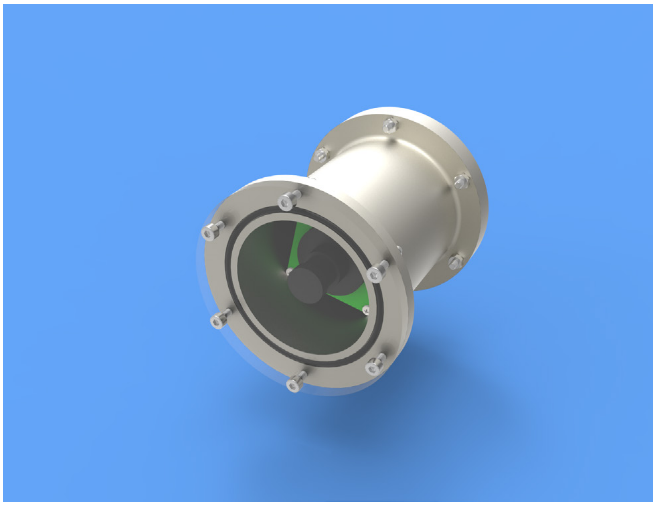


Figure-11 : Ground Station

8. Ground Station

For the vehicle to be commanded on the ground there was a need to develop a groundstation. We first started with selecting a tough carrying case as housing and after that we selected the components that we would place inside of the case, which include: monitor, mini computer, wireless keyboard and mouse combo, voltage and amperage meter, fan for cooling, safety switch, 12VDC power supply for the fan and the meter and finally a power strip for powering various components. To avoid drilling holes in the case most of components are secured in place by various types of glue and tapes that include, montage glue, hot melt glue and double sided montage tape. The groundstation's main frame is a custom made black acrylic plate that sits on the bumps of the carrying case, the plate holds the keyboard and mouse combo, cooling fan, voltage and amperage meter, safety switch and the Anderson connectors. All of the components and the wiring under the plate is neatly routed and safely secured.

IV. Manipulator Design Rationale

1. Gripper Manipulator

After looking at this year's aircraft, earthquakes, and energy missions that have various cylindrical shapes to grip we decided to design a two finger parallel gripper that has arc shaped fingers for secure gripping. The gripper is actuated by a T-motor U5 KV400 waterproofed brushless DC motor. We chose a 400KV brushless motor for its water-resistancy and high torque output. The actuation is further provided by an 8mm lead screw. The fingers are joined to the main plate via two parallel linkages and are secured by pins with snap rings. The grippers linkages and main plate are laser cut from 6061 aluminium and bent where necessary. The pins with snap ring grooves are turned from a 6mm stainless steel rod on a turret lathe. The finger parts and main actuator part that has the lead screw's nut are manufactured from 6061 aluminium on a CNC mill.

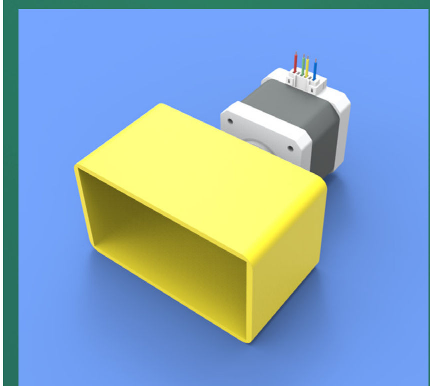


Figure-12 : OBS Leg Turner

2. OBS Leg Turner

For the OBS mission the ROV needed a specific turner manipulator that points downwards to effectively turn the OBS's leveling legs. We designed the turner with a NEMA 17 stepper motor and attached a 3D printed manipulator end that holds the OBS leg easily and snugly. The reason why we applied NEMA 17 stepper motor is easiness and of stepper motor. It gives us a chance to set speed of stepper motor. We used a plexiglass for mounting the stepper motor to lower plate. Also, we used two couplings to assembly 3D print part and stepper motor each other.

V. Electrical Design Rationale

1. Enclosures

Our vehicle consists of two main electronic enclosures which consist of an aluminum cylinder and a rectangular custom aluminum case that we called the Network Case. Main electronic system is placed inside main electronics tube. Similar to a shelf system, two different sized trays are used to optimize electronic components. A PCB that is mounted on the lower part of the tray was designed by our team to distribute power properly inside the vehicle, to decrease voltage from 12V to 5V where needed and to increase optimization inside the cylinder. Except our network based modules which are placed properly in network case. The network box houses the ethernet switch that connects two IP cameras and the Raspberry Pi to the Fathom X ethernet over powerline module. There is also a power distribution board inside the network box to distribute power to the switch, Fathom X and to the IP cameras.

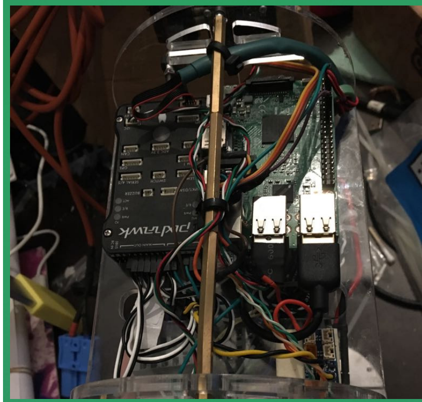
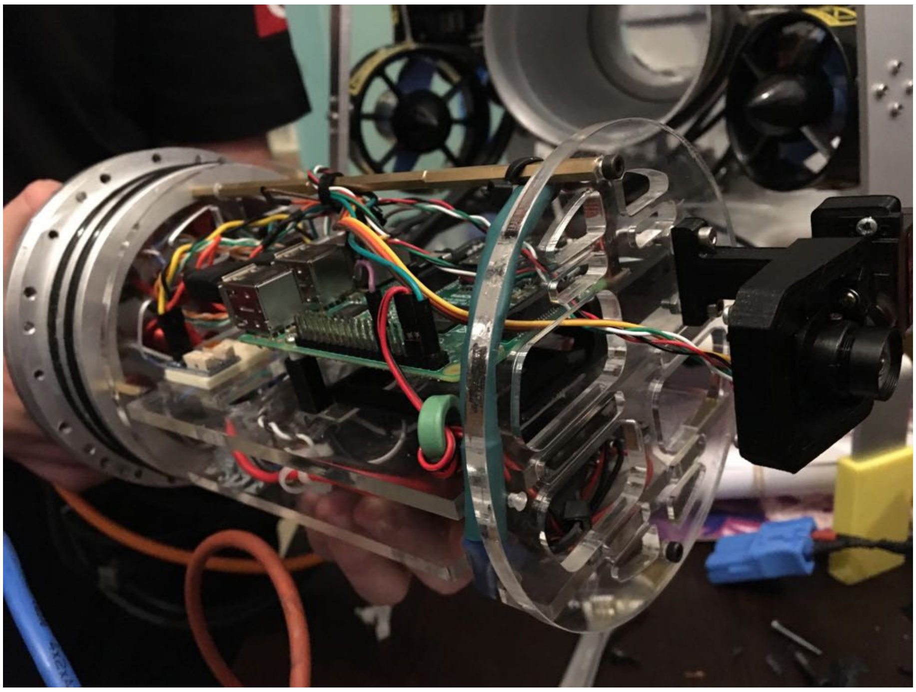


