ROV COMPETITION 2021
EXPLORER

ITU ROV TEAM

Technical Documentation

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ABSTRACT

ITU ROV Team is an experienced team that has developed a remotely operated vehicle (ROV) and has been continuing to work since 2017. ROV that's been developed by the team can perform studies in areas such as ensuring public safety, protecting the underwater habitat and preserving historical artifacts.

ITU ROV Team consists of mechanical, electronic, software and organization sub-teams and has a structure that focuses on different disciplines. The sub-teams have worked on designing and producing the ROV type vehicle that will be able to fulfill the tasks to be assigned with the capabilities and obligations of different disciplines in the shortest time and in the best way. At the same time, the team has shown the necessary sensitivity about occupational safety and field safety during the production phase of the vehicle and during the operation.

ITU ROV Team is an open-source team. As it continues to learn from its large open-source community, the ITU ROV Team contributes and gives back to the community. All software and hardware designs can be accessed on the project's GitHub page, at *https://github.com/iturov*.

Figure 1 - Team Photo

Figure 2 - Our Vehicle "DERE"

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1. Safety

1.1 Philosophy

In addition to technical works such as the design and assembly of the ROV, the top priority was occupational safety and security. In tests, workshops, non-workshops, in short, the priority at every stage was to create a safe and comfortable space to work. It was not avoided to apply every precaution to prevent any harm to the team members and to prevent possible work accidents. For this reason, it was decided to apply the occupational safety protocols and procedures in place and completely.

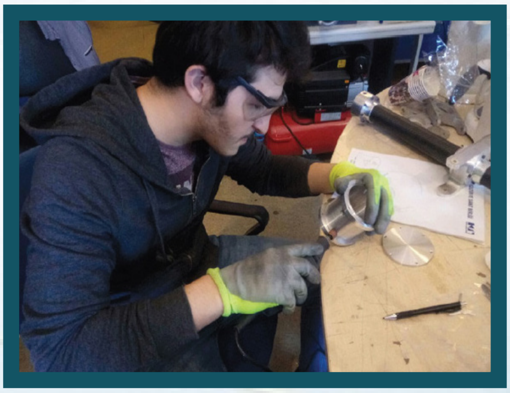


Figure 3 - Safety Precautions

Figure 4 - Safety Precautions

1.2 Safety Standards

No safety application was omitted during the production of the vehicle. In the workshops, it was not neglected to use personal protective equipment such as glasses, gloves, masks, earplugs suitable for the work (Figure 3), and also to have an emergency eye bath, fire extinguisher and first aid kit in the workshop. Warning signs and stickers were used in all work areas (Figure 4). In addition to these, experienced team members applied the rules to be followed within the workshop rules without skipping. Before starting work in the workshop, our team was given a short training (Figure 5) on occupational safety and the rules to be followed in the workshop, with the support of the ITU Occupational Health and Safety Club. Team members also need to use any tools, both in tests and in other work areas. vertical drill, milling machine, sander - they have taken care to create a suitable and comfortable working environment both for themselves and for others by following these rules. Personal protective equipment (PPE) such as goggles and gloves are used for eye protection while using equipment that may cause an accident. Electrical technicians also made the necessary controls and tried to prevent risks by identifying them. In addition, since the works were carried out during Covid 19 Pandemic, everyone continued to work with appropriate protection (Figure 5).

Figure 5 - Safety Training

Figure 6 - Safety Precautions at Olympic Pool

1.3 Safety Features

While paying attention to the technical features of the vehicle, security measures were not ignored. The position of the thruster on the vehicle is also positioned in such a way that it will not be damaged from the outside or harm the outside. In short, it is mounted in a way that does not interfere with the use of operators. In addition, all plastic clamps on the vehicle are shaved in a way that they cannot harm users. No sharp surfaces are left on the vehicle that could harm users. In case of any problem during the operation of the vehicle under water, the vehicle can be stopped quickly thanks to the emergency stop button on the ground station. In addition, during the operation of the manipulators on the vehicle, it is possible to cut the power of the manipulators on the vehicle from the pilot's control center. Besides, the following substances were applied based on safety.

- AC electricity is not used in the ground station; the ground station is completely isolated from the city network.
- All cables used have been selected considering the currents that will pass over them, and their cross-sectional areas have been taken into consideration.
- The electricity supply of ROV and Non-ROV devices is provided by passing through suitable fuses.
- All connectors used have been selected by considering the appropriate values.
- When the main vehicle's power is cut off, the battery inside the MicroROV is also completely disabled.

Figure 7 - Safety Precautions

1.4 Safety Checklist

Startup Checklist

1. Check around
2. Keep power supply off
3. Connect the power cable to the ROV
4. Connect Anderson connectors to the power supply
5. Check electronic enclosure

Pre-Dive Checklist

1. Start ground station
2. Power up the ROV
3. Start the ROV
4. Control the electronic system from the control station
5. Put the ROV down and make sure people stay away from the thrusters
6. Put your ROV in manual mode
7. Activate ROV
8. Press the forward / backward bar forward to check that the vectored thrusters rotate freely.

9. Press the up / down bar forward to check whether the vertical pushers rotate freely.
10. Disable the ROV.
11. Put the ROV in the water
12. Engage the ROV.
13. Check the entire vehicle again from the ground station (camera, electronic device ...)
14. Leak control
15. Buoyancy and stability control of the ROV

Diving Checklist

1. Start the timer
2. If the mission is completed, drop the ROV to the ground

If Balloon Found (If the balloon was found while the vehicle was running)

1. Turn off the power
2. Take the ROV out of the water
3. Check ROV and find problems
4. If the problem is resolved, restart the ROV

Incorrect Communication (If there is a communication deficiency)

1. Check communication
2. Start looking for a problem
3. Restart ground station
4. If ROV fails to restart, power off
5. Take ROV to ground
6. Check ROV and find problems
7. If the problem is resolved, restart the ROV

Post Dive Checklist

1. Wash the vehicle with clean water
2. If working in a sandy environment or seaweed, remove the sand and seaweed from the propellants.

2. Electronics and Power System

2.1 Ground Station

Ground station is designed to provide "plug and dive" solution to the operator within a secure manner. All parts, which are required to operate a ROV, are included in the ground station. These parts are protected from external factors in the ground station while operation and transport.Ground station consists of a Fathom-X communication module, one tether connector, one 48V power input with an Anderson SBS50 connector, one fuse holder on the power input cable, one emergency stop button, one controller board and all required controls (flight sticks, buttons, toggle switches). Ground station should be connected to a computer via USB and Ethernet cable. Joysticks or gamepads are not required since ground station already has all required controls itself, the controller board functions like a gamepad. Since controls are specially designed to operate an ROV, operator can handle the vehicle on all movement axes. If the computer connection is established, the ROV can be operated after 48V input and tether connections done.

2.2 Tether Cable

The connection between the ROV and the ground station is established with the tether cable. Tether cable enables power transmission and communication. While two wires of tether cable supply power to the ROV, other two wires enable the communication. Wires, which are used for power transfer, have cross-section of 3.6 mm^2, this thickness is calculated with considering the power consumption of the ROV. Two-way resistance is equal to 1/8 Ohms per 10 meters of cable. Wires used for communication are produced as 18 AWG twisted pair and screened with aluminum foil. This twisted pair is used as a tether line for Fathom-X communication modules. Tether cable is designed as neutral-buoyant to ensure mechanical stability of the ROV. Tether cable is fabricated in accordance with standards VDE0295 / IEC 60228 class 6 [1].

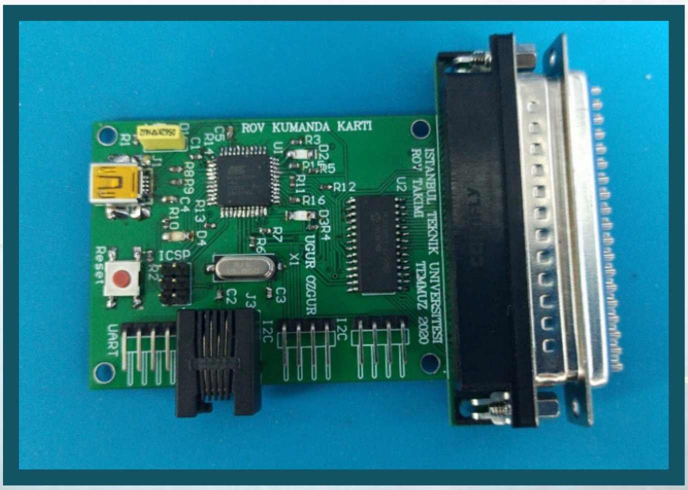


Figure 8 - ROV Control Card

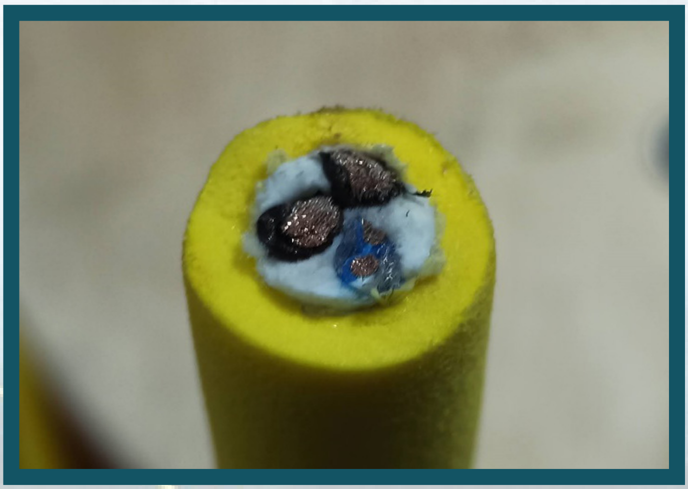


Figure 9 - Tether Cable

2.3 Power Bricks

On the vehicle side of the tether cable, 48V tether power is regulated down to 12V via parallel-operated Quarter-Brick sized two power bricks. These power bricks are capable of provides 50 Amperes of output current by oneself with 96% typical efficiency. To ensure proper cooling for these power bricks, they are located on separate aluminum enclosures, outside of the main tube. Due to electrical resistance on the tether cable, voltage on the vehicle side drops when electrical current passes through the tether cable. To prevent sudden shutdowns, maximum possible voltage drop is calculated, and power bricks are chosen in accordance with these calculations. The minimum input voltage of these power bricks is 36 Volts.

