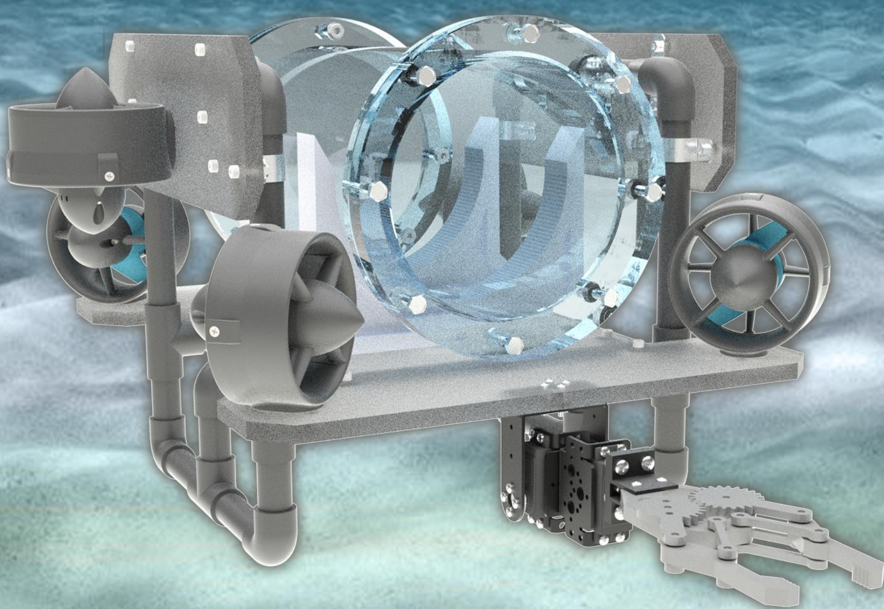
ITU ROV TEAM

Company Mentor

Name		Department	Role
Mr. Bilge	Tutak	Civil Engineering (BSc) Coastal and Oceanographic Engineering (PhD)	Team Consultant

Company Employees

Name		Department	Role	Degree
Mr. Vatan Aksoy	TEZER	Aerospace Engineering	Chief Executive Officer	Sophmore
Mr. Yasin	YAĞIN	Meteorogical Engineering	Chief Operating Officer	Sophmore
Mr. Ulubilge	ULUSOY	Aerospace Engineering	Chief Technical Officer - Mechanics	Sophmore
Mr. Sencer	YAZICI	Control And Automation Engineering	Chief Technical Officer - Software / Pilot	Freshman
Mr. Özgür Cem	TAŞ	Electronics And Communication Engineering	Chief Technical Officer - Electronics	Freshman
Mr. Ege	SAYGILI	Control And Automation Engineering	Chief Safety Officer	Freshman
Mr. Enes	DEMİRAĞ	Electronics And Communication Engineering	Chief Financial Officer	Freshman
Mr. Emre Göktuğ	AKTAŞ	Electronics And Communication Engineering	Electronics	Freshman
Mr. Alparslan	HALAÇ	Mechanical Engineering	Mechanics	Freshman
Mr. Bedir	ACAR	Naval Architecture and Marine Engineering	Mechanics	Freshman
Mr. Fethi	KÜP	Shipbuilding And Ocean Engineering	Mechanics	Senior
Mr. Burak	ÇOBAN	Shipbuilding And Ocean Engineering	Mechanics	Senior
Mr. Tarık Şansal	Şükür	Mechatronics Engineering	Electronics	Sophmore
Mr. Mustafa Oğuzhan	Akdoğan	Aerospace Engineering	Software	Freshman



Istanbul Technical University, Istanbul, Turkey

MATE International ROV Competition 2017 Explorer Class

Table of Contents

1. Abstract

In Turkey underwater vehicles are not common. Knowing this and in the light of our past experiences we have decided to build a ROV to raise a common sense in our country by giving seminars, building such vehicle and make use of the vehicle in various areas. We plan to use MATE ROV competition as a step for further developing the underwater industry in Turkey. Our robotics club has been working on numerous fields, such as Rover (which will be attending to University Rover Challenge this year), UAV (Unmanned Aerial Vehicle), Hyperloop, thrash hunter and finally ROV.

This year mission concept is crucial, as it is futuristic concept. Especially, having 2 members in our team who have contributed developing an Hyperloop concept that competed in SpaceX Hyperloop Pod Competition finals, we are aware of how near future is.

This year we have decided to build an easily-controlled ROV. With 6 thrusters 5 Degrees of Freedom (DOF) control is achieved. We also designed a 3 DOF robotic arm and a two finger gripper so that we will be easily manipulating and carrying objects. Trusting our software abilities, we have developed all the control algorithms by ourselves, by backing up ourselves with a commercial autopilot.

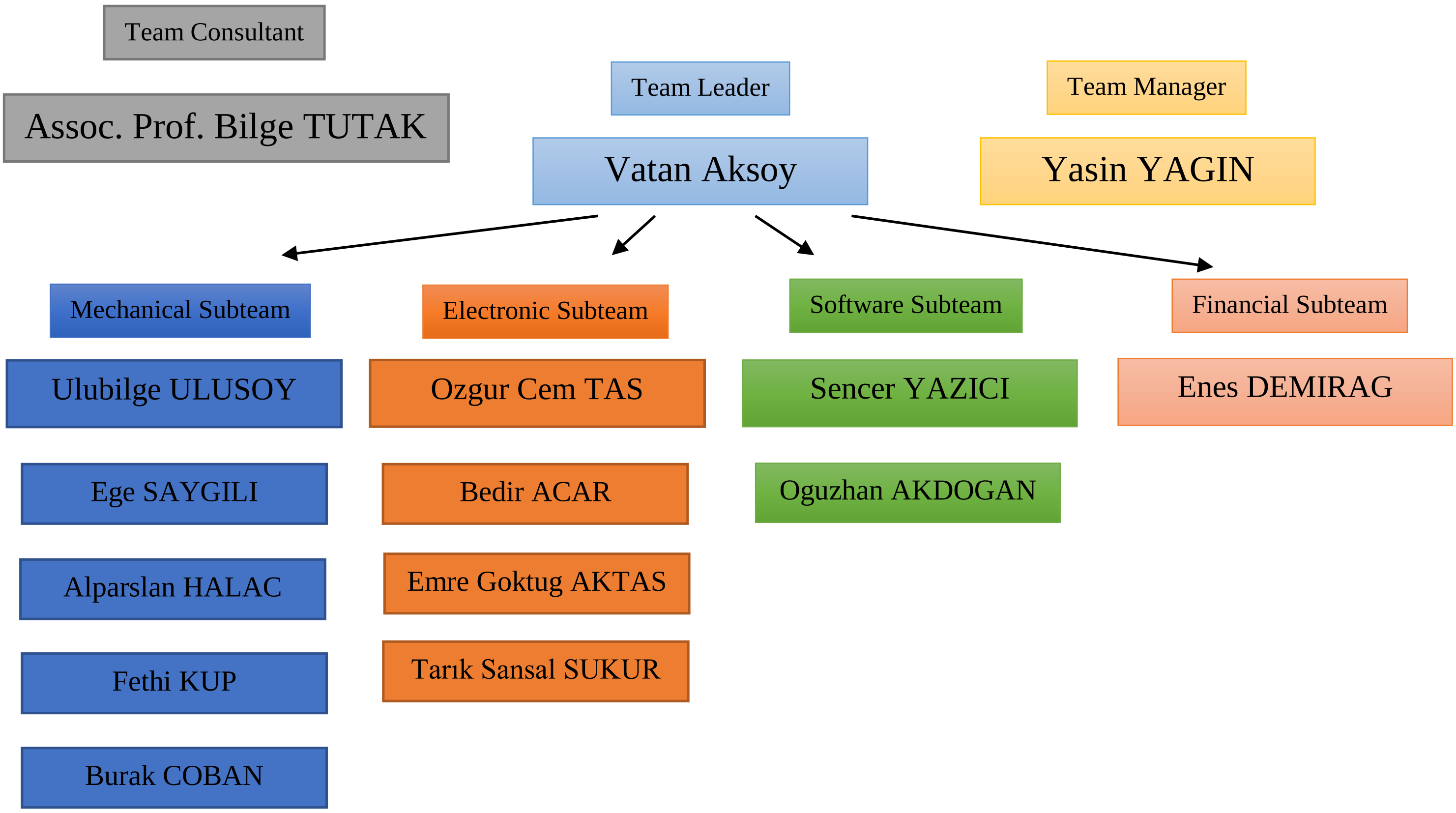
As it's our first attempt to build an ROV, we have always considered to keep things simple in the designing phase. Also considering the bonus dimensions, we have designed our ROV to get maximum of the bonus points by keeping the vehicle lightweight and small in physical dimensions.