Figure-13 : Electronics in Tray

2. Main Electronics

As the main computer a Raspberry Pi 3 is used in the vehicle. The Raspberry Pi communicates with our main controller board which is Pixhawk via serial communication. With use of these two boards vehicle can navigate by Pixhawk and it can communicate with surface ground control via Raspberry Pi. Pixhawk generates great stability in ROV by incorporating it's own PID control. A Pressure sensor is used in order to obtain depth feedback to be used in the depth hold mode in our cotroller which allows our vehicle to stabilize it's vertical position. To be able to know if there is leakage inside the vehicle, a leak sensor is used inside the cylinder to establish maximum security. Leak sensor probes are located in different places inside the tube to increase the probability of detecting a leak. A micro servo motor is used to increase view of the camera which helps pilot to navigate better during the tasks. 30mm mini fans inside the tube are used to reduce risk of overheat inside the vehicle. As the main power supply being 48VDC, our team used a 48v to 12v waterproof converter that is mounted on the lower plate of the ROV to lower the given voltage, that lower voltage is used by, six ESC's used to run six main thrusters, other two ESC's used to run turner and the gripper manipulators and two LED lights.

Figure-14 : PIXHAWK



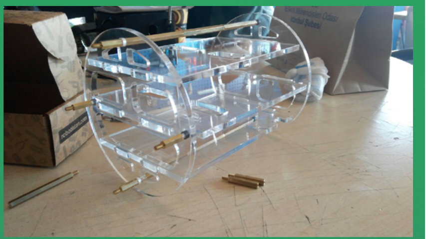
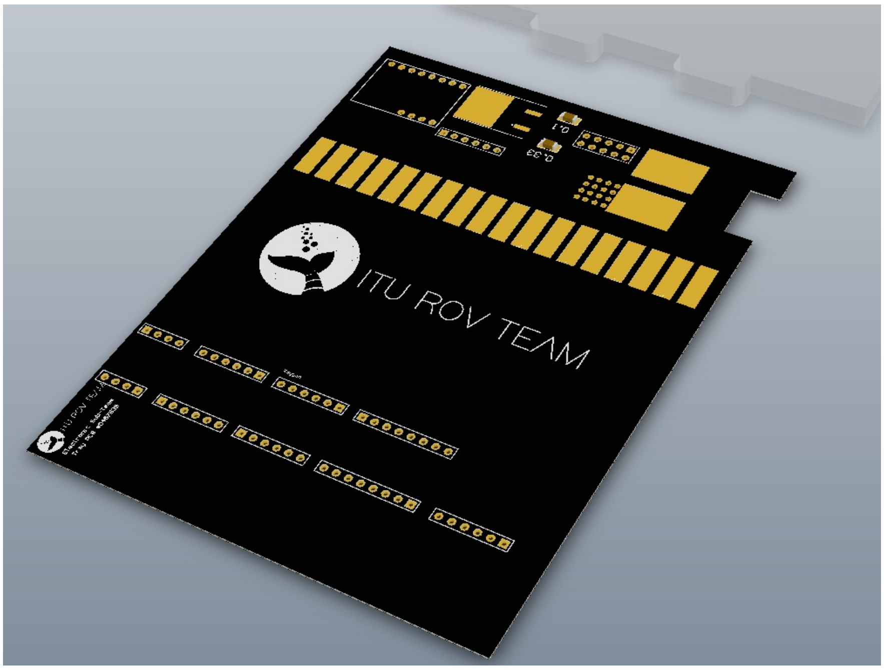


Figure-15 : Tray Chasis

2.1. Power Distribution Board

The Power Distribution Board(PDB) is designed to position electronic components properly into the system. 12V to 5V regulator inside the PDB allows to supply 5V using components including RaspberryPi, PixHawk and Servo Motor. PDB also decreases number of cables that is used inside the cylinder.



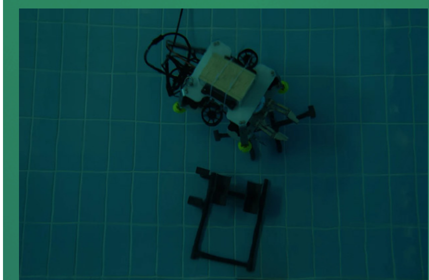
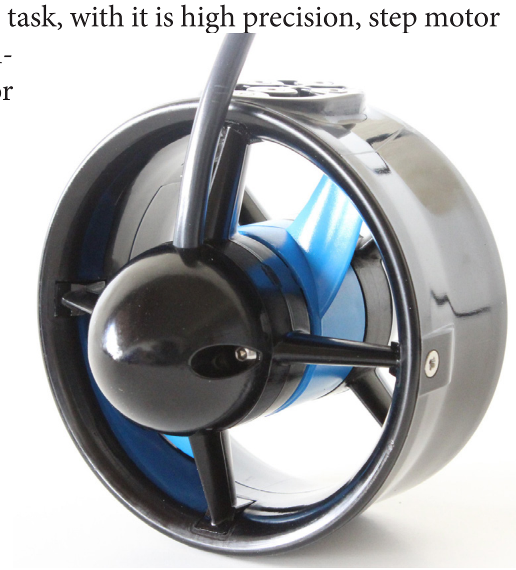