2.4 Power Distribution Board

12V output of the power bricks gets distributed to ROV systems via Power Distribution Board (PDB). Power Distribution Board is a “2 layers”, 70 oz Cu per ft^2, printed circuit board, which holds Electronic Speed Controller (ESC)s of the thrusters. To prevent heating of the PDB, power connections of the ESCs are installed on copper bars, which are on the PDB. PDB also functions as a passive cooler for the ESCs with its copper area. Since one PDB can carry up to 4 ESCs, two PDBs are in use on the ROV to supply power to the 8 thrusters. PDBs also has onboard regulators with fuses and indicator lights. PWM inputs of the ESCs are routed to an IDC connector.

2.5 Mainboard

ROV mainboard carry and connects all control systems of the vehicle. A Pixhawk and a Raspberry Pi are connected to the mainboard via headers and secured on the mainboard with screws. Mainboard has one 5V step-down regulator for Raspberry Pi, one 5V step-down regulator for general use, one relay to switch on/off the headlight, two IDC connectors to send PWM signals to the ESCs on the PDBs, two dual H-bridge motor drivers for brushed DC motors and various connection terminals. Mainboard gets 12V from the copper bars on the PDB.

2.6 Computer and Network

Raspberry Pi, that mounted on the mainboard, is connected over LAN to the ground station computer. The connection part, which establishes a Local Area Network (LAN) over single twisted pair on the tether cable, is Fathom-X module. Fathom-X utilities an Homeplug AV (IEEE 1901) module onboard, which is capable of create a LAN with up to 5 devices on the same tether line [2]. Raspberry Pi sends Mavlink commands between ground station computer and Pixhawk, streams live video from USB cameras and controls mainboard electronics through GPIO pins. Pixhawk is connected to the Raspberry Pi via an USB cable and Raspberry Pi is connected to the Fathom-X via an Ethernet cable.

2.7 Temperature and Humidity Tracker Board

Temperature and humidity tracker board use a DHT22 sensor to get measurements about ambient conditions and sends data over UART protocol to the Nextion HMI LCD screen. LCD screen prints ambient conditions and shows sponsorship gallery. Tracker board can also drive WS2812B addressable LEDs to setup temperature reacted RGB lights.

3. MicroROV

3.1 MicroROV Electronics

The responsibilities of the MicroROV electronics are to run MicroROV's motors, to switch headlight on/off, to transmit image to the ground station computer and to process incoming commands from the ground station computer. To function these responsibilities, MicroROV has one Raspberry Pi, one Fathom-X module and one Raspberry Pi shield board.

3.2 MicroROV Power System

MicroROV use 4 pieces serial connected LR6 (AA) alkaline batteries to power motors and headlight. All other electronics get power from the 12 Volts supply of the ROV. While Fathom-X module use its own regulators to regulate 12V to a proper voltage, other components benefit from LM2596S-5V regulator, which placed on the

3.3 MicroROV Computer and Network

MicroROV use a Raspberry Pi as a controller. Raspberry Pi is connected to a Fathom-X module via an Ethernet cable. Fathom-X module is connected to tether line of the MicroROV cable, which connected to the main tether line on the ROV. Three Fathom-X modules on the same tether line, establishes 3 device LAN (Local Area Network) and makes possible to seamless communication between ground station computer, ROV and MicroROV. In the datasheet of the "LX200V20" module, which Fathom-X carry on, it is expressed that up to 5 modules can operate on the same tether line [3].

3.4 MicroROV Tether Cable

MicroROV tether cable consists of two wires to carry 12V to the MicroROV and two wires to carry Fathom-X signals. To protect Fathom-X tether line from EMI, the cable wires are twisted and screened.

3.5 MicroROV Shield Board

MicroROV Shield Board is designed as a module, which seats on the GPIO pins of the Raspberry Pi. It has a L298P motor driver IC to drive two brushed DC motor, one L293DD motor driver IC to drive a stepper motor, one MOS-FET to switch headlight on/off, one LM2596S-5V regulator IC to regulate 12V supply. All power connections on the MicroROV are located on this board. An op-amp on the board turns off the battery indication LED when the battery voltage drops below a predetermined threshold, so it is easily understood that the battery is over.

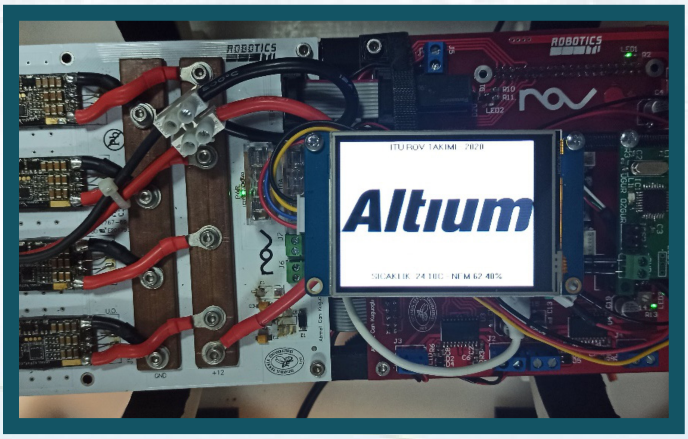


Figure 10 - PDB and Mainboard

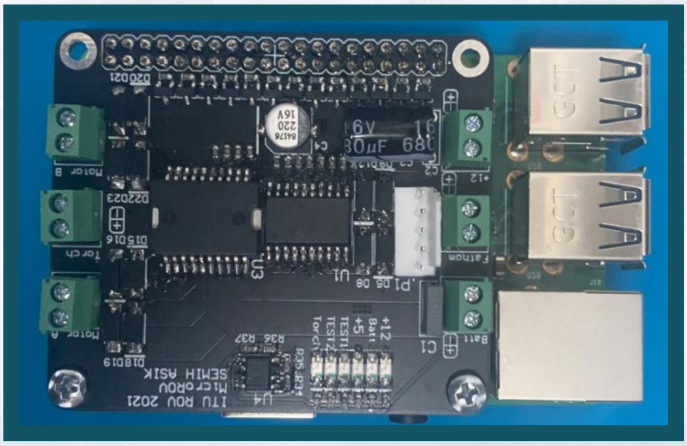


Figure 11 - MicroROV Shield Board

4. Mechanics

4.1 Electronics Housing

A custom made Poly (methyl 2-methyl propanoate) (PMMA) tube with 152.4 mm internal diameter, 298.45 mm long, and 6.35 mm wall thickness was mounted on the top side and in the center of the ROV to shield the electronics from water. In terms of compressive strength, water absorption and lightness we determined that the plexyglass tube is superior to 3D printed or metal cut materials based on our experiences and researches. We can instantly see and fix if there is an issue with electronic cards thanks to the transparent tube. The cylindrical form can withstand pressure and allows for more available space. Two aluminum flanges are attached to the front and back of the tube. The O-rings in the radial grooves of the flanges provide the seal between the acrylic tube and the flange. An aluminum, 6 inches End-Cap completes the sealing of the tube at the back. End-Cap has the 15 holes for the cables with penetratorscovered with epoxy that cast for sealing. The electronic cards are carried by a 3D printed tray that is inserted into the tube. In emergency cases, the electronics can be quickly attached and removed. The front of the acrylic cylinder, encased with a purchased 6 inches dome. Between the dome and the flange, a liquid gasket is used to seal it. Inner and outer rings were used to link the dome and flanges. An USB camera placed in the dome on a pan tilt platform controlled by two micro servo motor. We gained space by providing full view with a rotation angle of 0-90, to the right-left and up-down, degrees by positioning the camera concentric with the dome. The enclosure was bolted to the chassis with two 3D printed clamps. The clamp system allows us to easily detach the tube from the frame and attach it back.

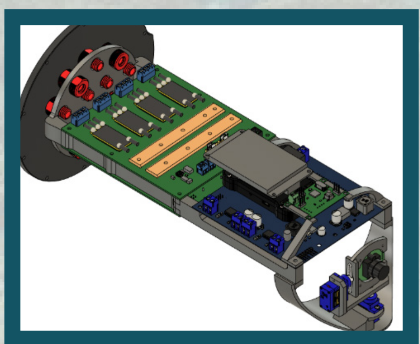


Figure 12 - Electronics Tray

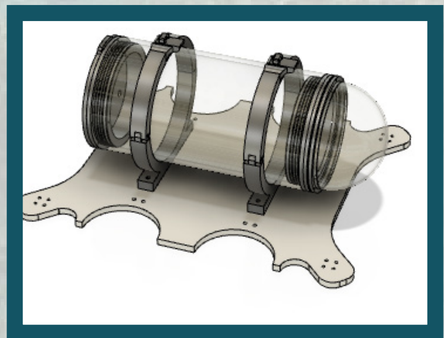


Figure 13 - Electronics Housing

4.2 Design Of The Chassis

The chassis of the ROV consist of 3 subparts. These subparts are the main plate, clamps holding the enclosure that covers electronics and lastly the legs.

4.2.1 Main Plate

The material of the main plate is “Delrin” (polyacetal) which is a thermoset polymer. The reasons behind this selection are sufficient mechanical and chemical properties such as high toughness, low water absorption and chemical stability under different environments like salty water. This “plate shape” provides a large area to hold all equipment together. This is the first reason why we design it like that and it is also easy and cheap to manufacture because of the shape.

4.2.2 Enclosure Clamps

The purpose of using clamps instead of fixed brackets is the easiness of disassembling. Thus, electronics can easily accessible and serviceable. For that purpose, we used hinges on one side and buckles on the other side. The clamps are manufactured with 3d printers because of the low cost and easiness of prototyping. Thanks to 3d printers, we can easily manufacture different designs and service them if it breaks.