Another point to mention is, we are a fully open-source team. As we keep learning from the big open source society, we have decided it is time to contribute and give back to this society. Doing this, helped us to be more organized. Our full software and hardware designs can be found at our project's GitHub page, https://github.com/iturov .

2. Team Structure

The ROV Team include bachelor students from Control and Automation Engineering, Electronics and Communication Engineering, Electrical Engineering, Aerospace Engineering, Mechanical Engineering and Naval Architecture and Ocean Engineering departments of Istanbul Technical University.

Table 1 - Team Structure



3. Safety

As it is our very first year, we are aware that we are not experienced about underwater. So, we put as much as safety features on ROV and we tried to wear safety equipment as much as we can while working with our ROV. Everything outside the acrylic tube is waterproofed by itself. And also water tightness of the final tube is tested by keeping it underwater for several days. As, we had so many problems with water tightness, we kept testing strict. At last, we have ensured that no water leakage will happen in a dive after continuous success in water tightness in our tests. Although we trust in our electrical system, as a general safety rule and as indicated in the competition rules a 30-amp fuse is used for protection. To ensure structural safety we used a high factor of safety for our calculations. To keep continuity of our ROV, all the screws, nuts and other small mechanical parts are stainless.

4. Design

4.1. Mechanical Design

In mechanical design, the first thing was the creation of the concept designs in computer-based environments. To do this, it was necessary to make research about underwater vehicle concepts from previous MATE competitions and commercial products. In research process, much brainstorming was done with academic people and team members. When the ideas were shaped, size and weight restrictions of MATE competition were merged with the ideas. Therefore, based on the ideas two concept designs (Figure 1 and Figure 2) were created by using Solidworks program, then one of them was chosen as the final product.

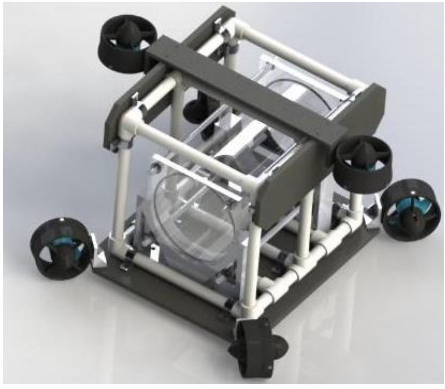


Figure 1 - Initial design number one.

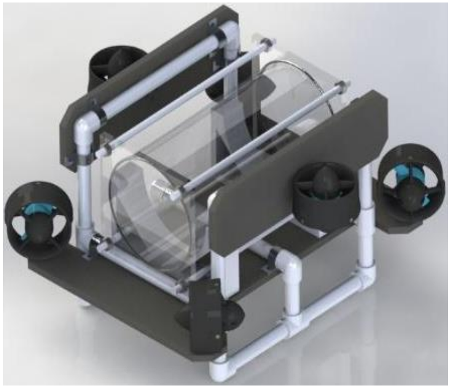


Figure 2 - Initial design number two

When the design was selected, the production phase was begun. Firstly, a test prototype (Figure 3) was created by using minimum financial resources to see the weak sides of the design. Considering the weak properties and the production issues, several iterations were done on the design in computer based environment. Finally, according to this design final product were produced(Figure 4).

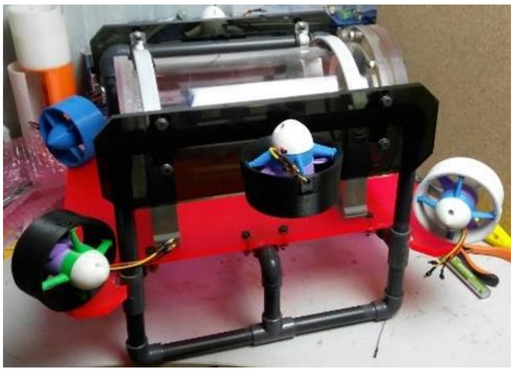


Figure 3 - First prototype.

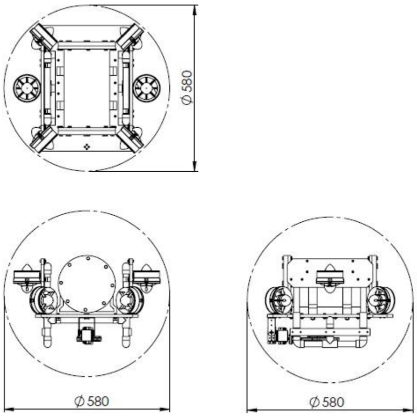


Figure 4 - Dimensions of BeeROV

4.1.1 Chassis

Chassis of the ROV was done by using only 20 mm PVC pipes and pipe fittings. According to technical drawings of the chassis design, PVC pipes were cut into several sizes by using PVC cutter. Then, these pipes were connected together with pipe fittings and special PVC glue. Pictures of the actual product(Figure 5) and 3D model (Figure 6) in Solidworks could be found in below figures. More details about the final product were reported in below sections.

Figure 5 - Assembly of Chassis

Figure 6 - 3D model of Chassis

4.1.2 Plates

In our design base and side plates have crucial effect on the vehicle. While base plate carries main payload and four motors, side plates carry other two motors, which are placed vertically, and completes the design as aesthetically. The plates were produced from 10 mm Plexiglas sheet by laser cutting according to technical drawings (Figure 7).

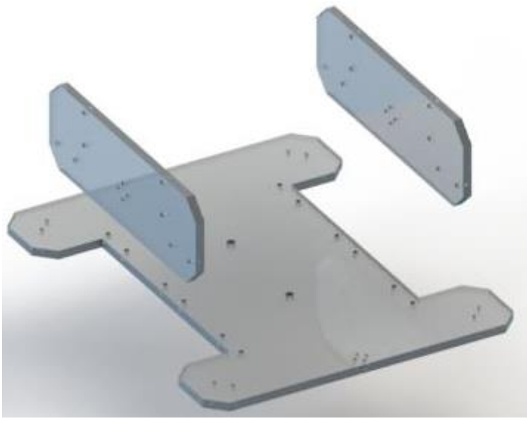


Figure 7 - 3D model of Plates

4.1.3 Electronics Case: Acrylic Tube

The electronics case design was one of the most important topic in the mechanical design process because the case is the heart of the ROV and electronic components inside of it must be protected well. The first concept design of electronics case was a sealed acrylic cylinder (Figure 9) with square acrylic lid (Figure 8) with closed with long grub screws.

However, after some brainstorming, square lid was changed to round lid with screw and nut joints and sealing was done with silicone gasket with rubber O-ring.