Figure-16 : Our ROV in testing with T100 Blue Robotics Thrusters

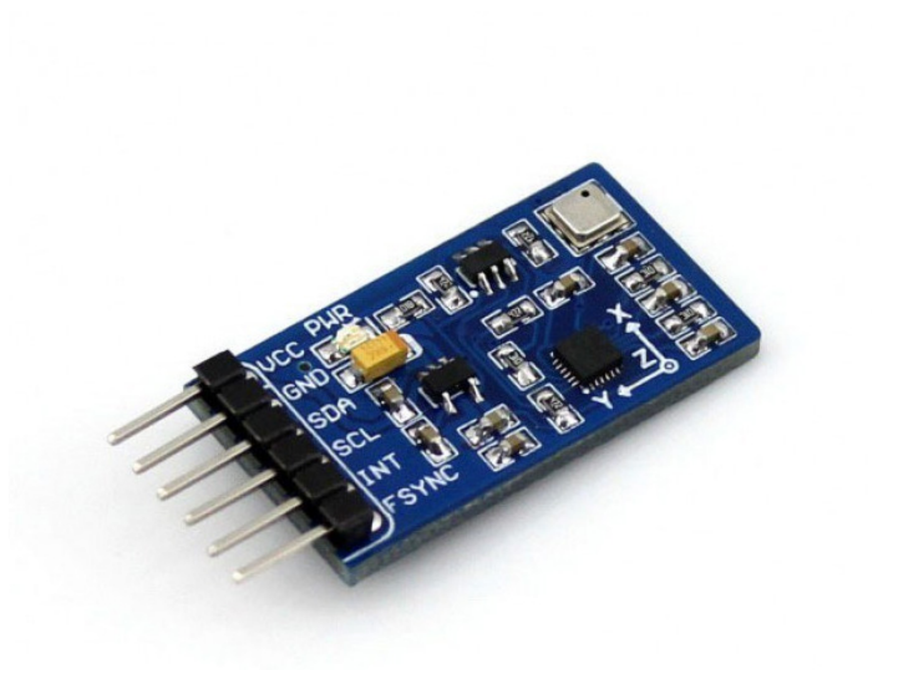
2.2. Motors

To establish maximum movement capacity inside the water two vertical and four horizontal motors are located in the vehicle. Four horizontal motors are mounted with 45 degrees. We chose that thruster positioning because of the motility. So, we can do lateral movement(crab movement) without turning any direction. All six motors are T100 from Bluerobotics. The reason why we used T100 is qualification and cost. The thrusters on the vehicle are from last year. All six motors are controlled by six 30A electronic speed controllers which are directly controlled by pixhawk. We chose that thruster positioning because of the motility. For the OBS task, with it is high precision, step motor is used to turn the valves easily by calculating number of turns needed for the each valve to stabilize OBS.



2.3. Sensors and Other Devices

To get better control several sensors are used inside the vehicle. Pressure sensor is used to get pressure feedback for the depth hold and IMU sensor is used for the horizontal stabilization. Wi-Fi dongle with the antenna is used to get data via Wi-Fi. In a leaking case to protect components leak sensor is used. Additionally four fans which are supplied with 5V are used to cool the vehicle and to establish air circulation inside the cylinder. Components which has risk of heating are protected with heat sinks.



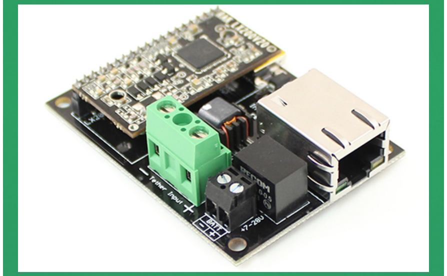


Figure-17 : Blue Robotics Fathom-X module

3. Tether

Fathom-X microcontroller is used to enable power line communication. Power line communication helps us to communicate over power lines. Vehicle is powered by tether which consists of only two cables ground and 48V. Using only power cable rises mobility of the vehicle. For the vehicle safety, tether is mounted to vehicle with eye-bolt and thimble. So, if we encounter a emergency situation; we can pull the vehicle to ground by hanging the tether.

Figure-18 : Our ROV with tether connection

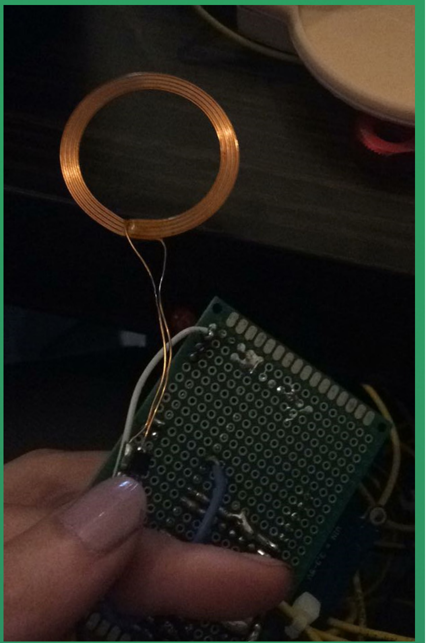
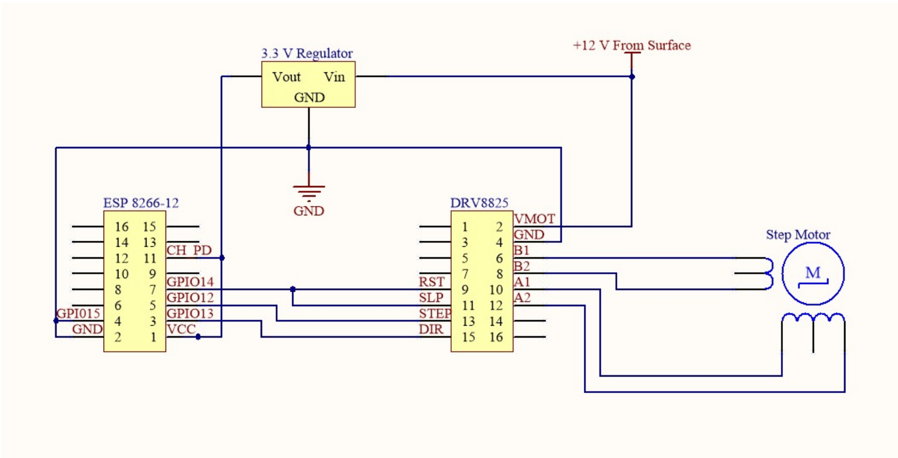
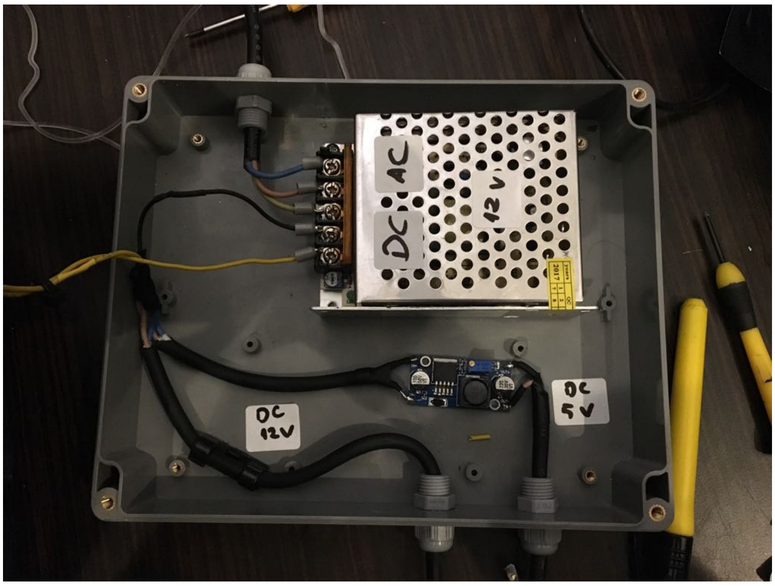


