الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

Arab Academy for Science, Technology & Maritime Transport

2016 MATE Regional ROV Competition

TORBINI ROV TEAM

2016 Technical Documentation
Alexandria, Egypt

Torbini's ROV: Dolphin

Name	Role	Major, Semester	Name	Role	Major, Semester
Yousef Awad	Chief Mechanical	Mechatronics Major, 10th Semester	Ahmed Abdulfattah	CADD Designer	Mechatronics Major, 4th Semester
Mohab Eweda	Co-Pilot	Electrical Major, 10th Semester	Ahmed El-Faham	Mechanical engineer	Mechatronics Major, 5th Semester
Hussien Roshdy	Software engineer	Computer Major, 10th Semester	Taher Nazeh	Mechanical engineer	Mechatronics Major, 8th Semester
Ziad Mostafa	CEO, Pilot	Electrical Major, 10th Semester	Mahmoud Badra	Mechanical engineer, Design Lead	Mechatronics Major, 8th Semester
Omar Badra	Tether man and Safety officer	Mechatronics Major,3rd Semester	Eng. Ahmed Ramy	Mentor	Rov pilot/tech
Abdulrahman Aboud	Payload manger	Mechatronics Major, 8th semester	Eng.Mohamed Elbana	Team support	Mechanical Engineer
Mohamed Hassan	R&D and Mechanical engineer	Mechatronics Major, 8th Semester	Eng. Abdulrahman Abouelkhair	Team support	Mechatronics Engineer
Abdulaziz Abdulghany	Payload manager	Mechatronics Major, 4th Semester	Eng.Mai Faramawy	Team support	Electronics Engineer

I. Abstract

Dolphin ROV is our company's fully functional product resulting from eight months of hard work. NASA and the Oceaneering Space Systems (OSS) are in need of a first-of-its-kind dual purpose remotely operated vehicle so Dolphin ROV will play a huge role in the field. It is designed specifically to operate in the harsh environment of both the deep ocean and outer space. Main features of Dolphin ROV are its ability to operate in the ocean under the ice sheet of Jupiter's moon Europa to collect data and deploy instrumentation as well as operating in the Gulf of Mexico to retrieve equipment, collect, analyze and photograph samples.

Dolphin ROV relies on six thrusters: Four thrusters in vertex position for horizontal movement and two for vertical movement. It is also equipped with one main gripper and three cameras.

Power and motion electronics were assembled and modified carefully and our software was developed and coded from scratch via Arduino software allowing the user swift correction of any fault. Furthermore, the ROV's design enables adding or removing any extra hardware or required software.

Safety is our company's main priority so for example fuses and safety labels have been added, control box is removable in order to fix any problem as soon as it happens and our electronics system ensures preventing current from increasing drastically.

This report will take you through the design and construction process and modifications done after the previous year, as well as expenses, safety considerations and future improvements.

From Left to Right:

1st Row: Yousef Awad, Mohab Eweda, Hussien Roushdy, Ziad Mostafa, Omar Badra, Abulrahman Aboud, Muhammad Hassan, Abdulaziz Abdulghany

2nd Row : Ahmed Muhammad Abdulfattah, Ahmed Elfaham, Taher Nazeh, Mahmoud Badra, Eng. Ahmed Ramy, Eng. Mohamed Elbana, Eng. Abdulrahman Abouelkhair, Eng. Mai Faramawy.

Table of Contents

II. Design Rationale

A. Design Process and Evolution:

1. Mechanical Design Process:

The ROV's designing process went through several stages. Firstly, the company's design team made some brainstorming sessions in order to come up with as many ideas as possible. Few sketches were made before settling on the final design of Dolphin. Upon designing Dolphin, several factors were considered such as cost, stability, complexity, ease of manufacturing and motion flexibility under water. The mechanical team was keen on building an ROV which is capable of accomplishing the tasks requested by the customer. The designs that were sketched complied with the size and weight limitations and sketches for the manipulator considered the minimum and the maximum size of the objects that would be held by it. A 3D model was then made using Computer-Aided Design and Drafting (CADD) to validate the concepts. The design was also modelled using SolidWorks™ and SolidWorks™ flow simulation to test it under real conditions and to make the required modifications. Finally, the design was prepared for machining by being converted into Drawing Exchange Format (DXF) files for the CNC mill. The design team was keen to finish the designing process in the least time possible to allow enough time for testing, troubleshooting and piloting.