4.2.3 The Legs

Chassis have four legs. These are bolted to the bottom of the main plate. Legs have more than one purpose. One of them is keeping the equipment to touching the ground. The other purpose is that they work as brackets for equipment like cable winders and gripper. In this manner, the need of using equipment brackets is eliminated and a more compact design is possible.

4.3 Ping-pong Ball Capturing Station

Our ping-pong capturing station is our second prototype that we designed. Catching the balls with the station that we first built was quite a challenge for our ROV pilot. In order to handle this job easily, we decided to redesigned our monolithic piece. We created a telescopic model instead. Our new station consists of parts that can be closed on top of each other. If needed, those can be opened and scan a wide area. In addition, these moving parts make our vehicle smaller during transportation and protect the station structure from possible impacts. It has dimensions of 284x236x156 mm in the open state and 180x160x92 mm in the closed state.

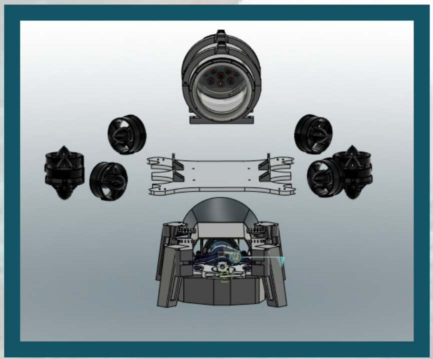


Figure 14 - Main Plate

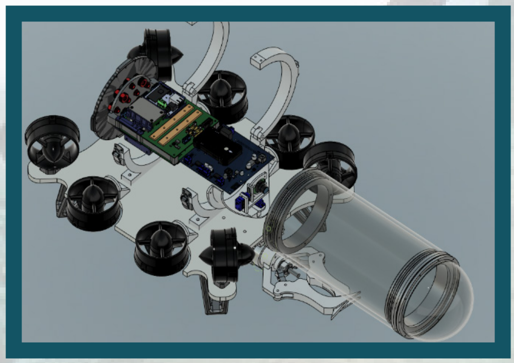


Figure 15 - Enclosure Clamps

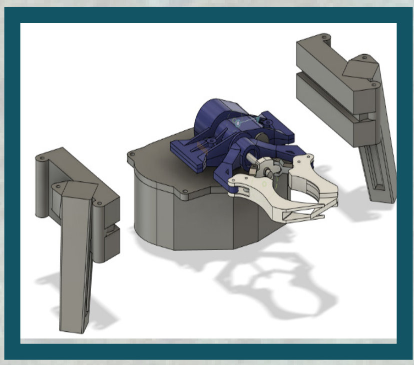


Figure 16 - Legs

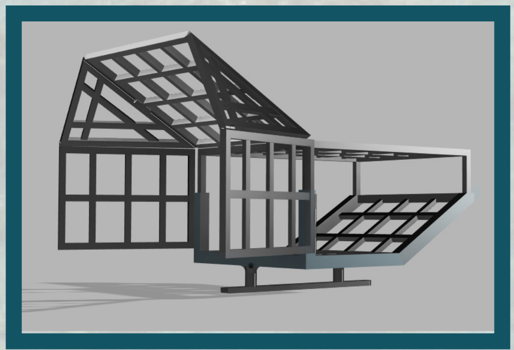


Figure 17 - Opened State of the Station

4.4 Gripper

We tried to use materials that are light and strong. Center of mass is an important aspect for us so we tried to balance while we creating new parts. We generally used 3D printer technology for producing our structures with given tolerances.

4.4.1 Design of Gripper

While designing we used two 10 rpm motors for our gripper. First one used for opening and closing the claws, second one used for changing the direction of body so that we can use it with different angles. For this axial motion we used straight gears. We used trapazoidal screw on a shaft with a nut. Also elastic coupling has been used for connecting trapazoidal shaft and motor exit shaft, prevent axial disorderedness and reduce vibrations. Nut placed on a part that gives motion to small arms which turns with the movement of screw. This motion leads to claws opening or closing related to turning direction. To calculate the moment which created by motor to move the shaft we need to know relation between moment and axial force on nuts. This relation calculated by bolt equations.

$$F_t = F_a * \tan(\alpha \pm \rho)$$

F_t : Tension Force
F_a : Axial Force
α : Screw Slope Angle
ρ : Friction Angle

In this equation meaning of "±", related to whether we put loads or not. Load will be always opposite direction to nuts movement, n the gripper arm mechanism. So it will calculated as $\alpha+\rho$. If we calculate screw slope angle with given information by producer as h=8mm, dm=8mm which also verified by us:

$$\tan(\alpha) = h / (d_m * \pi)$$

The materials of nut and shaft is an important aspect on calculating friction angle. Since our shaft is steel and nut is brass according to producer we can take dynamic friction coefficent as 0.35 :

$$\tan(\rho) = \mu_\kappa = 0.35 \qquad \rho = \tan^{-1}(0.35) = 19.3$$

The moment created by motor is production of tension force and shaft radius.

$$M = F_t * (d_m/2) = F_a * (d_m/2) * \tan(\alpha \pm \rho)$$

If we insert values we previously found:

$$M(Nmm) = F_a(Nmm) * 3\ (mm) \quad \text{or} \quad 333.3 * M(Nm) = F_a(N)$$

With this calculation we can see how much we gained with trapazoidal screw. Lastly we created a shell to connect body of gripper, axial motors and gears which then attached to legs in both sides [4].

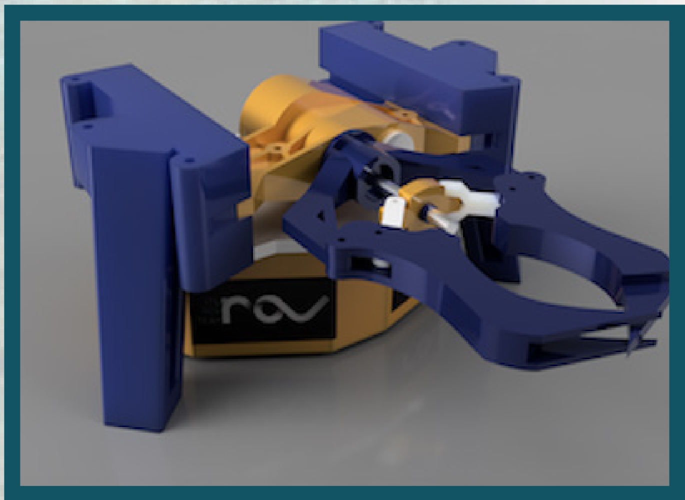


Figure 18 - Gripper Assembled

4.4.2 Structural Analyses for Gripper

Strength analyses has been made against vertical and horizontal forces which helps to make optimizations on the vulnerable zones. We used Fusion 360 program for this analyses and we also tried similar analyses on ANSYS program. In used figures we used forces much stronger than our safety coefficient to show vulnerable zones we also adjusted the displacement to understand how system affected.

Horizontal Forces

Main horizontal forces are originated from weights that carried between claws. These weights have similar effects to each claws so we simulated loads for individual claws normal to upper surfaces. In the analysis we obtain how arms will be damaged the most with the loads so we optimized main arms and added rips to them. Displacement we obtain meant no direct harm or function loose if we memorize it is adjusted.

Vertical Forces

Another important analysis is about vertical loads created by motors while gripping objects. Past years we encounter a problem caused by these forces which leaded to breakage on one of the main arms. While we inspect the analsis we found out that main reason for this caused by overgripping which means we squezze gripped object more than it is needed. It was caused by motor which was too much strong than needed so we changed it to a smaller weaker 10 rpm motor. These way we increased lifetime of our gripper and we prevent damage given to objects we carry.

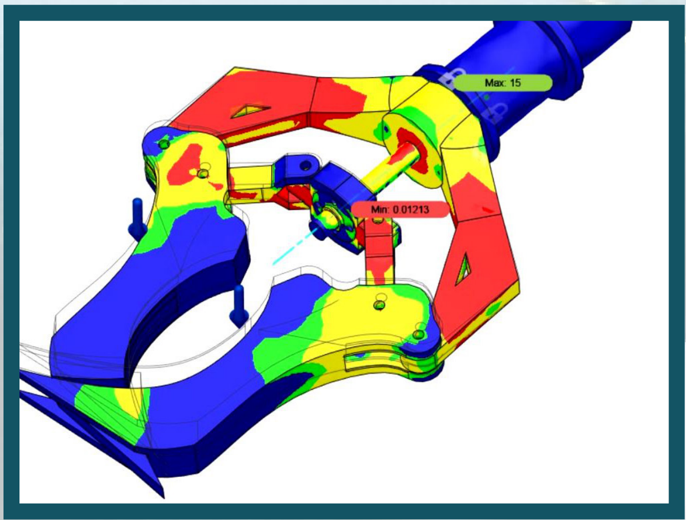


Figure 19 - Horizontal Forces

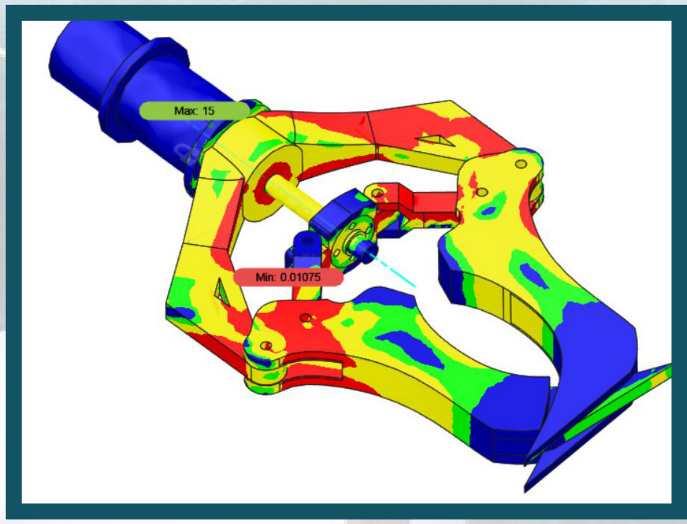


Figure 20 - Vertical Forces

4.5 Camera Box

Two HD USB cameras were used in the vehicle. One of them was under the vehicle to see below. The other camera was placed in the dome in the front of the tube to see the front of the vehicle. The camera box was being designed, the main purpose was that the box should not receive water. For this, 3D printing boxes were tested first, but it was observed that the life of this printed box was not very long and after a while it lost its protection. Therefore, the camera box was obtained by plastic casting method. The first step for this was printing of mold models from 3D printer. Molds were created with RTV2 silicone using these models. Then, the final shape of the box was given with polyurethane casting. The camera was screwed to the parts on the cover of the box made of polyurethane and plexiglass was attached to the front of box. In addition, the box was covered with epoxy to provide the sealing.