Figure-19 : OBS Circuit

4. Non-ROV Devices

Lift bag and wireless charger are two main devices which are completely excluded from the vehicle. 3A fuse is used to work safer which is connected directly to the power supply by Anderson Plug. Non-ROV powerbox is used to secure electronics that are used to power Non-ROV devices. Fuse, regulator and Anderson connectors are placed inside the box. Linear selenoid is used in Lift bag for the relaease mechanism which is triggered via ESP module. ESP module allows to communicate via Wi-Fi signal. Wi-Fi signal range decrease dramatically inside the water. Our sub-team planned to design extension mechanism to decrease distance between two Wi-Fi sensors by using additional 8dBi Wi-Fi antenna. To achieve second non-ROV task we designed a device which has a coil, regulator and weight creating mass. This device allow us to charge another non-ROV device completely wirelessly. This wireless charging device is designed to fit perfectly into OBS prop.

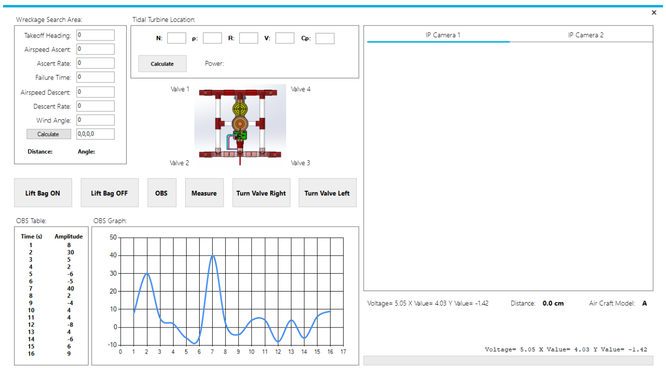




VI. Software Design Rationale

1. Ground Station

Our ground station consists of a PC with Windows 10 OS installed, two monitors, and a keyboard and mouse set. One of the monitors is for the pilot and the other is for the co-pilot. Our software runs on the Windows platform. Firstly, for the navigation of the ROV QGroundControl base station software's BlueRobotics edition is used. The thrusters, gripper, lights, and camera servo can be controlled by this interface via the joystick. Additionally, we can receive real-time video from two IP cameras on the ROV using our Graphical User Interface (GUI) which we developed using C# programming language. We can do operations such as drawing a graph of the OBS data, recognizing the plane model using image processing methods, and communicating with the Raspberry Pi on ROV to send commands like releasing the Lift Bag. To achieve these goals there are several services working on the background which we developed using Python programming language. Also we are logging all processes with time and date. Measuring the distance to an object is calculated with a number of vector calculations using distance between selected pixels from video image and known length of the object. OCR (Optical Character Recognition) has been used in our system in order to complete image processing missions. We have modified an open source licence plate recognition code into a plane identifier. Firstly text on the plane tail is recognized and turned into the strings afterwards, according to the recognized text the model of the plane will be determined. In addition to all of these, it is possible to do mathematical calculations needed for task 1 and 3 from GUI by just entering the given values.



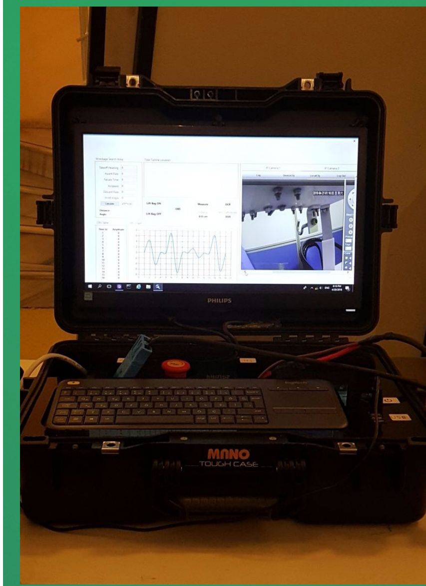


Figure-20 : Graphical User Interface (GUI)

2. Vehicle

On ROV, Raspberry Pi 3 used as the main processor. It broadcasts real-time video from USB camera to ground station. The navigation of ROV is controlled from Pixhawk. It is a popular autopilot development card originally for aircrafts. We have used a firmware on the Pixhawk which is specially developed for ROVs that is called "Ardusub" that makes the necessary configurations. There are two IP cameras on the ROV. The main program is running on Raspberry Pi and developed with Python programming language. This program communicates with the surface using Transmission Control Protocol (TCP). The main loop firstly receives commands from ground station, after that it executes various processes. Finally it sends data back to the surface. Raspberry Pi can connect to Wi-Fi networks for releasing Lift Bag wirelessly and connecting the OBS platform using the Wi-Fi dongle on it. Additionally the stepper motor which we use as a valve turner is controlled from GPIO pins on Raspberry Pi. Using the data received from gyroscope data from OBS, the number of turns needed for all of the valves can be calculated and the stepper motor can be used for levelling OBS exactly, quickly and easily.

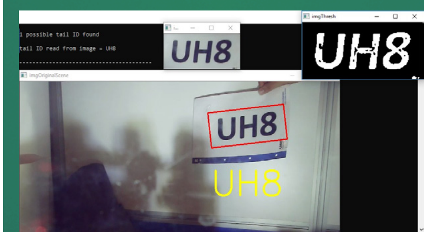


Figure-21 : Image Processing

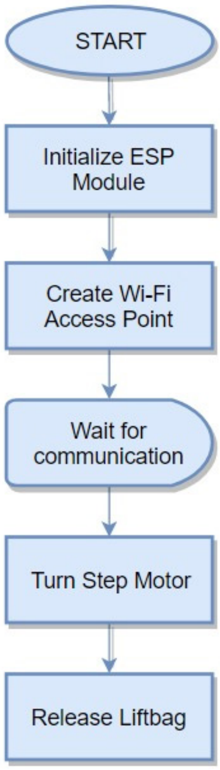
Figure-22 : Wireless Communication Testing