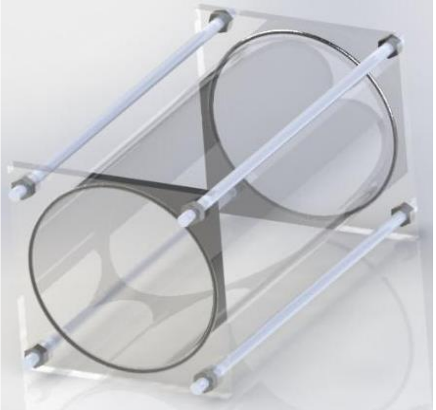


Figure 8 - Acrylic cylinder with square acrylic lid

Figure 9 - Acrylic cylinder with cylinder acrylic lid

Therefore, the design of acrylic tube as electronic case was finalized and produced as an acrylic cylinder and two round acrylic lid and one extra stainless steel lid for unexpected situations. One acrylic lid and the stainless steel lid was specialized for cable exit with cable glands (Figure 10) that are used to extend the cables from inside of the electronics case. Both lids were designed and produced separately.

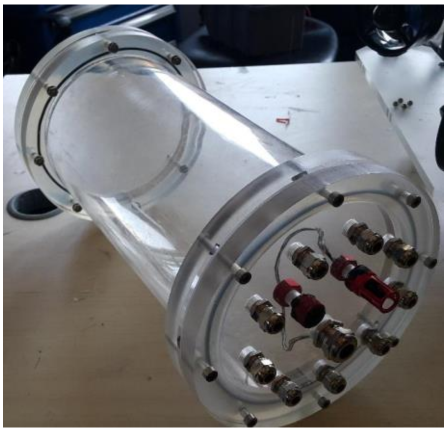


Figure 10 - Acrylic cylinder with cylinder lid and glands

For acrylic lid, holes were opened and tap and die set was used to create threads inside of holes for cable glands because of thickness of acrylic lid. However, metal lid was produced from thin stainless steel sheet and the cable glands fit perfectly to the lid. The acrylic lid with cable glands, which is the main lid of our ROV, could be seen in above and below figures and the stainless steel lid which was produced as a safety precaution could be seen in below figure.

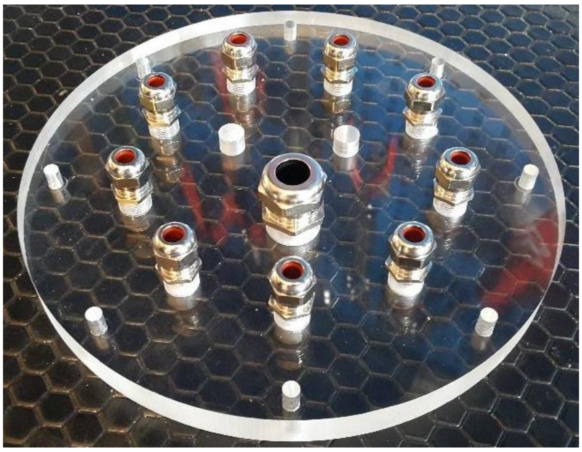


Figure 11 - Acrylic lid and metal glands

Figure 12 - Metal lid with metal glands

4.1.4 Robotic Arm

Robotic arm is one of the most important parts of our ROV. So we worked very hard during solid modeling. As a result of tests, it was decided to use aluminum with a suitable waterproof coating (white aluminum oxide) according to design parameters. As the ROV has 5 DOF control without the pitch control, it was decided to add pitch axis control to our robotic arm.

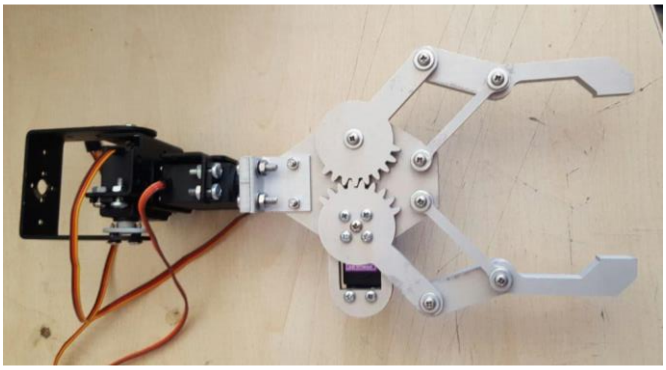


Figure 13 - Robotic Arm

Also to accomplish tasks, it was added a rotation axis and a grabbing axis to the gripper. By having mentioned flexible control mechanism, it was achieved a 3 DOF robotic arm (Figure 13) control on our ROV. This will surely help the ROV a more dominant control on the tasks.

4.2 Water Proofing

Unlike any other environment, being underwater brings many challenges. Almost all of the components used in the making of an ROV (motors, cable connections, fasteners etc.) needs to be waterproofed. In the BeeROV, the initial consideration about waterproofing was how the electronics case could be safe in water environment. To achieve a waterproof electronics case there are two things needed to be done; sealing of lids and cable exit locations. Lid sealing was done by using a silicon gasket and O-ring together (Figure 14) as a hybrid system. For cable exit locations, the primary idea was using underwater connectors, such as Weipu SP13s, but this solution proved to be expensive and an overkill for our specific application. Therefore, special underwater cable glands (produced according to our specifications by one of our sponsors, Figure 16) were used as it was stated previously.

Figure 14 - Gasket and O-ring

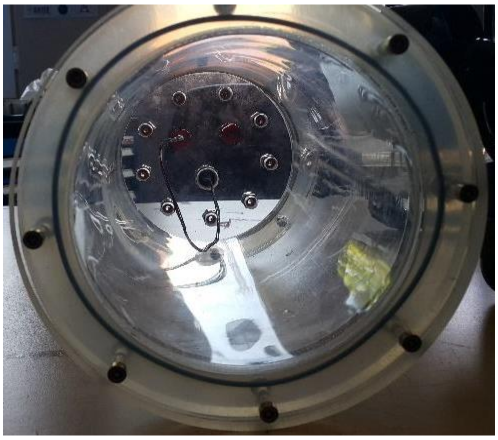


Figure 15 - Acrylic cylinder and lid with gasket and O-ring

Figure 16 - Metal glands

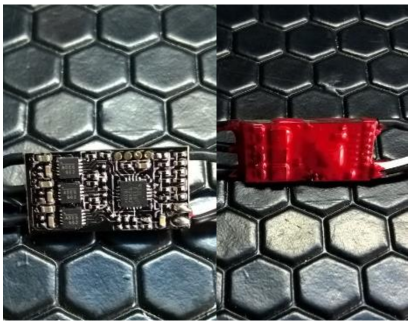


Figure 17 - Left: Non-covered ESC Right: Covered ESC

At this stage, we were faced with the problem of exposed wiring underwater. Given that soldering and heat shrinking a connection will not be sufficient enough for water tightness we decided to use polyurethane mastic and hot melt glue in the spaces between the heat shrinking tube and the cable. However, after some tests we have found out that water has leaked into the cables. Doing some more research, we settled on using liquid electrical tape on the cable connections exposed to the water. Another challenge was the water tightness of the servos used in our robotic arm. Firstly, Emax ES3005 waterproof servos was used for our robotics arm. In the early tests, servos worked properly, but after the regional competition, some water found inside the servos, which caused noise. As a result, servos didn't function properly, so we decided to further waterproof our servos. First off marine grease was used for mechanical part of the servos and liquid electrical tape used for electronics on the servos and covered with plastidip. An oring placed on around the shaft. 2-meter underwater test passed. Lastly, all ESCs and main circuit covered with liquid electric tape (Figure 17) in case of condensation of moisture on circuits.

4.3 Propulsion

It has considered having lightweight, easily controlled set of motors for our propulsion system. Being a low budget team, firstly, it was tried to remove and use our drone's motors, which was built in the previous year by our club. It was designed a nozzle for the motors and 3D printed (Figure 19) them by using a handmade 3D printer. The waterproof of the motors were tried by using several epoxy types. Although, a few successful pool tests with the motors, it was eventually decided that waterproofing of these motors not enough as soon as seen rust inside (Figure 18) of some motors after the tests.