2. Design Evolution:

The company believes in continuous development, therefore the company's design team is keen to improve and refine Dolphin over years. Although Dolphin has been stable since the company first built it, there was always a room for improvement. Torbini's latest version of Dolphin is lighter in weight, easier to maneuver and smaller in size. That was due to this year's tasks that limit size and weight. The previous versions of Dolphin also proved to the design team that the Seabotix® thrusters were more efficient in the vertical motion but they were not needed in the horizontal motion. Thus, this year bilge pump thrusters are used for horizontal motion and Seabotix® thrusters are used for vertical motion.

B. Mechanical System

1. Frame

The mechanical team decided to design the body in multi-stages, starting with simple sketches on paper (Figure 1) to a very detailed design using Computer-Aided Design and Drafting (CADD). *Dolphin's* frame is designed for optimum functionality with curved edges which provide smooth motion underwater as the curved edges decrease drag force imposed on the vehicle's body, therefore increasing the thrust efficiency. Weighing 1.5Kg, Dolphin's frame is lightweight and compact in size in order to minimize NASA's expenses of launching payloads per kilogram.

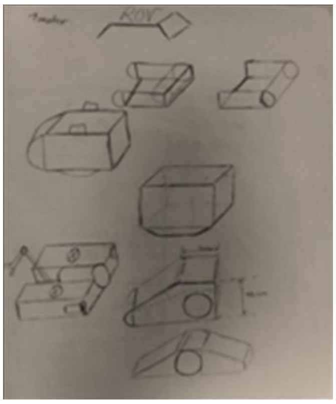


Figure 1: First Sketches of ROV

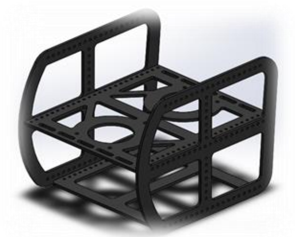


Figure 2: Solid Works™ Frame Design

Polyethylene was the selected material after comparing it to other materials such as aluminum, stainless steel and acrylic. Polyethylene was chosen as it is easy to cut, robust, lightweight, non-corrosive and act as a shock absorber. The body frame consists of four parts: one squared sheet with two holes for the two vertical thrusters and the two control enclosures, one bottom squared sheet for the gripper and two curved sidewalls which hold the two squared sheets together (Figures 2,3). Polyethylene sheets were purchased and the final exact measurements of dimensions were handed to the Industry Service Complex at the Arab Academy campus to reshape the polyethylene sheets into our design.

As time is an important factor, the polyethylene sheets were cut using Computer Numerical Control (CNC) machine instead of cutting it manually, producing smooth frame with no sharp edges to facilitate the movement of the vehicle in deep water.

3. Thrusters

The propulsion system consists of six thrusters: two for the vertical motion and four for the horizontal motion allowing five degrees of freedom. Two Seabotix™ BTD150 thrusters were used and mounted in the holes of the upper sheet of the body between the two electronics enclosures allowing the vehicle to heave and pitch. Each Seabotix™ thruster operates at 19.1 VDC with a maximum current 4.25A. (Figure 3)

Figure 3: Seabotix® thrusters

Figure 4: Modified Bilge Pump Thruster

Four Johnson™ modified bilge pumps are used as thrusters and positioned at 45°degrees allowing the vehicle to surge, yaw and sway. The bilge pump has a flow rate of 1250 GPH (Gallons per Hour), 12V DC at 3 AMP, 5 AMP fuse and power of 36 Watt. The decision of using the bilge pump was upon calculating the drag that acts on the body of Dolphin by assuming it has a submarine shape and calculating the power needed which is equal to 11 Watt after being multiplied by safety power factor, finding that the bilge pump power is suitable for the motion of the vehicle.(Figure 4)

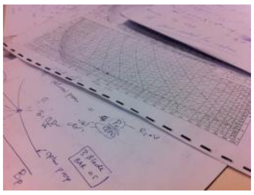


Figure 5: Selection Propeller Graph

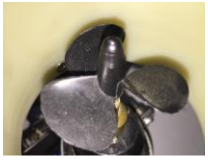


Figure 6: Propeller

The company has reused previous year's thrusters, seeing that there was no need of buying new ones, as they were all tested finding that their condition and efficiency are still the same as when they were first purchased.