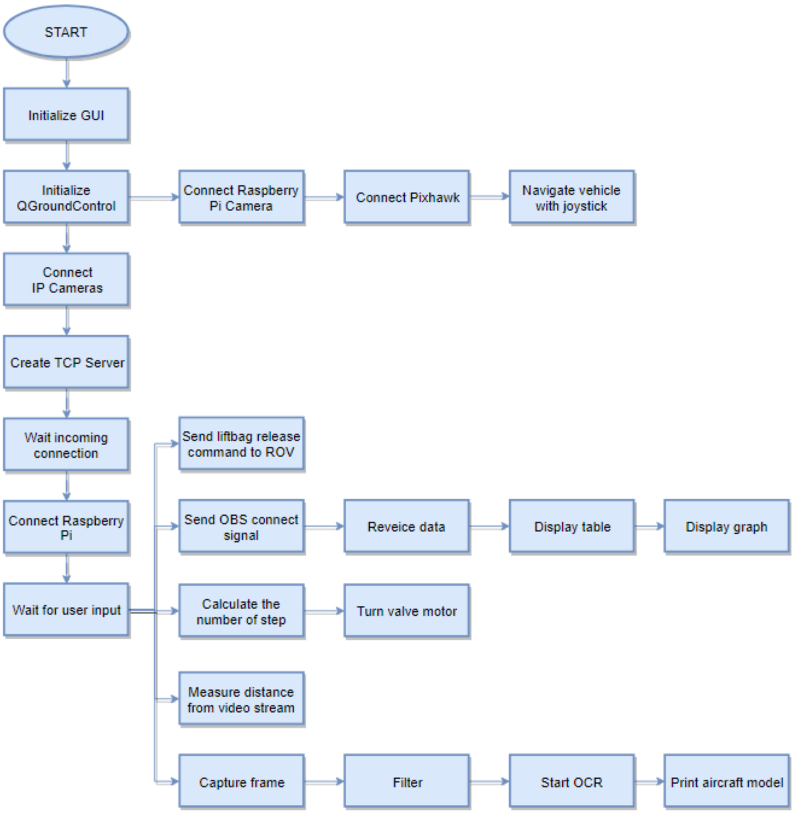
3. Communication

To achieve communication between ROV and ground station via single cable, BlueRobotics Fathom-X board which houses the Rak Wireless LX200V20 module is used to enable power line communication. Power line communication helps us to communicate over existing 48VDC power line that powers the ROV. Ethernet cables from Raspberry Pi and two IP cameras are merged to one Ethernet output using a network switch. Ethernet cable coming out from switch connects to Fathom-X module. Fathom-X encodes communication signals to be transferred with the power cable. Another Fathom-X on surface decodes the signals from power cable to Ethernet and finally Ethernet cable goes into PC's Ethernet port. To establish two-way TCP communication one of the sides has to be server and the other, client. On our system the PC in our ground station acts like a server, the Raspberry Pi and two IP cameras act like clients. The reason for this is that PC's can perform router behaviour much easily and can assign IP addresses for others like DHCP server faster. IP cameras broadcast real-time video from 192.168.2.120 and 192.168.2.30 static IP addresses and they stream from port 8080. Ground station's IP address is 192.168.2.1 and Raspberry Pi's IP address is 192.168.2.2 and they communicate each other on port 1864. Also Raspberry Pi streams USB camera video on port 5600 using User Datagram Protocol (UDP).

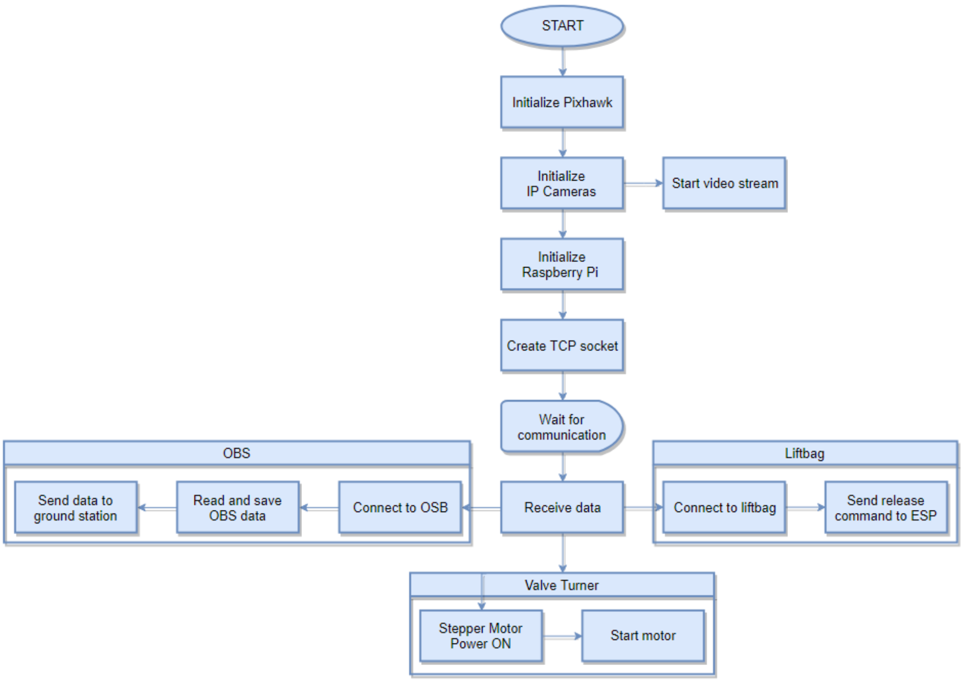
4. Non-ROV Devices

On lift bags ESP 8266-12 Wi-Fi modules are used for releasing wirelessly. These modules create wireless networks with SSIDs "Liftbag1Net" and "LiftBag2Net" and passwords "password". ESP module has two main function. After creating the Wi-Fi network, it publishes a web server. If the ROV connects that network, it automatically sends request to the ESP module on the Lift Bag using Python code. In this way releasing Lift Bags wirelessly is being done. Raspberry Pi connects to lift bags using its Wi-Fi dongle's antenna and sends the release command. Similarly if ROV is close enough to the OBS platform Raspberry Pi will try to connect and obtain the gyroscope data.





Ground station flow diagram



Vehicle flow diagram

Figure-23 : Our Weekly Meeting

Figure-24 : During Pressure Test

VII. Organization Management

1. Company Organization

ITU ROV Team is formed under ITU Robotics Club which consists students from different departments. Team is composed of three technical departments – mechanical, electrical and software, each department has a department lead who works on communication between each department member and between departments, and present their reports directly to the CEO. Mechanical and electrical departments are also divided into groups in order to focus on a specific aspect of the Sliperry ROV. These groups are Ground station, Props, and Mission Tools. Each subdivision works with other groups and informs the departmental leader about their work.

2. Project Management

In order to facilitate project management in our team, we arranged the processes according to the deadlines that are determined before by using Gantt charts. We divided our preparation process into three phases such as design phase, production phase and test phase. We benefited by the ANSYS WORKBENCH program to analyze the strength of the vehicle. By using the Failure Mode Effects Analysis (FMEA) method during the design and manufacture of the vehicle, we have been constantly improving the tool and trying to eliminate the possible problems as far as possible.