4.6 Micro ROV

The micro-ROV is consisted of a functional gripper, a camera, 2 DC motors, 3 wheels, acrylic tube and electronic parts with their mounts. The main purpose of the vehicle is to pull a sediment sample from the end of drain pipe out and turn back to main vehicle.

4.6.1 Enclosure

Enclosure is a 200 mm long, 0.25-inch thick and 3-inch diameter see-through tube made of cast acrylic. Besides being the main structural part, enclosure is being used to place and preserve electronics. The compressive strength of the tube used is around 40psi according to the manufacturer's data. This magnitude allows to go down to 50 meters in fresh water.

4.6.2 Motors and Wheels

The mobility of Micro-ROV is provided by two 12V 50RPM DC motors. The power requirements of these motors met by batteries inside. The current drawn by each motor varies between 50-530mA. Each motor transmit power to wheels designed to increase the grip in the 6-inch diameter pipe.

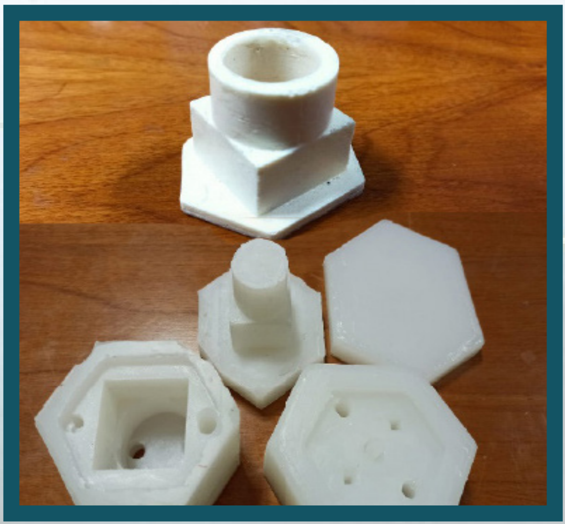


Figure 21 - Cold Casted Camera Box and Silicone Molds

Figure 22 - Motors and Wheels

4.6.3 Gripper

Gripper is a component that is emerged as a result of different design experiments to grip the prob declared in the mission requirements. Due to the problems we encounter in our trials, servo motor that be used replaced with a step motor. Fulcrum part of the gripper designed replaceable for assembly and production concerns. Teeth on swinging arm designed to increase the grip of prob.

4.6.4 Tray

Tray is produced to carry electronic components and prevent them from short circuiting. It consists of three sections (electronics mount, battery slot and camera mount). Main purpose of it is to carry Raspberry Pi, Fathom X, Micro-ROV Mainboard, batteries and camera. Besides, in case of a deficiency or replacement, the tray is designed to take all the parts out from the tube in one move because it is bolted on to the aluminium end cap via penetrator nuts.

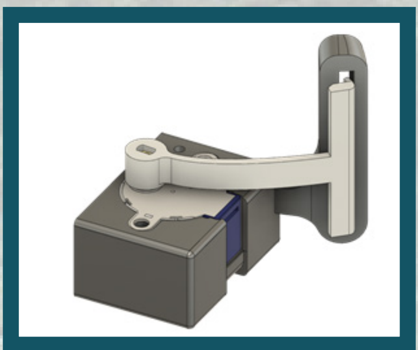


Figure 23 - Gripper

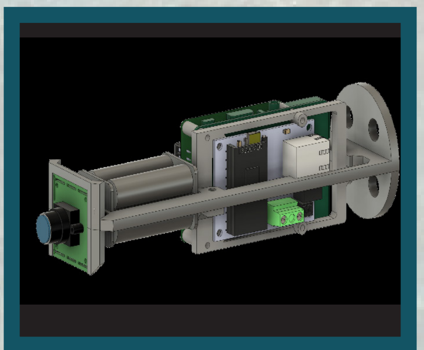


Figure 24 - Tray

4.7 Cable Reel System

Our mechanical team designed a cable reel system for use in the Micro ROV task. The cable reel mechanism consists of 5 components. If we enumerate these five components; Component one is reel, component two is idler pulley, component three is self-reversing screw, component four is cable puller and final component is motor mount. These components designed in Fusion 360 and Rhinoceros 3D CAD (Computer Aided Design) programs. We used a three-dimensional printer using PLA (Polylactic acid, or polylactide, is a type of thermoplastic polyester) filament while producing the cable reel parts. Producing components with three-dimensional printer allowed us to rapidly produce different prototypes.

4.7.1 Cable Roll

This part is basically a roller that is supported by two bearings (SKF 608-ZZ) and driven by a GT2 type pulley with forty teeth integrated on it. In order for the cable to come out, the middle of the shaft, which is bedded with bearings, is made empty. The inner diameter of the cable wrapped part is 60mm and the outer diameter is 100 mm.

4.7.2 Idler Pulley

Toothless relocatable pulley is being used to ensure the tension on the belt. The pulley is toothless because it is suppressing the belt from outside. This part supported by two bearing (SKF 608-ZZ) and moves in a slot. It can be fixed to the desired position with a bolt.

4.7.3 Cable Puller

This part, during its movement, provides the movement of the cable by compressing the cable between two rollers and driving one of these rollers by the pulley through the gear. On these two rollers there are slots to prevent the cable from dislocating. This slots profiles radius of curvature is slightly greater than cable radius. Thereby successful compressing can be accomplished. The non-driven roller is located on the end of an L-shaped arm. This arm is attached by a shaft going through its perpendicular side. The other side of the arm is being pulled by an elastic band to meet the required clamping force. Tension the elastic band can be set by a sliding bracket. Bearings (SKF 625-ZZ) are being used on required positions.

4.7.4 Self-Reversing Screw

Self-reversing screw is a part that is mainly being used in ships and cranes to gather heavy and thick cables up back to the reel system. The proper self-reverse screw system for Micro ROV is being used. Main purpose of self-reverse screw system is to gather the cable back to the reel properly by passing it through a ring which is connected to the mechanism. The shaft in the system is supported from both ends by bearings (SKF 608-ZZ) and has dual helix groove. The shaft is driven by GT2 pulley. Shaft diameter, groove width and sliding parts dimensions designed compatible with each other in case of situations like dislocating. Additionally, the system supported by linear bearing guide for stability issues. To prevent any jamming issues caused by friction force articles about linear bearings [1] have been analysed. Hereby jamming between sliding part and linear bearing guide has been prevented and stabilized.

4.7.5 Motor Mount

This part fixes the 90-degree reduced brushed DC motor to the outer case. This motor is equipped with a forty-teethed GT2 pulley. This pulley drives the system belt.

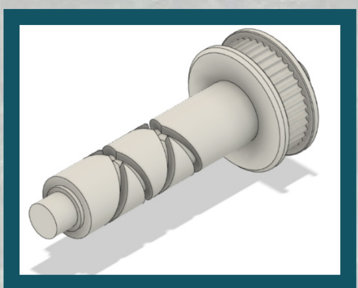
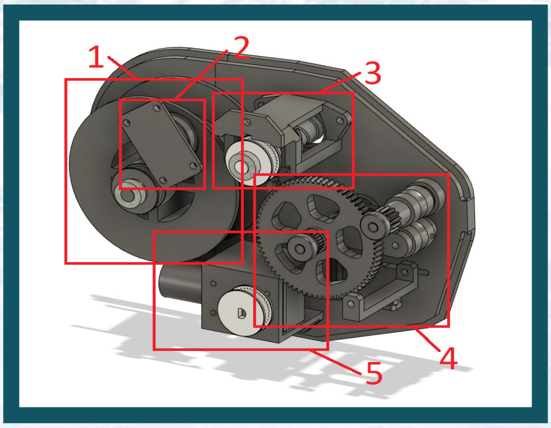


Figure 25 - Dual Helix Groove



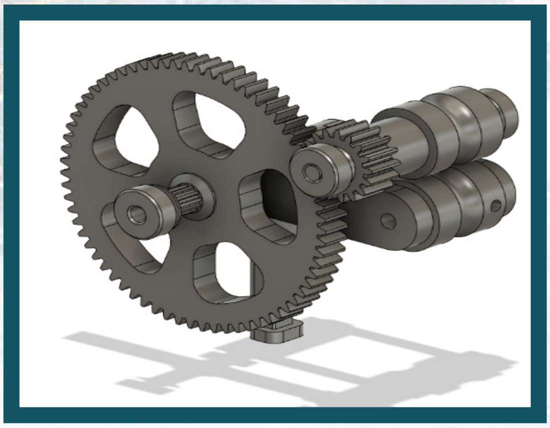


Figure 26 - Cable Puller Mechanism

Figure 27 - Parts of Cable Reel System

5. Software Development

5.1 Ground Control Station

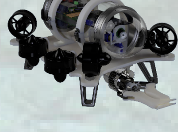
Our ground control station contains a ubuntu based computer with Qgroundcontrol, special joystick that gives us the opportunity to control the rov, microrov and and it's grippers. Communication with the vehicle and power supply to the rov can be made from ground station. There are 2 different interfaces to make more easier for pilot to use the vehicle and copilot to make the tasks. Pilot can control the vehicle by using Qgroundcontrol's interface, that interface gives us the anterior camera's view. Copilot is using the special interface that produced with PyQt5 library to make tasks. With our ground station; we are getting live stream for coral reef task , we are taking photos for photomosaic task and also we are taking the video with the same way for mapping task .Ground control station is designed for maximum comfort and ergonomy for pilot to use with best performance.