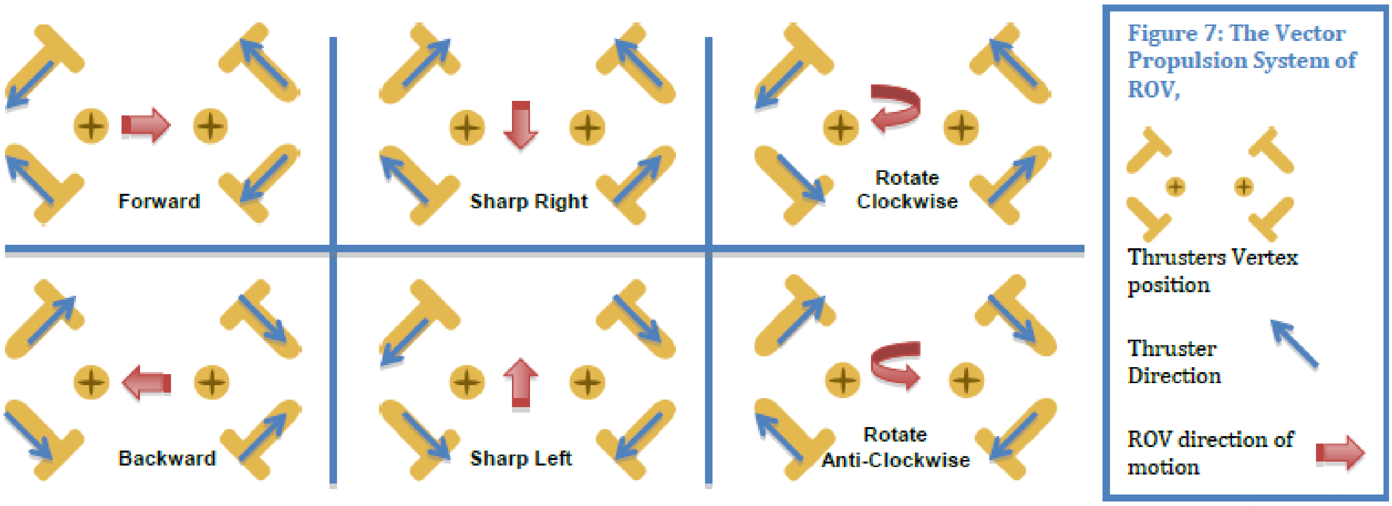


Figure 7: The Vector Propulsion System of ROV,

4. Electronic Enclosures

This year, the mechanical team decided to reduce the vehicle's weight to meet this year's weight limitation by using acrylic instead of polyethylene as a material of the enclosures. Unlike last year, the mechanical team divided the components of the electronic enclosure into two enclosures. The dimensions of both acrylic tubes are 25 cm length, 12 cm outer diameter and 11 cm inner diameter (Figure 8). The electronic enclosures are tightly sealed with two polyethylene end caps. Each cap has two O-rings incorporated in it, sustaining complete sealing.

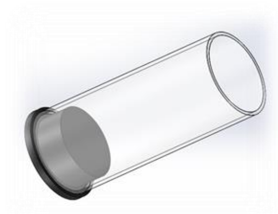


Figure 8: Enclosure *SolidWorks*™

5. Buoyancy

Dolphin is equipped with buoyancy package specifically designed to balance its residual buoyancy and give the ROV positive buoyancy. The mechanical team decided to start with the neutral buoyancy equation to calculate the buoyancy and dimensions of the buoyancy package. These calculations were made using Solid Works ™software. As the mechanical team was highly concerned with the vehicle dynamics, time and effort were saved in troubleshooting weight distribution and buoyancy. Previously, buoyancy was not given a high priority by the company but this year all calculations were made first and then the ROV was tested to ensure that it returns slowly to the water surface even in the case of thruster failure.