We made our drawings for the manufacture of mechanical parts during the production and design phase by the SOLIDWORKS program. First of all, the main parts of Slippery ROV, such as the cameras, the chassis and the power converter were assembled before the tasks were announced.The work has begun towards to the purpose of improving equipment for the tasks when the requirements of the tasks were certain. Before all, brainstorming was done for the task equipment to be designed. Afterwards, we added the task equipments such as holder, hook and valve turner for the tasks on our vehicle whose assembly is completed. The SOLIDWORKS program was used to design and manufacture these equipment. During production, it was preferred to produce parts that would be easy to produce and would not harm human health as much as possible. We aimed to reduce the cost by making the production of the parts in the club room with the help of the selection of production parts that made from the easily producible materials. To make the vehicle easy to carry, two handles were attached to the top plate of the vehicle and the connector was used so that the power cable could be separated from the vehicle.

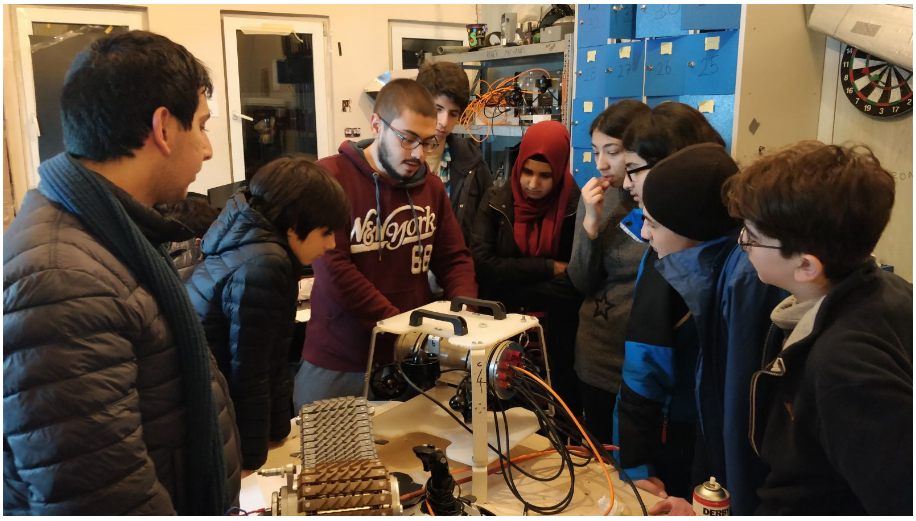
In our testing process, we worked on completing the task as soon as possible. We experimented the vehicle to the 8 bar pressure test for our leak tests. In order to test the tasks, Ata Nutku Ship Model Experimental Laboratory at Faculty of Ship and Marine Sciences and İstanbul Technical University Olympic Swimming Pool were used.

In order to be able to follow the project in a general sense, the Trello application was used to support the Gantt chart. The weekly business plan was made so that the works were carried out according to this plan. We shared our works via GitHub to make our software and designs accessible within the team and to share with the robotics community.

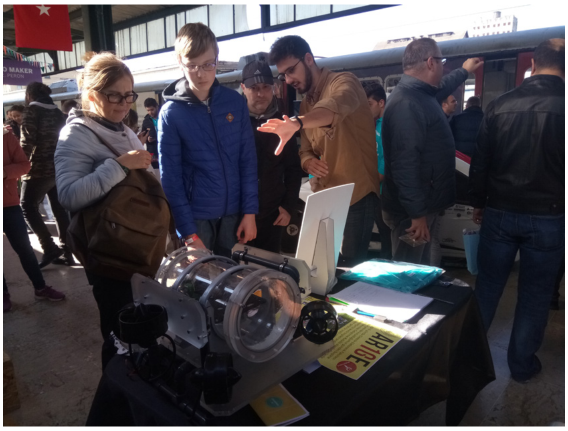
VIII. Corporate Responsibility

As ITU ROV Team, we firstly want to raise awareness of underwater technologies in our country. For this purpose, we have participated in maker events and technology fairs. In addition, we provide mentorship to primary and high schools about building ROVs. We are also in touch with other universities about underwater vehicles.
In addition, our team is invited by Turkish Undersecretary for Defense Industries to make a presentation. Our team also helped to create the competition rule book in Teknofest - Unmanned Underwater Systems Competition.

Our team with Turkish Undersecretary for Defense Industries



While our mechanical team leader introducing our vehicle.



Our Team when introducing our vehicle in the event of Maker Faire

IX. Conclusion

1. Testing and Troubleshooting

As ITU ROV Team, we have tested every single part of the vehicle this year, not only after the vehicle is built, but also before the preparation and during the building phase. In particular, the team has made great efforts in this regard by concentrating tests on waterproofness and resistance to pressure. Tests are achieved successfully. Our team, which is more experienced than the previous year, has determined which subject to focus on and how to work and gives weight to the tests in this regard. Many fields have been used for the test and the most frequently used areas are ITU Olympic Pool and Ata Nutku Ship Model and Test Laboratory. Even before the vehicle was prepared, tests were carried out in order to start to work here and to be able to measure and observe the water reaction in every part produced. When a new addition was made to our ROV, the added part was first passed through tests such as workability and adaptability. Once the vehicle is ready, these two field tests have been carried out weekly on a regular basis. In these tests the pilotage and the vehicle's performance are concentrated. Apart from these, not only mechanically but also in electronic and software fields, everything we planned to use on the vehicle was tested in a suitable environment and then the performance on the vehicle was investigated. Tests have a huge share in our ROV's efficiency and appearance. In the problem solution, if any problem is encountered, the problem is focused on solving the problem as soon as possible. We can examine our troubleshooting approach in three steps: determination of the problem, solution detection and problem resolution. As an ITU ROV Team, when we encountered a problem, we found it convenient to go this way for a solution. If we did not get a solution from these stages, we sought new solutions by expanding our solution pool, taking other alternatives into account.

2. Challenges

We have experienced a number of mishaps in the construction and development of vehicles, due to lack of experience and occasionally our lack of facilities. For example, we could not get the parts as we wanted. As a result of long efforts, we could get the necessary elements for our ROV. Unfortunately, we have not always found the environment for the test, and it has caused some hanging in our schedule. Nevertheless, when we could not find the required environment, we were able to avoid it as quickly as possible by creating the optimal environment for testing. As with all projects, we also faced a number of technical problems. We have done a lot of research in order to live a problem in this issue. First and foremost, impermeability is the most important issue. We have done a lot of research in order to live a problem in this issue. We have found a number of problems in the mechanic team and produced solutions to them. As a result of our tests, we have seen that there is no problem in this area and we think that we will not have problems in the competition.

In addition, the motors we used in our gripper and turner needed to be water-resistant and we made this choice accordingly. At first, we had a robot arm designed according to servo motors. Later we thought that both our experiences in the past and our researches lead us to think that servo motors will cause problems under water. So we had to change our design. There were times when we had financial difficulties as long as we had technical difficulties. Sometimes, we could not get the materials we wanted or we could not produce them in the quality we wanted. But we came from all over the challenges and build the ROV.