5.2 User Interfaces

In order to satisfy the mission requisites of competition and to access determined specifications of our vehicle easily, there are used two different interfaces in two ground stations. One of the interfaces which is an interface of the QgroundControl is to be used by the pilot. The other one is developed using OpenCV and PyQt5 libraries of the Python programming language. While our pilot can control the vehicle and observe the front of the vehicle via QGroundControl, our co-pilot can see through the bottom and the micro-ROV camera and can take the control of our micro-ROV vehicle with the other interface. For the missions in the competition, there are different functionalities like taking a photo, concatenating photos, finding differences in photos, switching the mode to the autonomous, mapping which can be activated via our interface. In addition to these, our interface can illustrate some data like the connection status of the vehicle, cables understandable. All in all, in the process of creating the interface, our team has shown great effort to make the interface as simple and quick as possible for commands that are used in missions.

5.3 Communication

The communication between the vehicle and the ground station is carried out by the Fathom-X module with the TCP / IP communication protocol. The ground station basically communicates with the main Raspberry Pi in the vehicle and the Raspberry Pi in the Micro ROV. The data output from both Raspberry Pi with TCP / IP protocol is encrypted by Fathom-X, which is available separately for both of the Raspberry Pi's, and transferred to the surface by the power cable On the surface, the data is analyzed by Fathom-X in the ground station and transferred to the computer. 2 Python codes running simultaneously on the main Raspberry Pi and the ground station computer are used to transfer the images of 2 USB cameras on the vehicle. First, these codes capture the image with the help of OpenCV and GStreamer libraries, then pack and transmit live images to the ground station via 2 separate TCP / IP ports. Totally 3 separate TCP / IP ports are created, these are two separate camera ports and vehicle control port.



There are 2 different python codes running simultaneously on the Micro ROV Raspberry Pi and the ground station computer. One of them transmits the camera image on the Micro ROV, the other sends commands to control the Micro ROV. The IP addresses of the ground station and all Raspberry Pi's are static, the ground station's IP address is 192.168.2.1, the main Raspberry Pi's IP address is 192.168.2.2, and the RaspberryPi's IP address on the MicroROV is 192.168.2.3. The server computer ground station in the communication network has been designated as a computer and TCP / IP communication is performed over 5 different ports, 3 from the vehicle Raspberry Pi and 2 from the MicroROV Pi. The package protocol which is used in vehicle and ground station communication has been determined by our electronics and software team, and every type of movement wants to be made, every flow of information received from the vehicle is done with the help of these packages.

5.4 The Softwares Which Were Developed For Competition Tasks

5.4.1 Flying A Transect Line Over A Coral Reef And Mapping Points Of Interest

One of Mate ROV Competition 2021 Explorer's tasks is "Task2.1 Flying a transect line over a coral reef and mapping points of interest". Our software which we have coded to succeed in this task consists of two-part. The first part of our software makes our ROV fly a transect line over a coral reef autonomously. In this part, considering the distance between the two blue lines, the angle between the two blue lines, and the distance between the camera and blue lines in the data we receive from the camera under the vehicle, we control the movement of the camera, horizontal-vertical movement, and rotation and yaw movement of the vehicle during autonomous movement. The second part of our software allows us to map the area with six points of interest that the vehicle passes over on the display screen during autonomous movement of the vehicle. In this part, to detect horizontal red and yellow lines which help us to map, we trained a Yolo model [7]. During the training process, we collected 1117 photos of task equipment. We took these 1117 photos of task equipment which was made by PVC pipes and red ropes under different conditions namely; underwater and without lightning, underwater and with lightning, above water and without lightning, above water and with lightning. Each photo includes about 3 lines, hence; approximately 3350 lines were labeled. We trained our Yolo model, with Google Colab [8] and the training process took about 12 hours. Moreover, we take advantages of CUDA [9] to process more frames in 1 second by using GPU instead of CPU [10].

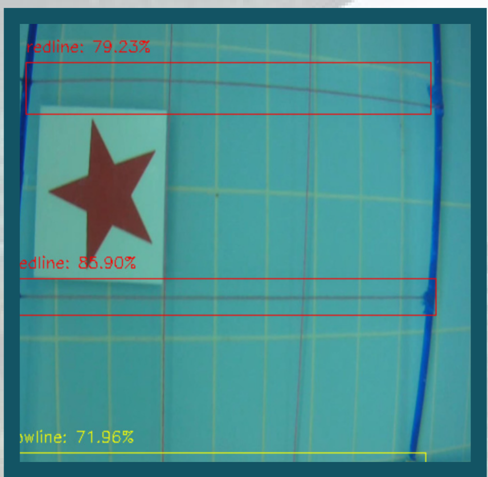


Figure 28 - Results of Line Detection Model on Live Stream

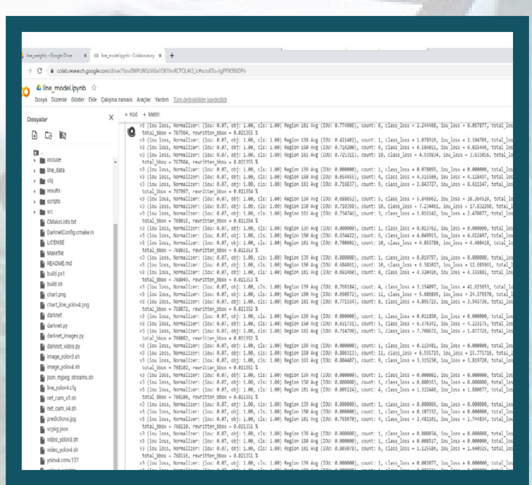


Figure 29 - Training Model on Colab

5.4.2 Determining the Health of a Coral Colony by Comparing Its Current

The purpose of this task is to detect areas of growth, damage, bleaching or recovered from bleaching with image algorithms from images of the coral reef taken at one-year intervals. The detected regions should be displayed with a rectangle surrounding the region on the received image using predetermined colors. The algorithm we use in this task works as follows: First of all, we get a live view from the camera in front of the vehicle.

Then we get ROI (Regions of Interest) according to the pink color in the image taken. So software continues processing with fewer pixels. Then the skeleton of the coral reef is extracted using the skeletonize function [11] specific to the Scikit-image library. This function erodes the masked image until it reaches 1 px thickness. The same steps apply to the coral reef photo taken one year earlier. After that software detects the intersection and end points of the two reefs skeletons and lists those points in a specific order. With the help of these points, two skeletons are superimposed. And finally, the software finds the differences between the two pictures and draws the necessary rectangles with the help of bitwise operations.

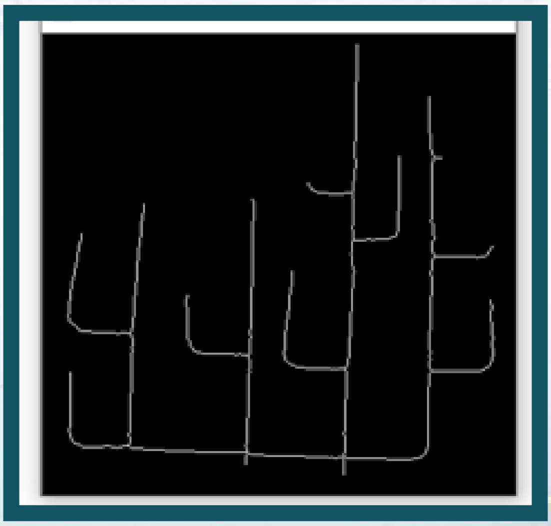


Figure 30 - Skeleton of Coral Reef

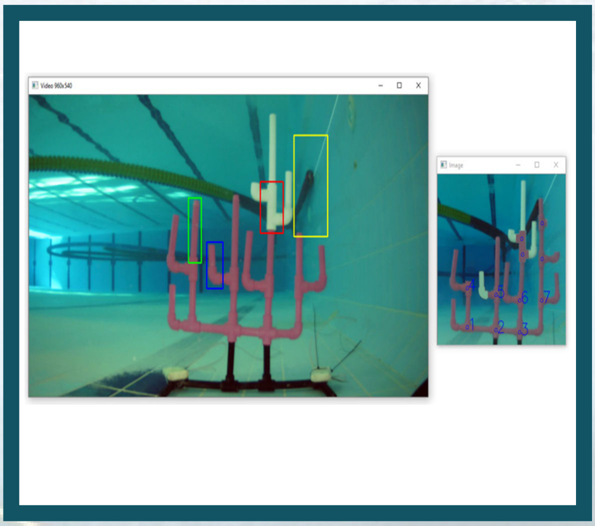


Figure 31 - Final Result of Coral Reef Differences

5.4.3 Creating a Photomosaic of a Subway Car Submerged to Create an Artificial Reef

The project aim to create a 5 face photomosaic of a subway car excluding the bottom face. The program runs in two steps. First it obtains the images of the subway car faces by cropping unneeded water views. Since the top face is brighter than the side faces the program uses threshold function to obtain the top face. HSV white filtering technique is used to obtain the side faces for its convenience. After cropping and saving all faces. In the second step, the program aims to stitch all faces in corresponding format. This is achieved by comparing four edge colors of the top face with the upper edge colors of side faces. To obtain the edge colors of the top face shown in Figure 32, the program uses k-means clustering in specified fields with the value of 2 to get the white and target color. The white color is erased and the target colors is saved. For the side faces the process is similar with one difference. The program only clusters the upper edges. When all faces are saved with their color values, the program tries to match the sides of the car by comparing the edge colors of the faces. The comparison is made in LAB color space. When the program matches two sides by their edge colors it stitches them together. If there is no match the program puts a black face instead of the correct face. So the pilot can take another picture of that face. Lastly, the result is shown.