Figure 18 - Rusty brushless motor

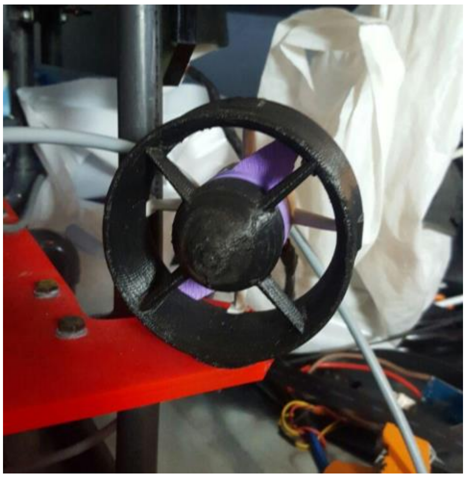


Figure 19 - 3D printed Nozzle

Having a monetary donation of $1400 from our sponsor, we could finally afford ready-made motors and thrusters. Therefore, it was ordered Blue Robotics T100 Thrusters, which are quite reliable in field of underwater robotics(Figure 20). After numerous successful tests, it was ensured that final propulsion system is reliable. Six motors were used with four of them being placed horizontally and 45° angle to each other at the bottom side of the vehicle. Other two motors are placed vertically at the top side of the vehicle for controlling the depth and roll axis. T-100 Thruster's performance table is given below, as obtained from spec sheets of the product. As can be seen, the thrust given by the thrusters are more than enough for having a smooth control.

Performance		
Maximum Forward Thrust	2.36 kgf	5.2 lbf
Maximum Reverse Thrust	1.85 kgf	4.1 lbf
Minimum Thrust	0.01 kgf	0.02 lbf
Rotational Speed	300-4200 rev/min	

Table 2 - T100 Thruster performance table

Figure 20 - T100 Thrusters on our final ROV

4.4 Electrical Design

As strictly indicated in the rules, this year 48 V power supplies with Anderson connectors will be used, and the DC-DC voltage conversion must be done on the vehicle. Also, again referring to rules, ROV's will be limited to 30 amps. Considering these rules, we have built a reliable electrical system using Commercial Off-The Shelf (COTS) products. For converting 48V to 12V we have used Mean Well DC – DC convertors which ensures an input voltage between 23V to 72V converted to a fixed 12V (Table 3). While this 12V will directly be used to supplying 6 motors, an UBEC, which basically takes 12V input voltage and gives 5V 3A output, will be used to supply the Raspberry Pi by the micro-USB cable. Two 5VDC 3A DC-DC regulators, which are embedded in our power distribution boards, are used in in parallel for a total of 6A to supply the robotic arm's 3 servo motors.

Figure 21 – 30-amper fuse

Figure 22 - T-Plug Connectors inside the ROV

To ensure safety, a 30A (Figure 21) fuse was placed to near end of the tether (within 30 cm of the power supply) to the main 48V voltage supply. Several voltage and current tests were done, using our university's Electrical Engineering Faculty laboratories. We have used standard high power T-Plug and XT60 connectors inside the ROV and Anderson Connectors on the 48V end.

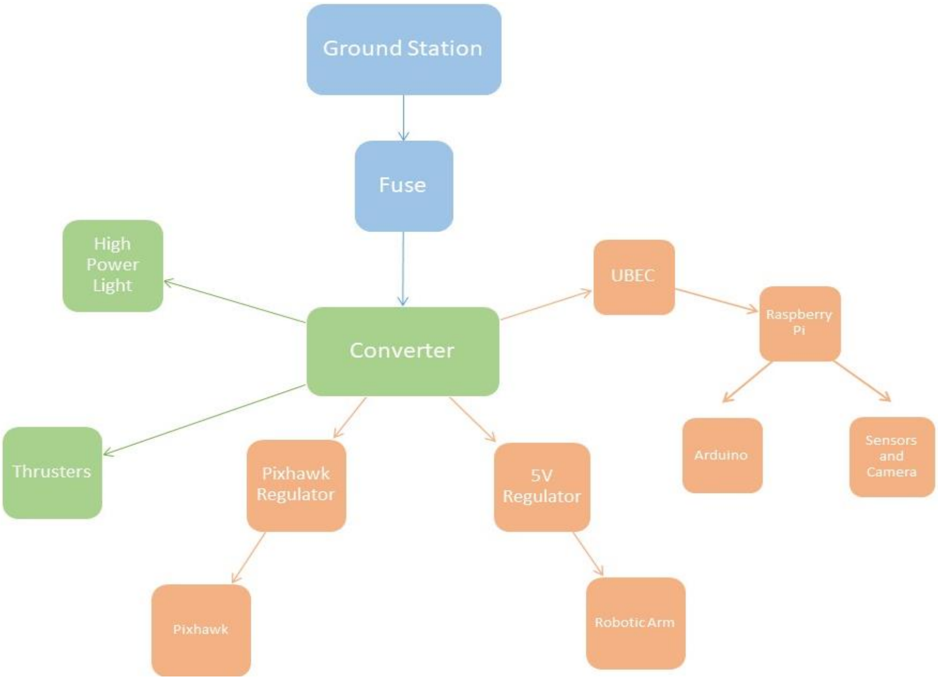


Table 3 - Electrical diagram of the ROV. Blue: 48 V, Green: 12V, Orange: 5V

Apart from those we have used 15-meter high power cable as our main tether. With its 9 AWG (Figure 23) thickness, it ensures our ROV is supplied with enough power with little or no loss of power.

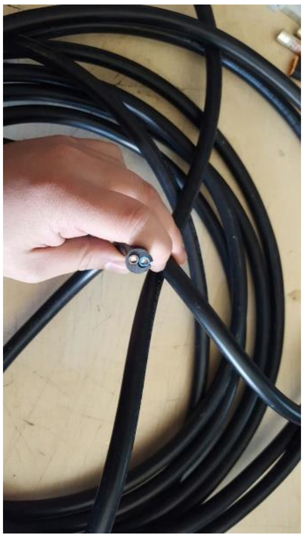


Figure 23 – 9 AWG Tether Cable

4.5 Software and Control System Design

4.5.1 Communication

The vehicle is controlled by a user from the surface. To achieve that a 2-way communication system had to be created. For that, an Ethernet line is used. The communication protocol between the vehicle and the ground station is TCP/IP based.

On the vehicle side, Raspberry Pi's network interface was used as the main processor. On the ground station side, a laptop PC with Windows 10 OS installed was used. To establish a TCP communication, one of the PC's must be acting as a server and the other as a client. In this system, Windows PC is the server and the Raspberry Pi is the client. The reason for that is Windows PC emulates its network port as a router and obtains an IP for the connected client. This is a benefit for PC to be server, because the PC obtains new IP's to the client. Therefore, the client connected has a non-static IP, but the PC has a static IP as follows: 192.168.137.1.

On the ground station of the communication, a server algorithm runs in a custom ground station software written by our team in the C# programming language, with the Visual Studio 2017 Community IDE.

The communication algorithm starts listening every IP from the given port in a new thread. This is required not to affect other processes running in the ground station application, as it runs the communication algorithm in the background.

On the vehicle side of the communication, Raspberry Pi uses its built-in networking libraries to receive and send data to the server. As a client, Raspberry Pi attempts to connect to server with a given port and IP, which is provided as follows respectively, [Any port number (See Note.1), 192.168.137.1(IP of the server)]. If the attempt results in success, client waits for the server to accept the communication. After that the communication begins. If the attempt fails, client keeps attempting.

The data sending between the server and client is an array of integers. The data coming from client to server (Outgoing Data), consists of sensor values and other necessary information about the vehicle. The data coming from server down to client (Incoming Data), consists of user commands, and other necessary commands in order to operate vehicle.