3. Lessons Learned

This year, the new members of the team started by getting general information about the vehicles and the competition from the experienced members. In this way, both the adaptation process was accelerated and a general infrastructure was created before the work on the vehicle started. As a team, new members had information on how to design an underwater vehicle, how ROV's general characteristics should be, and how to prepare for a submerged test. We realized that the density of the parts to be used in a robot to move under water should not be higher than the density of the water and that if we use a substance with a high density, we need to use other substances with low density or float to balance it.

Mechanically, we have come to the point where we can draw our own parts in 3D CAD programs like SOLIDWORKS. Apart from meeting the features we want to draw the pieces, we learned that it is also an important factor in being technically and economically producible. We learned how to adjust the torque of the motor and the rotational speed of the motor by using the electric motors in an electric motor circuit, which can be produced and operated in an electric circuit. Apart from that, team had the knowledge to organize the computer program so that members could use all the engine and electronic components of the vehicle, both software and electronically.

4. Future Improvements

We are a club that aims to learn new things from projects we do every year and to improve ourselves. This year we are especially interested in material choices and design phases, adding to ourselves important things. In this area, we aim to produce a ROV with a more specific design and with the ITU Polar Researches Application and Research Center Team (ITU Pol-ReC) for research in poles. On the one hand, we continue to work on autonomous vehicles, which are among our targets last year.

5. Reflections

"This is my first year both in ITU and ITU ROV team. As I was looking for a team my important criterias were the team has to be filled with open minded people, the team has to be a place where I can improve myself and the team has to has an profound sense of perception. Throughout the year I can clearly say that my criterias were comprehensively fulfilled and I am glad to being a part of this team. I have improved myself in image processing such as optical character recognition, color detection and shape detection. While I was improving my skills of image processing also I have improved my skills of python. This event made me understand that if you step in something that you do not know anything about it, rather learning just that thing you improve yourself in many ways which are related about it. I believe that the experience of this team is a great opportunity for all engineer candidates in order to see and understand what is working in a team and what does people do while creating a complicated product."

Atahan ÖZER

"Working at ITU ROV Team was the best experience of my university life. I've participated in various tasks and gained experiences on different branches that I will need on my business life such as CAD drawing, material planning, technical part knowledge and how they works. Besides I gain experience on electronical and software branches that I haven't experienced before. As I participated ITU ROV Team I made my greatest long-term team work on my life and learned how can I take responsibilities and be a part of a team. After all I made good friends that spent really good times together."

İsmetcan SARAÇ

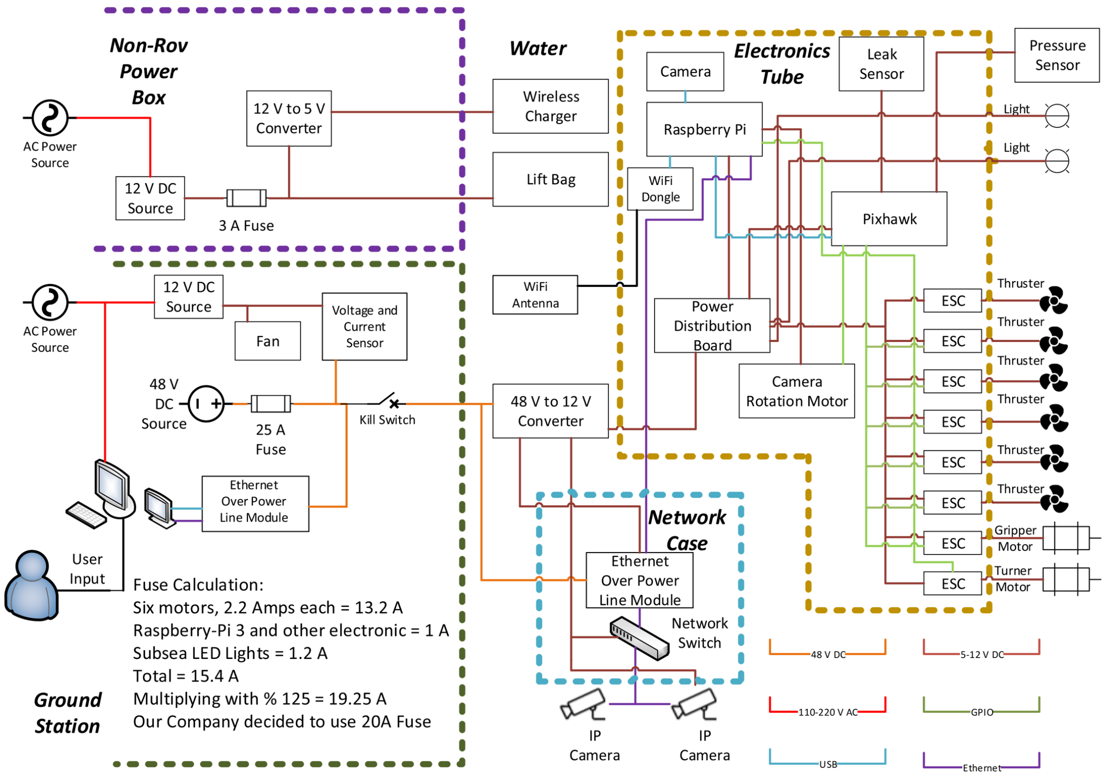
X. Acknowledgements

As ITU ROV Team, we would like to thank our parents & families, friends, our precious sponsors, MATE Center for providing such a competition event, and everyone who supports us!

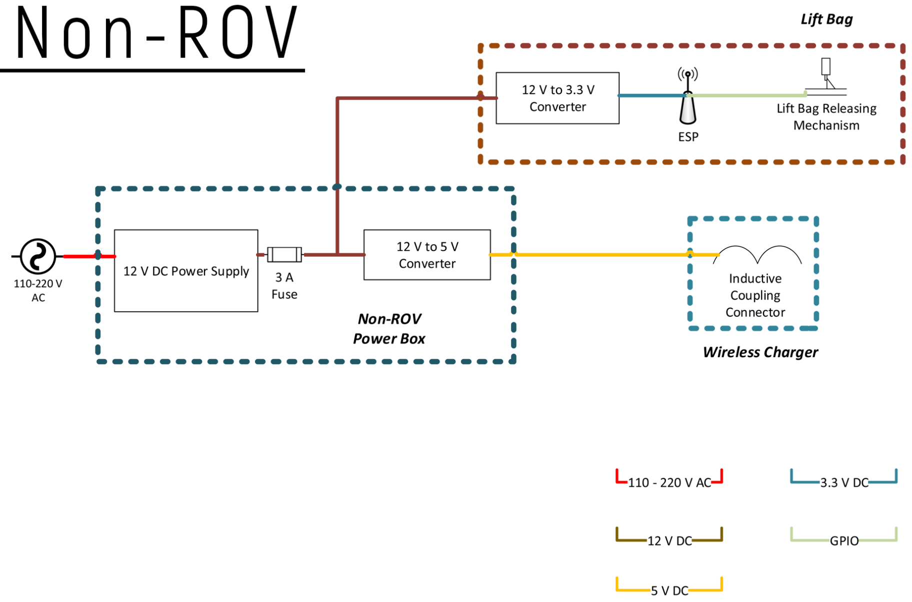
XI. Appendix

Appendix 1. SID

SID Electrical



SID Non-ROV



Appendix 2. Safety Check List

Pre-Launch Checklist

- Check around
- Keep power supply off
- Connect power cable to the ROV
- Connect Anderson connectors to power supply
- Check electronics enclosure