6. Manipulator

Dolphin's manipulator is a polyethylene claw shaped manipulator which is powered by a single pneumatic piston (figure 9). The motion of the piston is pushing up the links with 5 cm which determines the degree of opening of the gripper. The piston and manipulator are fixed in the lower polyethylene squared sheet of the body.

The mechanical team designed the Grippers According to theory of Grip Strength (GS):

· Grip force= part weight x (1+part GS) x jaw style factor.

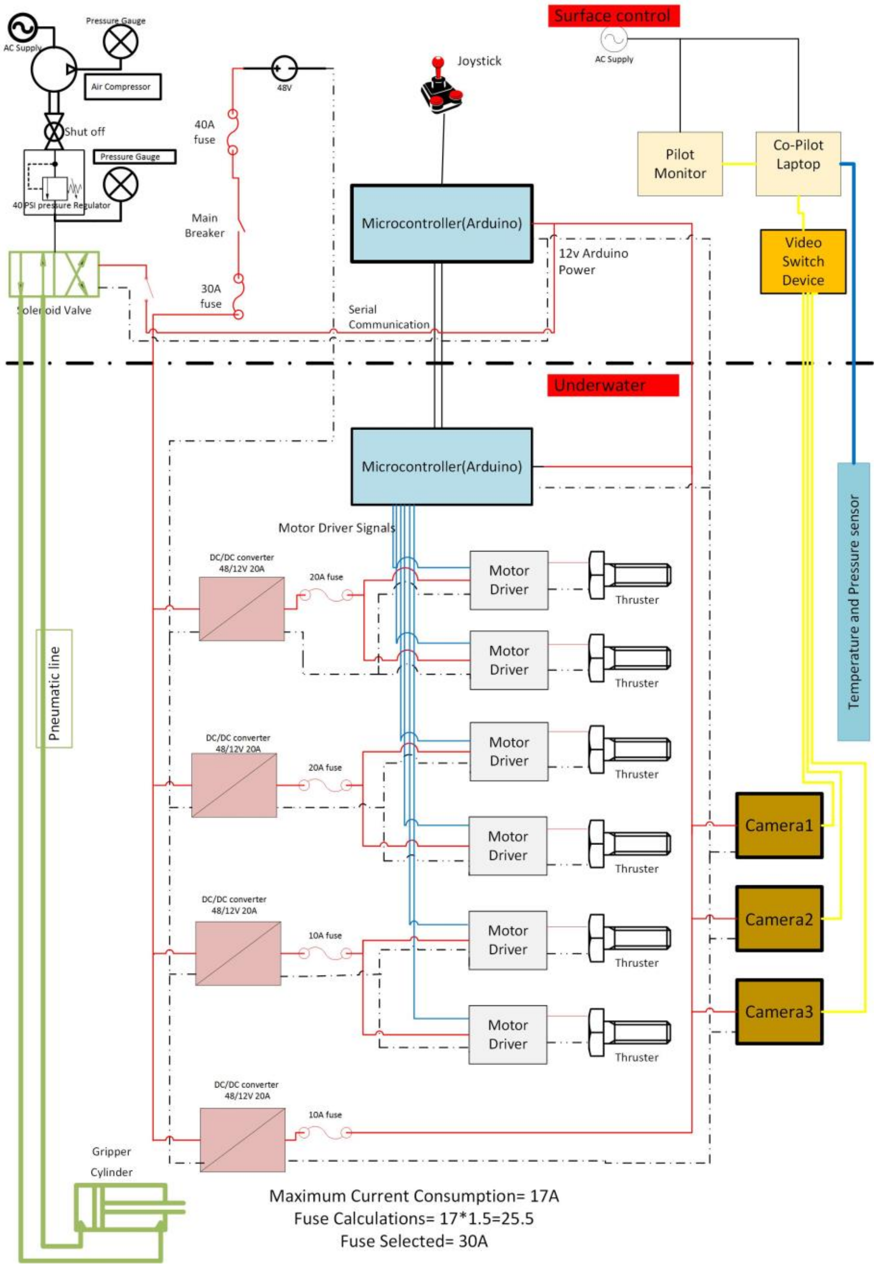
· Grip torque= Grip force x jaw length.