Outgoing Data[Array]

1.st member: PRESSURE SENSOR DATA [Float]

2.nd member: DEPTH DATA [Float]

3.rd member: TEMPERATURE DATA [Float]

4.th member: DISTANCE DATA [Float]

5.th member: BLUETOOTH DATA [String]

Incoming Data[Array]

1.st member: THROTTLE VALUE[Integer]

2.nd member: FOWARD/BACK VALUE[Integer]

3.rd member: RIGHT/LEFT VALUE[Integer]

4.th member: LIGHT INTENSITY VALUE [Integer]

5.th member: ROLL VALUE[Integer]

6.th member: YAW VALUE[Integer]

7.th member: ROBOTIC ARM ELBOW 1 VALUE[Integer]

8.th member: ROBOTIC ARM ELBOW 2 VALUE[Integer]

9.th member: ROBOTIC ARM ELBOW 3(Gripper) VALUE[Integer]

[Note.1: The port number is an unsigned 16-bit integer, so has to be in range 0-65535. This port has to match the port that server listens. In our system the port number is 8092.]

A. Camera Streaming

For capturing video, as a main camera Raspberry Pi Camera RaspiCam is used. Then, captured frames streams in M-JPEG format. The streamer used in this application is Raspberry Pi MJPG Streamer by Jackson Liam.

The link to his and the project's GitHub page: "https://github.com/jacksonliam/mjpg-streamer". The camera stream is running on port 8091.

On the ground station side for receiving streaming frames, an external library Aforge.NET, is used. The link to Aforge: "http://www.aforgenet.com".

In AForge's video library MJPEGStream class is used to receive stream. The stream can be accessed via a web browser, too. To set MJPEGStream classes' source or to access via web browser the following link should be obtained:

"http://IP_ADDRESS_OF_STREAMER:STREAMING_PORT/?action=stream"

In our case the link is: "http://ip_address_of_raspberrypi:8091/?action=stream"

The received frames are displayed on the ground station in bmp format.

B. Direct Connect

A direct connection to Raspberry Pi can be done by 2 ways: With SSH or with VNC

-SSH (Secure Shell): This protocol enables user to connect Raspberry Pi's Terminal.

To connect following information are provided

IP: raspberrypi.local

Port: 22

-VNC: This method enables user to see Raspberry Pi's desktop real-time. VNC viewer application is used for connecting. To connect following information is provided:

IP: raspberrypi.mshome.net

Note: VNC viewer connects to the raspberry pi at a specific port "8000". This "port" option wouldn't be asked for connection.

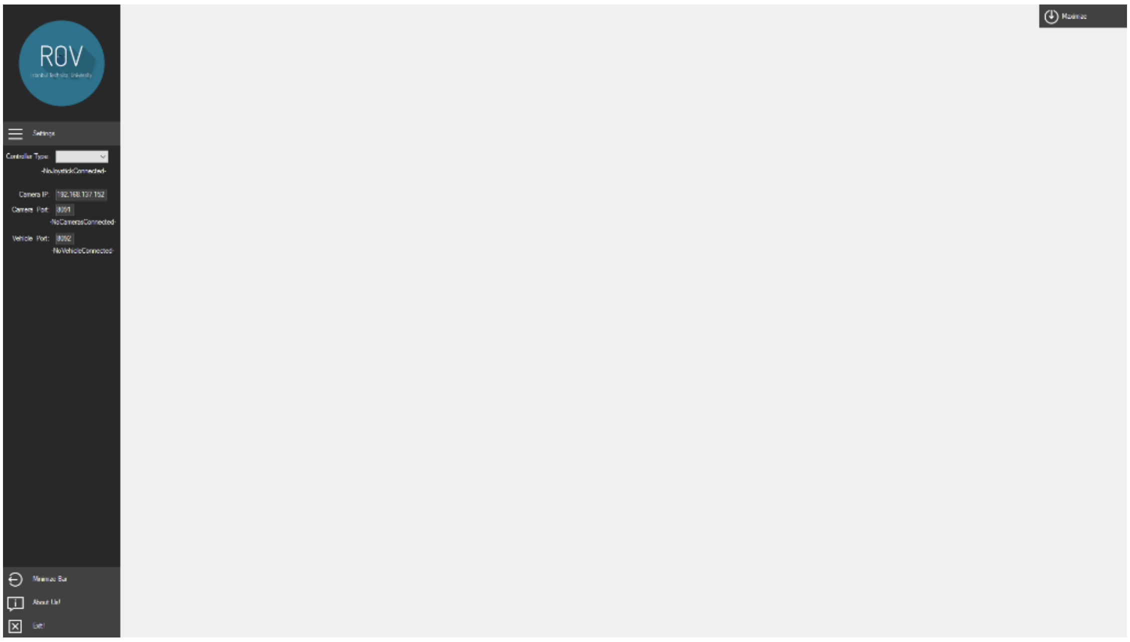


Figure 24 - User Interface

4.5.2 User Interface

User can interface with the software through the visual/graphical interface of software (Figure 24). User can change settings such as ports, IP's etc. User can start/stop a connection with the vehicle, start/stop receiving camera stream, or start/stop polling data from Controller.

Polling controller data algorithm uses SharpDX DirectInput libraries. In the software user can use the Dualshock 2 or DualShock 3 as a Controller. User can select between them depending on the type of controller. In the future new controller will be added. User can see received video stream on the background of the software which has 95%- 80% area of the entire screen.

4.5.3 Control System Design & Sensors & Motors & Servos

A. Control System Design

BeeROV operates with a Raspberry Pi as a brain. With the power and capabilities of Raspberry Pi, some control systems can be added in order to stabilize the ROV. In BeeROV, depth values from the sensors used as a feedback for Depth-Lock Control System in order to stabilize ROV at a certain depth. Also, the Gyroscope data and Euler degrees are used as a feedback for Route-Correction Control System in order to move in the route that user wants. Analysis and characteristics of BeeRov made at Istanbul Technical University Robotics Lab.

B. Sensors

BeeROV uses temperature, laser range finder, pressure sensor and a Bluetooth module. Raspberry Pi directly receives pressure sensor data through i2c line, for the temperature, laser range finder and Bluetooth module raspberry pi listens an Arduino Nano on a serial port. Arduino Nano uses built-in ADC (Analog to Digital Converter) to calculate range data from laser range finder, i2c to receive temperature data, UART to receive Bluetooth data.

C. Motors

BeeROV has 6x Little Bee ESC's and 6x T100 thrusters. Esc's are programmed with a Bl-Heli firmware with custom settings. Esc's uses 1000-2000 us pulse width for input. Also ESC's are bi-directional which makes them reversible thus, range of "1000(-max) ----- 1500(zero) ----- 2000(+max)" is used. After receiving user commands, they are directed to the control systems as input, after the calculations in control systems the output feeds in to the motors directly.

D. Servos

BeeROV uses Arduino Nano as Servo motor controller for the robotic arm. The user commands are sent through the serial port to the Arduino Nano. Arduino Nano, uses built-in libraries to control Servos. The external light has the same algorithm with a built-in library to control Servos. The external light has the same algorithm with a servo motor, so it is treated as a servo motor.

4.6 Electronics Design

As stated before, acrylic cylinder used with 30cm length to put all the electronic components including 48V to 12V DC/DC converter, which is the biggest element in our ROV. Volume that needed for converter in acrylic cylinder is a serious problem because of the converter which is really big and which takes lots of space in the acrylic cylinder. We decided to buy smallest ESC that can be find. After buying ESC’s with really small size they are connected with motor cables. ESC’s are located between first tray and second tray where power cables to our power board connected. In tray, power board used in order to optimize number and width of the cables that used in acrylic cylinder.

2 different PCB circuits were designed, to connect components that were used in BeeROV, clearly and precisely to the main controller of the BeeROV electronics system Raspberry Pi B+ also called BeeROV's brain. In order to make Circuit, first of all, long list is made with the components that company decided to use in BeeROV. After that, a schematic design is made in Altium.