Pre-Dive Checklist

- Launch ground station
- Give power to ROV
- Launch the ROV.
- Check electronic system from ground station
- Put the ROV on the ground and make sure that people are clear of the thrusters.
- Put the ROV in manual mode
- Arm the ROV.
- Press the forward/reverse stick forward to check that the vectored thrusters are spinning freely and in the correct way.
- Press the ascend/descend stick forward to check that the vertical thrusters are spinning freely and in the correct way.
- Disarm the ROV.
- Put ROV into water
- Arm the ROV.
- Check whole vehicle again from ground station (camera, electronic device…)
- Leak check
- ROV's buoyancy and stability check

Dive Checklist

- Start timer
- If mission completed, take ROV to the ground

If Bubble Found (If bubble found while vehicle is running)

- Shut down the power
- Take ROV out of the water
- Check ROV and find problems
- If problem solved, run ROV again

Miscommunication (If lack of communication is encountered)

- Check communication
- Start look for a problem
- Restart the ground station
- If ROV cannot be restarted, cut off power
- Take ROV to ground
- Check ROV and find problems
- If problem solved, run ROV again

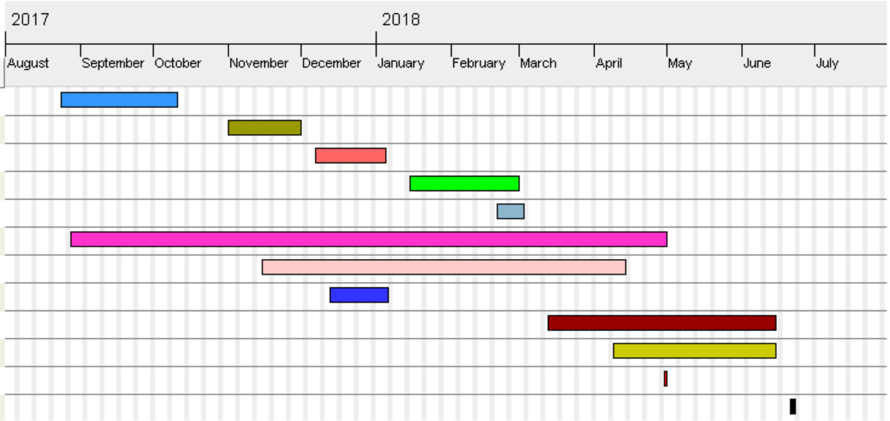
Post-Dive Checklist

- Rinse down with fresh water.
- If you were operating in a sandy environment or seaweed, clean sand and seaweed from the thrusters.

Appendix 3. Gantt Chart

ITU ROV TEAM

Name	Begin date	End date
New Recruit Training	8/24/17	10/10/17
Mechanic Design	11/1/17	11/30/17
Manifacturing & Assembly	12/7/17	1/4/18
Prototype Evolution	1/15/18	2/28/18
Props - Manufacturing	2/20/18	3/2/18
Research	8/28/17	4/30/18
Software Development	11/15/17	4/13/18
Electronics Assembly	12/13/17	1/5/18
Tests & Troubleshooting	3/13/18	6/14/18
Pilot Training	4/9/18	6/14/18
Regional Competition	4/30/18	4/30/18
International Competition	6/21/18	6/22/18



Appendix 4. Budget Planning

Budget Plan			
Vehicle Expenses			
Expenditure	Amount (USD)	Number	Total (USD)
Thrusters	80	8	640
Frame / Chasis	100	1	100
Epoxy	45	1	45
Penetrator	15	10	150
Housing	70	1	70
Electronics	835	1	835
Power Cable / Tether	70	1	70
Ground Station Frame	670	1	670
Computer	390	1	390
Power Supply	110	1	110
Electronics	225	1	225
Monitor	45	1	45
Joystick	45	1	45
Vehicle Expenses Total			3395
Other Expenses			
Transportation	1000	16	16000
Accomodation	600	16	9600
Rent a Car	1000	2	2000
Other Expenses Total			27600
TOTAL BUDGET			30995

Appendix 5. Budget

ITU ROV TEAM 2018						
	State	Expenditure	Source	Amount(USD)	Number	Total
Mechanical Expenditure	Reused	T Motor	Blue Robotics	-	6	-
	Purchased	Coupling		2	1	40
	Purchased	Piston Ring		0,78	10	7,8
	Purchased	Hardware		27,5	1	27,5
	Purchased	Aluminium Eloxal		10	1	10
	Purchased	Lift Bag		44,5	1	44,5
	Donation	Connector	Seacon	-	1	12
	Purchased	Micro Servo Motor		12,99	1	12,99
	Purchased	Gripper Motor		100	1	100
	Purchased	Power Connector	Anderson	17,28	2	34,56
	Mechanical Expenditure Total					289,35
Electronical Expenditure	State	Expenditure	Source	Amount(USD)	Number	Total
	Purchased	ESC	Rovertech	19,89	7	139,28
	Purchased	Stepper Motor		42	1	42
	Reused	Stepper Motor		-	1	-
	Purchased	Power Supply		144,5	1	144,5
	Purchased	Arduino		10	1	10
	Purchased	Ground station		690	1	690
	Purchased	Controller		48,5	1	48,5
	Purchased	Antenna		13,5	1	13,5
	Purchased	VGA Cable		4	1	4
	Purchased	IMU		9,3	1	9,3
	Purchased	ESP Wifi Module		6,5	1	6,5
	Reused	Autopilot Hardware	Pixhawk	-	1	-
	Purchased	Wireless Charge		33,5	1	33,5
	Purchased	Wifi Dongle		14,5	1	14,5
	Purchased	Regulator		1,5	2	3
	Purchased	Antenna Cable		30	1	30
	Electronical Expenditure Total					1188,58
Total Expenditure						1477,93

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