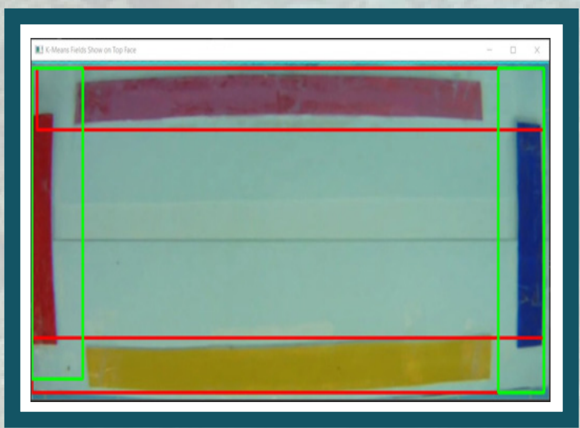


Figure 32 - K-Means Fields Show on Top Face

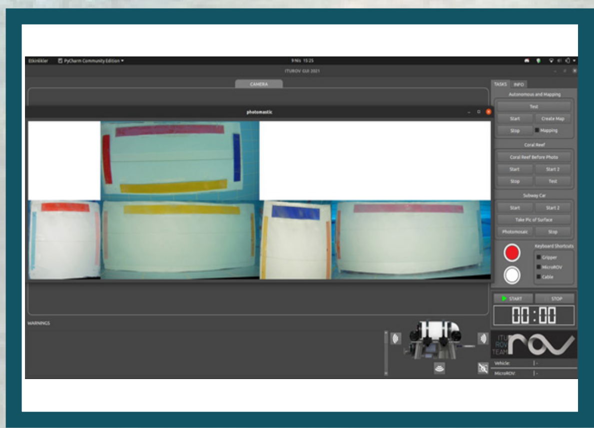


Figure 33 - Photomosaic result with GUI

6. Organization Management

6.1 Company Organization

The ITU ROV Team was established within the ITU Robotics Club, which consists of students from different disciplines and from various faculties. The team consists of four technical teams: Mechanics, Electronics, Software, and Organization. Each team has a sub-team leader who keeps communication with each other and submits their reports directly to the CEO. Mechanical and electrical teams are also divided into some groups to focus on a specific part of the ROV. These groups are control station, micro ROV, and duty stations. Each sub-department works in communication with the other sub-team and informs the department leader about the developments.

6.2 Project Management

In our team, in order to facilitate project management, we used Gantt chart for monthly processes and Trello for weekly processes, and we adjusted the processes according to the deadlines we predetermined. We divided our preparation process into three parts as the design phase, production phase, and testing process. During the design phase, we made our drawings for the production of mechanical parts in the FUSION 360 program. We also used the FUSION 360 program to analyze the strength of the vehicle. By making use of the error mode and effects analysis (FMEA) method during the design and production process of the vehicle, we tried to improve the vehicle continuously and to eliminate the problems that may occur as much as possible. During the production phase, ROV's main equipment such as cameras, chassis, and power converter were brought together before the tasks were determined. When the requirements of the missions were determined, work was started to develop equipment to complete the tasks. First of all, the task stations to be designed were brainstormed. Later, on our vehicle, which was assembled, mission equipment such as gripper, flagger, valve converter was added. Fusion 360 program was used to design and manufacture this equipment. During the production phase, it was preferred to produce parts that are easy to produce as much as possible and will not harm human health. We aimed to reduce the cost by producing the parts in the club room by choosing the production parts from the materials that can be produced easily. Two handles were added to the top plate of the vehicle for easy portability and a connector was used to make the power cable detachable from the vehicle. In our testing process, we worked on completing the officer as soon as possible. For our impermeability tests, we subjected our vehicle to an 8-bar pressure test. To test the missions, the Istanbul Technical University Olympic Swimming Pool and the Faculty of Ship and Marine Sciences Ata Nutku Ship Model Experiment Laboratory were used. In order to make our software and designs accessible within the team and to share with the robotics community, our work was shared on GitHub.

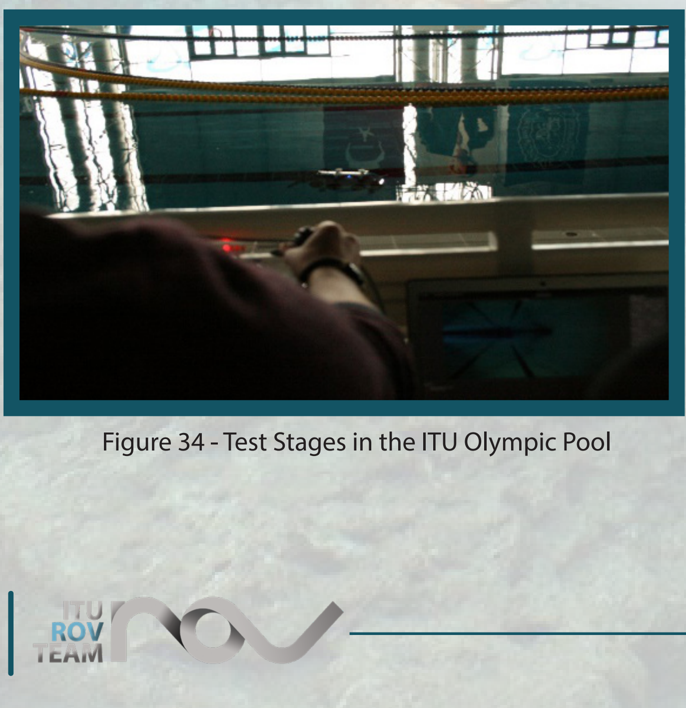


Figure 34 - Test Stages in the ITU Olympic Pool

Figure 35 - Weekly Team Meeting

6.3 Corporate Responsibility

As ITU ROV Team, we want to create awareness about underwater technologies in our country. We participate in maker events and technology fairs held for this purpose. In addition, we provide consultancy to primary and high schools on ROV and other underwater systems.

Figure 36 - The Meeting of ITU ROV Team with Mehmet Tugrul Tekbulut High School ROV Team

Figure 37 - The Meeting of ITU ROV Team with Mavi College Students

In addition to our efforts to raise awareness of the underwater world in our country, we donate saplings to our sponsors through the TEMA Foundation, which aims to protect nature. We have donated 73 saplings for our sponsors until now.

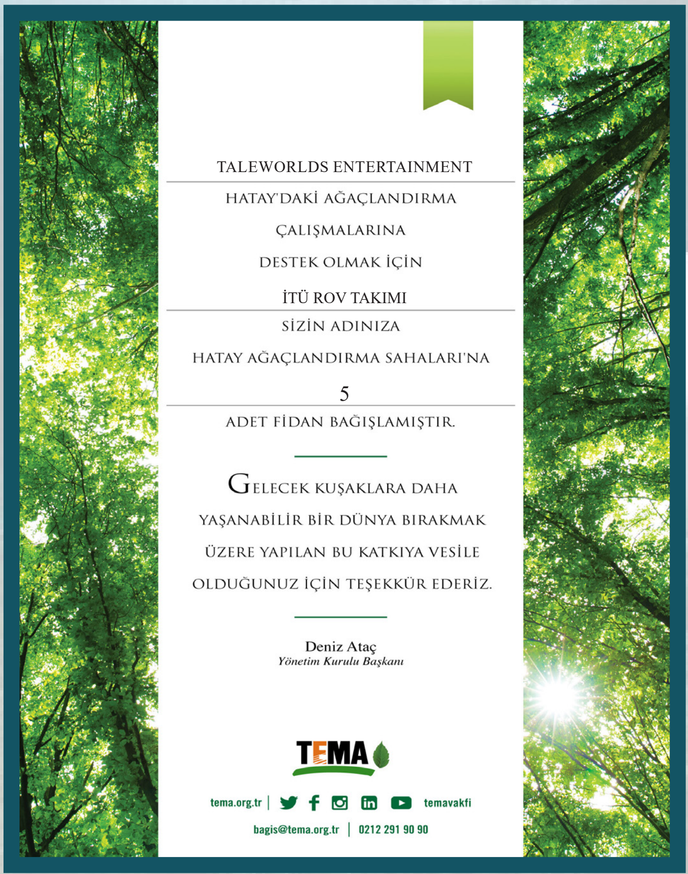
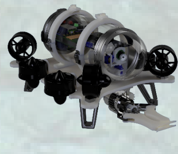


Figure 38 - Certificate of the Sapling Donation Our Sponsor-1

Figure 39 - Certificate of the Sapling Donation Our Sponsor-2



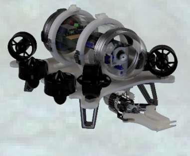
7. Conclusion

7.1 Testing and Troubleshooting

This year, the ITU ROV Team has tested everything it has produced and designed not only after the construction phase of the ROV but also during the design and construction phase of the ROV. Our team, which has increased its experience every year, has determined in advance which subject we should concentrate on and how we should work and has intensified its tests in these areas. Our team, who pays particular attention to impermeability and works on this topic, has achieved successful results on the tests. We have used many areas for testing, and the areas we use are ITU Olympic Pool and Ata Nutku Ship Model and Experiment Laboratory. Every part of the vehicle produced during the vehicle's construction was tested in these areas to measure and observe its response in water. Our ROV has tested such workability after every part added on it until the ROV is ready. When the vehicle construction phase is over, our vehicle has been tested in these two areas every week. The weekly tests focused on piloting and the running performance of the ROV. First of all, everything is tested and, its performance on the vehicle has been researched. All these tests have a significant effect in getting our ROV its current efficiency and appearance. In problem-solving, the focus has been on working on the emerging problem immediately and producing solutions as soon as possible. We can examine the troubleshooting process in 3 stages: troubleshooting, fixing, and resolving the problem. As the ITU ROV Team, we find it appropriate to solve the problems we have in this way. If we could not find a solution from these stages, we looked at the problem from a broader perspective and looked for new solutions by expanding our solution pool.