Designer program which helped to add and remove components each time as electronic team decided. As tests started by company members in mechanical, waterproofing and software groups, there were few changes including sensors and servos. Every component was checked before design was printed. After planning all the components in acrylic cylinder, BeeROV's main board with 2 layers designed. Circuit with 2 layered design optimized the space by decreasing its volume. PCB that was printed connects Raspberry Pi to BeeROV's electronic system. After some software tests, unfortunately critical problem about I2c converters occurred because of the IP codes of the controlling and electronic system. With having only one option, another PCB should be designed. After some debates, Arduino Nano is chosen to use additionally, to read data from one of I2c which means there should be 2 circuits with one I2c for each. Other electronic elements including Servos, Lumen and Sharp sensor are chosen by electronic team to connect them to Arduino Nano which became second brain of BeeROV. Another PCB is designed in Altium with the same sized and located holes as the first PCB board to fit these 2 boards to each other precisely. Second board is designed with only one layer, which is enough to connect rest of the components. In the end, 2 boards are used in electronic system. As shown in the figure below, 4 M2 screws are used to connect the first circuit to Raspberry Pi (Figure 25).

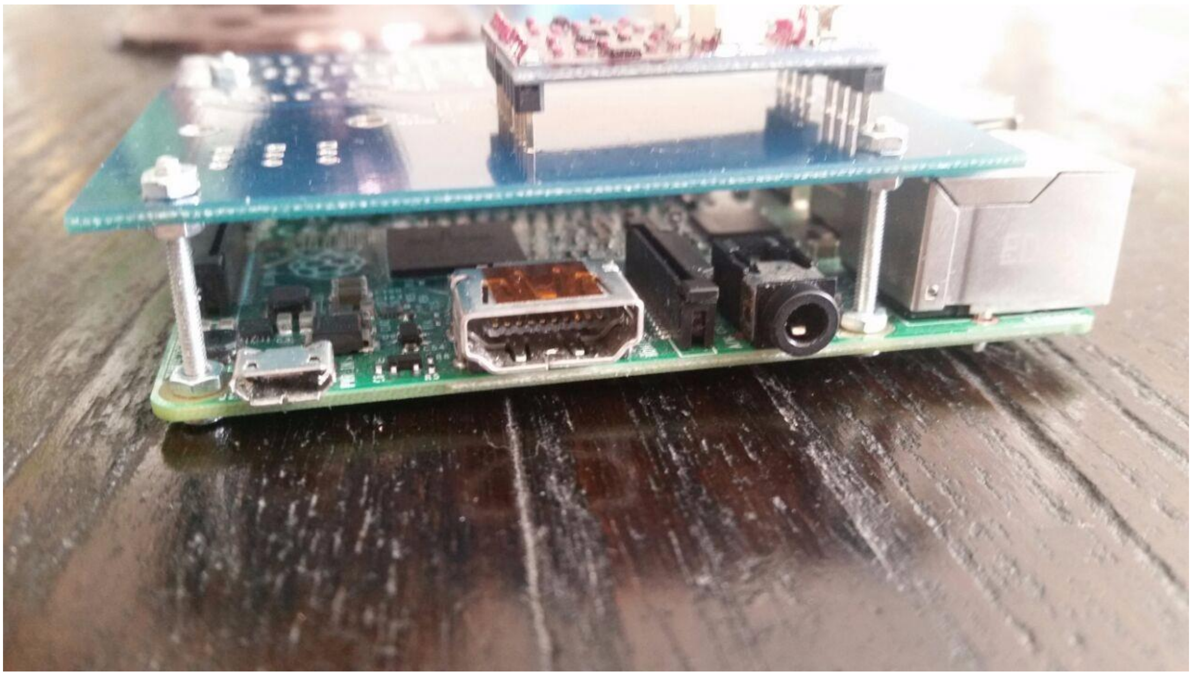


Figure 25 - First board connected with Raspberry-Pi

At the end, lots of components are used and these components connected to each other with PCB that designed in PCB design software Altium. Images below show schematic (Figure 27 and Figure 29) and PCB designs (Figure 26 and Figure 28) for the first circuit which named ITUROV.

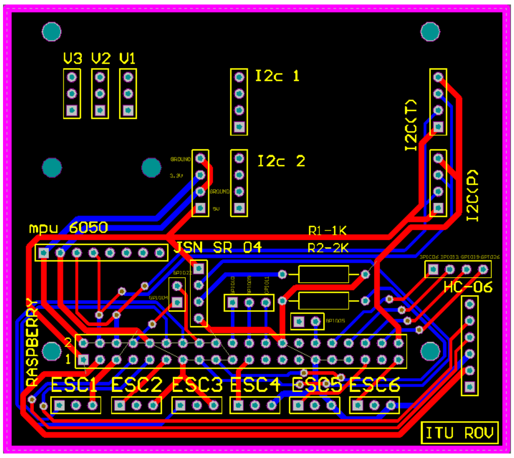


Figure 26 - Two layered first PCB

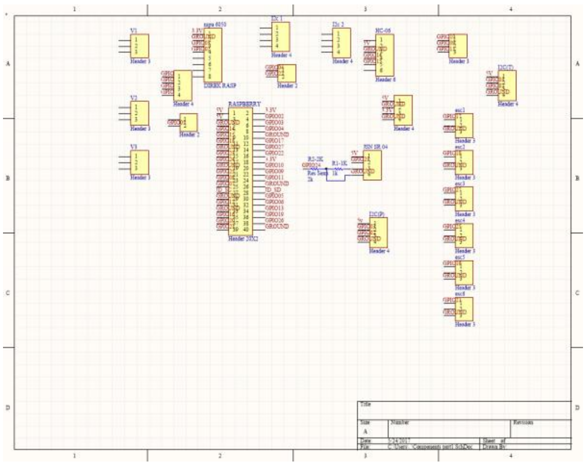


Figure 27 - First Schematic

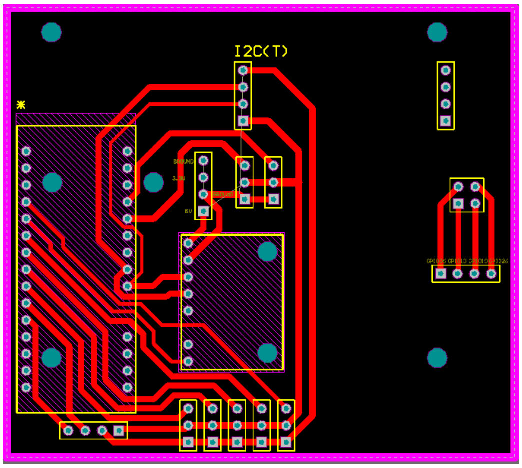


Figure 28 - One layered second PCB

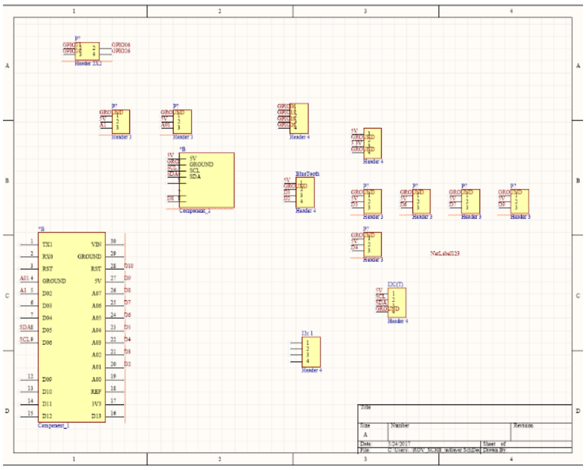


Figure 29 - Second Schematic

After printing these 2 boards headers are connected to fit components and cables precisely to the electronic system. All the cables and headers are grouped by their function. For example, elements with the same input order like Servos and Lumen (Signal-5V-Ground) located together to package cables easier.

4.7 Troubleshooting and Testing

We have limited resources and options to be able to test our prototypes. Most of the test were done in a stability tank in Faculty of Naval Architecture and Ocean Engineering in Istanbul Technical University. The model tank (Figure 30) has dimensions of 7 x 7 m with a depth of approximately 1 m.

Figure 30 - Initial version of ROV in stability tank test

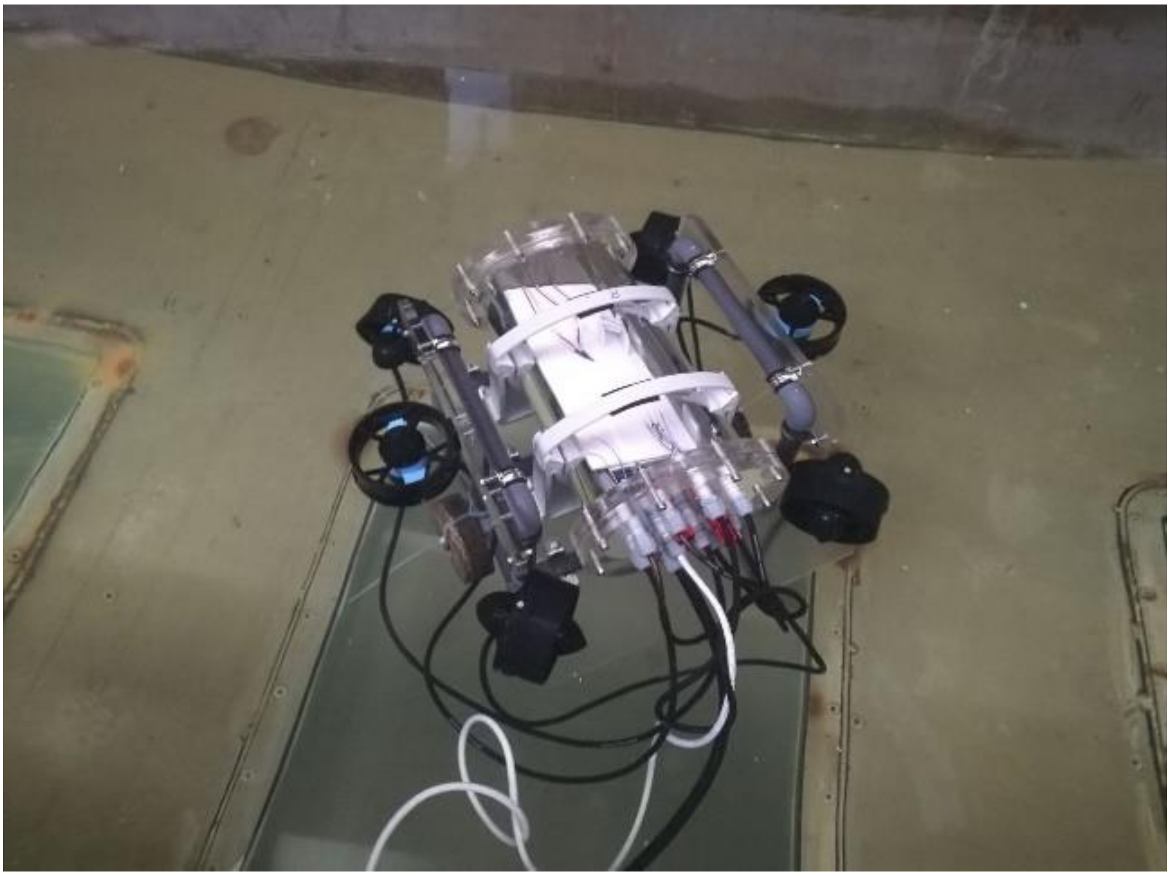


Figure 31 - Final version of ROV in stability tank test

In addition, Istanbul Technical University has a small pond inside the campus that we can do real environment test with the vehicle. At the final stages of the BeeROV, we have tested our model also in the small pond (Figure 32). Therefore, we have made sure that the BeeROV is tested against an uncontrolled environment.

Figure 32 – Our Final ROV in the pond test at night

5. Challenges

During the building of BeeROV, our biggest challenge was time management. Our young and inexperienced members had hard time working with deadlines. Adapting to work environment for new engineering candidates can be a daunting task.

Finding sponsors to fund us was another important issue. It is usually hard to find a sponsor in Turkey, but we proved ourselves to our supporters and got the funding we need.

In technical means, waterproofing is a common problem in underwater vehicles. First thing we found was a costly and was a satisfying enough solution, yet something we could not afford. This situation forced us to find a better solution for water leakage. After brain-storming and researching, we came up with a simpler but an effective solution. We redesigned our cable systems and used water-proofed cable glands. These simple yet innovative decisions helped us overcoming the obstacles in our way.

6. Lessons Learned

Although our robotics club is a well-established club among our university, the BeeROV project was accomplished with the new members of the club mostly. We all learned how to design, build and test a vehicle that will work in underwater. Due to lack of experience, the team spend so much time on balancing the center of gravity and center of buoyancy. We saw that testing is as important as designing the vehicle in these kind of projects, as the project has a limited time to be finished. Also we have learned how time management helped us to recover from our past mistakes.

In mechanical manner, it was learned that by thinking simple, useful solutions could be found. By this way, our mechanical design was created with standard industry products with a small budget in brief. For more detail, main lessons were taken from waterproofing of electronic case which was produces as acrylic tube which is consist of cylinder with lids. To make this system watertight, first, a thin rubber gasket was used. However, the rubber gasket did not perform well because it was too hard to compress between cylinder and lid. Then, 3 mm silicone gasket was used between lid and cylinder to prevent water entrance. Several tests were conducted in water pools in faculty laboratories and it was seen that this system also cause water leak in the tube because there was still a thin film pattern causes this problem, the leakage was small but it was not an option. Finally, a hybrid system was created with 3 mm silicone gasket and a 2 mm O-ring, so the straight pattern was broken with extra O-ring. The system was tested in several ways and as a final test it was rested in a pool for 24 hours, there was no leakage in these tests. Therefore, a watertight case was created without cable exits. For cable exit, it was also another challenge for our team. Due to low budget at the beginning of production phase, it was used standard plastic cable glands for cable exits but because of the continuous work on the ROV, plastic fatigue occurred on these cable glands and water leaked at these locations. After some industry research, a cable gland manufacturer was found and special underwater cable glands were provided from this company with the great effort of our team. Therefore, this problem was also solved and the waterproof electronic case was finalized.

7. Future Improvements

This year we have learned how to deal with an underwater vehicle. As most of the team is interested in software and electronics, we want to start building an Autonomous Underwater Vehicle next year if everything goes accordingly. Also as indicated in Electronics Design section of this document, we have bought high quality sensors and will add more to our ROV. We plan to use the BeeROV in minor research and exploration projects (ocean engineering, marine pollution, oceanography etc.) as well.

8.Reflections

This being my first year at my university I had an unquenchable thirst for new experiences and new fields. So I figured my best shot for these experiences was to join a project group and looking back I must say I made a great choice. I have learned so much, and I think you learn best when you are deeply involved with what you are doing; at least I do learn best this way. The ROV process was difficult, very informative and "making" an underwater vehicle was very rewarding and a lot of fun. I wish to continue to take parts in projects in the years to come and to improve myself and people that I am working with. I want to thank my newly made friends for their devotion to this project, I have learned so much from them. Thank you all for being there! (Ege Saygılı, Team Member)

9.Budget

At the start of the year, one of the first things we did was to prepare a budget plan to present what we needed to realize our project to our sponsors. Initially we have estimated a lower budget in the electronics part as we were thinking to 3D print our nozzle and use the brushless motors from an old drone of our robotics club. After we were dissatisfied with our motors we have decided to buy a reliable motor from Blue Robotics. Also having less monetary donation than we have expected caused less people to get their flight tickets and less people to attend to the competition. All the differences can be seen if compared with the project costing part of this document.