7.2 Challenges

The biggest challenge we faced this year was the Covid-19 pandemic. We were in lockdown due to the pandemic and, we couldn't continue our work. Due to the restrictions imposed, it was not feasible for our teammates to work in the workshop. Besides, the small workshop also challenged us. Since we are a crowded team, we could not work comfortably in the working area. In addition to these, we also experienced some setbacks in vehicle construction. These were caused by the lack of experience and sometimes by our lack of financial means. To give an example, we failed to get some fine-grained parts we wished for and, as a result of long efforts, we were just able to get the necessary elements for our vehicle. From time to time, finding a suitable field for testing was also a problem, which caused our work to delay. As in all projects, we encountered some technical problems. The most important of these was impermeability. We did a lot of research in order not to have any problem with this subject. Within the mechanical team, we identified several problems and produced solutions for them. As a result of our tests, we saw that there was no problem and we think that we will have no problem in the competition. For example, the motor we use in our holder and rotator had to be water-resistant and, we made this choice accordingly. At first, we had a robot arm designed for a servo motor. That's why we had to change our design but, when we needed to use servo motors, we started looking for new methods to use servo motors underwater and, as a result of our tests, we successfully achieved servo motors that work underwater this year. We have dealt with these and all other problems with our effort and made the vehicle fit. Apart from the production of the vehicle, although we had difficulties in organizing at first because we were a more crowded team compared to last year, as time passed, we started to work more regularly with the use of Trello. We thought that as the number of people working on the vehicle increased it would make things difficult for us and, we tried to customize the work of everyone as much as possible to use the high number of employees in our favor.



7.3 Lesson Learned

Since we have limited time for production due to pandemic, it was necessary to minimize the number of prototypes. For this reason, we made more detailed analysis and modeling during the mechanical design process. we learned different methods on analysis and design. In this way, we learned the ways to reach the final product by producing as few prototypes as possible.

While we were working on our ROV's electronic system designs, we persued related technical documentations and industrial standards to develop a reliable electronics infrastructure. All of our PCBs functioned very well and almost every electronic system worked without any trouble. The only difficulty we faced was occasional power cuts on the vehicle. We discussed about the topic and performed brainstorms to find out the cause. We revealed the crux of the problem after recalculating all factors of the power system. Resistance of the tether cable causes voltage drops on the power line. Our 48V to 12V regulators has a minimum input voltage threshold value and regulators are not working with an input voltage which is lower than this threshold. Our regulators' minimum input voltage threshold value was too high, and it was causing power shutdowns when some amount of current passes from the tether cable. We changed our regulators with a model which has a lower minimum input voltage threshold value and problem is completely solved. ROV's software development process has added a lot to us about autonomous driving. It enabled us to do a lot of research on autonomous driving. Problems arose that we could not solve with classical image processing techniques. These problems also allowed us to improve on methods of learning from data, and ultimately we used learning methods to perform tasks.

7.4 Future Improvements

We are a project team that aims to learn new things from the things we produce every day, improve ourselves, and pioneer new things in our field with more creative designs. This year, we have gained beneficial knowledge especially in material selection and design. With a more specific design in this respect, we aim to produce a vehicle to be used in polar researches with the ITU Pole Research Application and Research Center Team (ITU Pol-Rec). On the other hand, we continue work on the autonomous vehicle, which was among our goals last year. This year we make an effort to design compact electrical systems and we reached our goal in no small measure. In next year we will increase the level of compactness via developing some other electronic systems ourselves. We will embed the Fathom-X (communication board) to the ROV's mainboard, and we will design our ESC boards. ESC boards will be in a modular format and they will be placed on the ROV's mainboard.

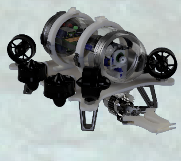
7.5 Reflections

"This is my first year in ITU ROV Team and, I am glad to be a part of this team. I have improved myself in image processing. By working with this team, I think I earned important things for my future life."

- İbrahim KÖSE

"Working with the ITU ROV Team has been one of the most exciting experiences of my university life. By participating in various jobs in the team, I gained knowledge and experience about CAD drawing, material planning, technical part knowledge, and how they work, which I will need in my future business life. I also learned many things in organizational management and teamwork. Joining the ITU ROV Team, I did the longest-running work of my life. In this way, I realized what kind of team I should be a part of by taking different responsibilities. Most importantly, I made friends with whom I have a good time."