Category	Type	Amount Expected($)
Electronics	Cost	-500
Electrical	Cost	-300
Mechanical	Cost	-300
Travelling and Other	Cost	-8400
Team Income	Income	+10000
Net Balance		+500$

10.Project Costing

10.1 Electronics Costs

Product	Type	Source	Quantity	Current Unit Market Value($)	Amount Spent($)
Blue Robotics T100 Thruster	Purchased	-	6	144	864
Bar 30 - Depth Sensor	Purchased	-	1	68	68
I^2C Level Converter	Purchased	-	2	14	28
Celsius Temperature Sensor	Purchased	-	1	56	56
Sharp Distance Sensor	Re-Used	Robotics Club	1	10	-
Lumen Subsea Light	Purchased	-	1	99	99
Fisheye Raspberry Pi Camera	Purchased	-	1	50	50
Raspberry Pi	Purchased	-	2	45	90
Arduino Nano (Clone)	Re-Used	Robotics Club	2	6	-
Little Bee 20 A ESC	Purchased	-	8	15	120
HC-06 Bluetooth Module	Re-Used	Robotics Club	2	6	-
Electronics Total					1375$

10.2 Electrical Costs

Product	Type	Source	Quantity	Current Unit Market Value($)	Amount Spent($)
Wago Terminal Connectors	Purchased	-	8	1	8
Mean Well 48V to 12V DC-DC Convertor	Purchased	-	1	131	131
Cat6 Cable	Purchased	-	20 meters	1	20
High Power Cable	Purchased	-	20 meters	1,33	27
12V to 5V Power Board	Purchased	-	2	6	12
Custom PCB	Donated	Sponsor	1	50	-
Electrical Total					198$

10.3 Mechanical Costs

Product	Type	Source	Quantity	Current Unit Market Value($)	Amount Spent($)
Emax 3005 Waterproof Servo	Purchased	-	3	28	84
Sg90 9g Servo	Purchased	-	1	3	3
PVC Pipes	Purchased	-	10 meters	2,5	25
Plexiglas Components	Purchased	-	-	-	45
30 cm Acrylic Tube	Purchased	-	1	20	20
Screws and Other Mechanical Parts Including Robot Arm	Purchased	-	-	-	45
Mechanical Total					222$

10.4 Travel, Lodging, Administrative and Other Costs

Product	Type	Source	Quantity	Current Unit Market Value($)	Amount Spent($)
Flight Tickets from Istanbul to LA	Purchased	-	5	630	3150
Accommodation for 7 days	Purchased	-	5	245	1225
Food	Purchased	-	-	-	1050
T-Shirt	Purchased	-	15	5	75
Mate Registration Fee	Purchased	-	1	250	250
Miscellaneous	Purchased	-	-	-	250
Traveling and Other Total					6000$

10.5 Income

Sponsor	Type	Amount Donated($)
Istanbul Technical University	Monetary Donation	6000
Turk Loydu	Monetary Donation	2000
Total Income		8000$

10.6 Total Project Cost

Category	Type	Amount($)
Electronics	Cost	-1375
Electrical	Cost	-198
Mechanical	Cost	-222
Travelling and Other	Cost	-6000
Team Income	Income	+8000
Net Balance		+205$

11.References

- Christ, Robert D., and Robert L. Wernli. The ROV manual: a user guide for remotely operated vehicles. Waltham, MA: Butterworth-Heinemann is an imprint of Elsevier, 2014.

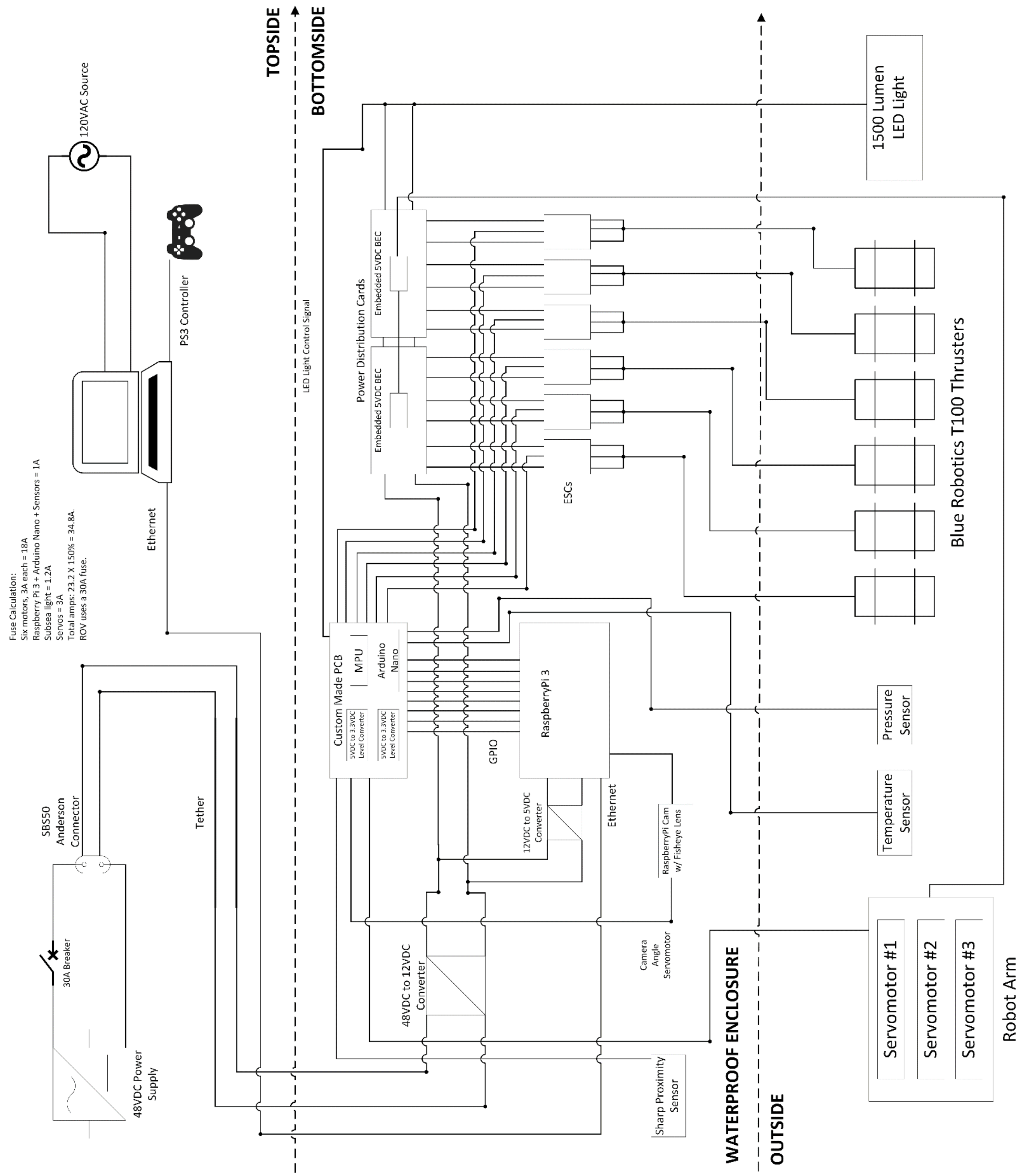
- "How to Build a Robot Tutorials." Society of Robots. Accessed May 26, 2017. http://www.societyofrobots.com/actuators_waterproof_servo.shtml.

- Nise, Norman S. Control Systems Engineering. New York: John Wiley, 2000.

12. Acknowledgements

Appendix

I. System Integration Diagram (SID)



II. Software Flow Diagram