- Elif Nur KAVAK

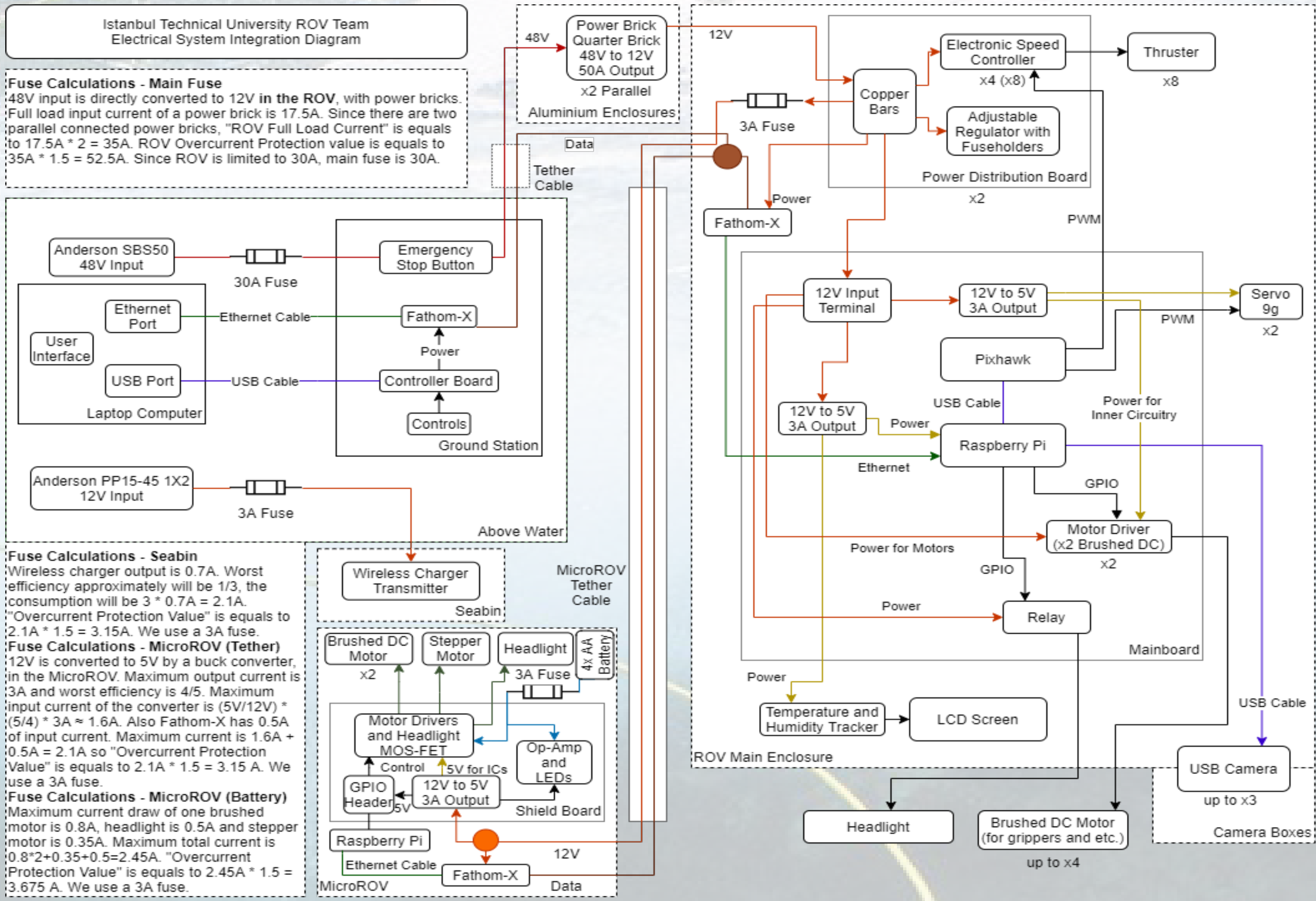


Acknowledgements

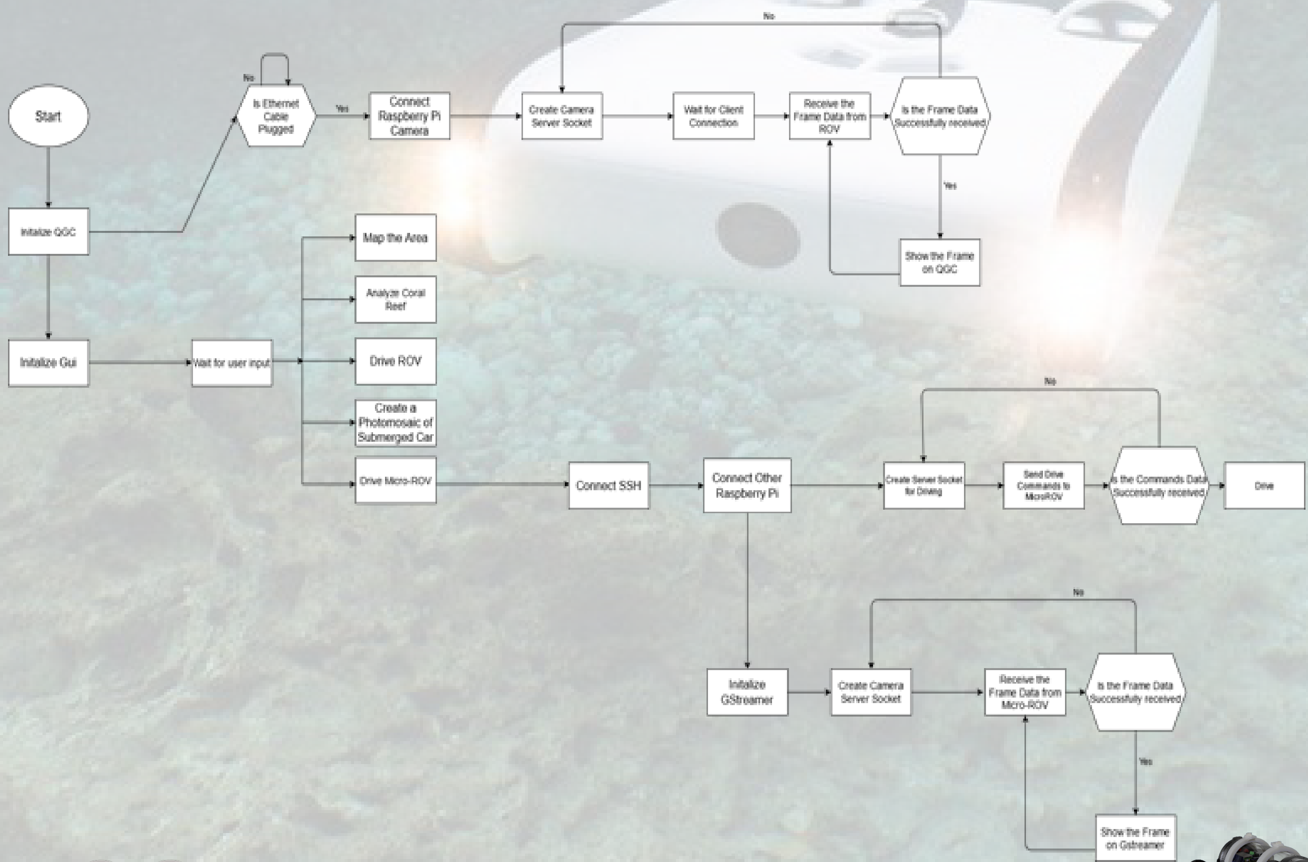
As ITU ROV Team, we would like to thank our parents & families, friends, our precious sponsors, MATE Center for providing such a competition event, and everyone who supports us!

Appendix

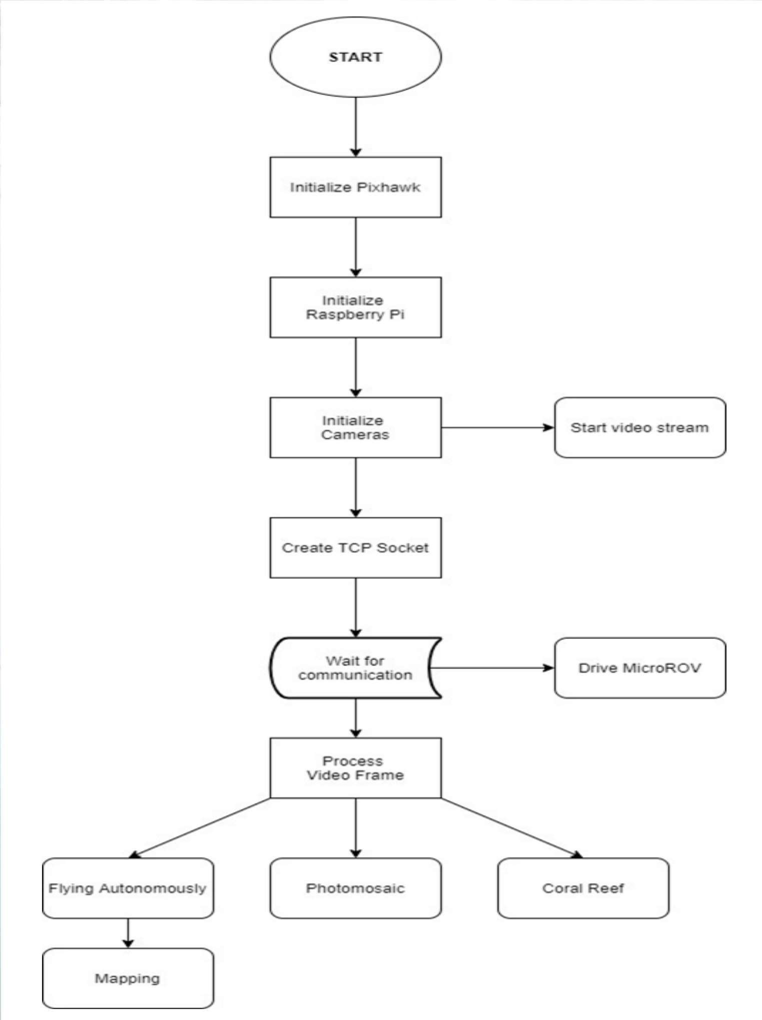
Appendix A - Electrical System Integration Diagram



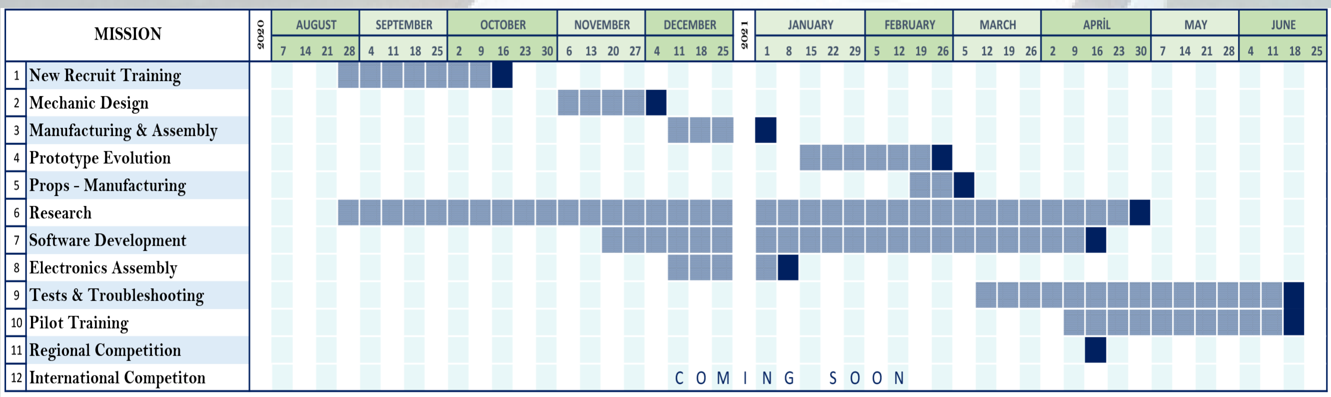
Appendix B - Ground Control Station Flow Diagram



Appendix C - The Vehicle Flow Diagram



Appendix D - Gantt Chart



- » July 1, 2021: Submission deadline for Marketing Display
- » July 1, 2021: Deadline to register for a scheduled time slot for the company's Engineering Presentation, which will take place between July 16-22, 2021
- » July 15, 2021: Submission deadline for the company's Product Demonstration and Safety Inspection videos

Appendix E - Budget

	State	Expenses	Amount USD	Number	Total
Mechanical Expenses	Purchased	Epoxsy Resin	14.55	2	29.1
	Purchased	RTV2 Silicone	48.13	1	48.13
	Purchased	Polyurethane Resin	13.34	2	26.68
	Purchased	Quick Setting Epoxy Glue	-	5	12.12
	Purchased	Alumium Sheet (8mm*1000mm*2000mm)	206.12	-	206.12
	Purchased	Polyethylene Sheet	33.95	1	33.95
	Purchased	Quick Setting Adhesive Kit	3.64	5	18.2
	Purchased	Insert Nuts	-	50	5.81
	Purchased	Nema 23	23.04	3	69.12
	Purchased	Pleksi Protector	65.47	2	130.94
	Purchased	608 Ball-Bearing	2.42	12	29.04
	Purchased	Acoustic Insulation	2.06	10	20.6
	Purchased	Coupler	2.42	8	19.36
	Purchased	Steel Shaft m8 1 m	3.96	4	15.84
	Purchased	Vibration Isolation	2.27	5	11.35
	Purchased	Spindle Motor	8.49	1	8.49
	Purchased	Acrylic End Cap (130 mm, 12 holes)	9.99	1	9.99
	Purchased	O-Ring Flange (130 mm)	32.99	1	32.99
	Purchased	Underwater Optical Glass Dome Lens (130 mm)	42.99	1	42.99
	Purchased	Waterproof PMMA Tube (130 mm diameter, 400mm length)	27.77	1	27.77
	Purchased	M10 Big Cable Penetrator	4.9	18	88.2
				Mechanical Expenses Total:	$ 886.79
	State	Expenses	Amount USD	Number	Total
Electronical Expenses	Purchased	Jetson Nano Developer Kit B01	143.10	1	143.10
	Purchased	DG832 Function Generator	479.34	1	479.34
	Purchased	AATech ADC-3306D Regulated Power Supply	190.99	1	190.99
	Purchased	Oscilloscope	179.06	1	179.06
	Purchased	Programmable Solderin Iron	110.78	1	110.78
	Purchased	J-Link EDU	92.93	1	92.93
	Purchased	Beaglebone Black 4G	67.01	1	67.01
	Purchased	Logic Analyzer	8.21	1	8.21
	Purchased	UT-201+ True Rms Digital Inductive Pickup	35.52	1	35.52
	Purchased	Silicone Mat 440mm x 310mm	10.52	1	10.52
	Purchased	5 m USB 2.0 Connector	8.36	2	16.72
	Purchased	ZD-11E Pcb Holder	8.60	1	8.60
	Purchased	STM32 Processor Kit NUCLEO-L432KC	14.00	2	28
	Purchased	48V to 12V 30A IP68 Regulator	28.53	1	28.53
	Purchased	Circuit Board	1000.00	1	1000.00
	Purchased	NUCLEO-H743ZI2	71.15	1	71.15
				Electonical Expenses Total:	$ 2,470.46
				Total Costs:	$ 3,357.25

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