This manipulator is capable of accomplishing all the required tasks such as inserting the temperature sensor into the venting fluid in Europa's mission and connecting the ESP to the power and communication hub. The manipulator will also be used in collecting coral samples and oil mats samples, installing a flange to the top of the wellhead and recovering the mission-critical CubeSats.

Figure 9: Gripper

C. Electrical and Control System

1. System Integration Diagram (SID)



2. Electrical System

2.1. Tether

Dolphin ROV's tether is 30 metres in length consisting of two 1.5 mm 30A power cable, a 4 core data cable, two cores for serial communication to transmit data from Arduino Mega ADK microcontroller board on shore and Arduino Mega ADK microcontroller board inside the electronic enclosure of the ROV and two cores for powering the cameras and the solenoid valve, and three camera cables. Data and power cables are made of stranded copper wires instead of TTL (Transistor- Transistor Logic) wires for much more powerful signal transmission. In addition, tether contain a two 8 mm hoses for pneumatic cylinder to transfer the pressurized air from the compressor on shore to the pneumatic cylinder attached to the ROV through the solenoid valve.

2.2. Power Regulation

Two types of DC-DC Converters are used in *Dolphin*:

- One DC-DC 48V to 24V (20A) Step down Buck Converter – with its own safety fuse. Used to supply Seabotix motor drivers (figure 10).
- Three DC-DC 48V to 12V (20A) Step Down Buck Converter two of them are used to supply Bilge pump thrusters and the other one is used to power Cameras, LED light system, Arduino ADK Microcontroller Board and solenoid valve.

Figure 10: DC-DC Converter used for control

2.3. Power Distribution

In order to avoid any mistake in connections and reduce the number of wires inside the power enclosure, power received from the DC-DC converter passes through a distribution board which in turn distributes the power to the six motor drivers, Solenoid valve, Arduino and cameras. The six motor drivers are connected via six connectors with safety 10A fuse for each motor driver.

This Table shows power needed to operate Dolphin ROV:

Unit	Current (A)	Volt (V)	Power/ Unit	Quantity	Max Power (W)
Thrusters (bilge pumps)	8	12	96	4	384
Thrusters (Seabotix)	4.5	24	93.1	2	216
Solenoid Valve	0.2	12	2.4	1	2.4
Arduino	0.75	12	9	2	18
Cameras	2	12	24	3	72
Peak Power Available (14.425A * 48V)					692.4

Table 1: Power Needed

3. Control System

3.1. Motor Drivers

6 Motor drivers (Figure 11) are connected to the DC converter. These drivers are of type MOT- D-1015 and dimension 7.5 cm*4.3 cm. They are capable of driving high current DC motors up to 10A continuous and 15A peak current at motor start.

Figure 11: H-Bridge

These drivers support both locked-anti phase and sign-magnitude Pulse Width Modulation (PWM) signal as well as using full solid state components resulting in faster response time and eliminating the wear and tear of the mechanical relay, in addition to supporting motor voltage ranges from 3V to 25V and no heat sink is required. Just like the DC converter it is easy to fabricate motor drivers but this was also going to be time-consuming and the cost would be approximately equal to the purchased ones. The rarely used technique of PWM soft start was applied here to prevent current from reaching about 6 times the normal operation at the start of motor operation.

This table shows the H-bridges PWM Technique output power percentage, at ROV full power operation:

			Dolphin Motor Drivers							
			Thrusters							
			1	2	3	4	5	6	7	8
Dolphin ROV Motion	Horizontal	Forward	100	-100	100	-100	0	0	0	0
		Backward	-100	100	-100	100	0	0	0	0
		Lateral R	100	100	-100	-100	0	0	0	0
		Lateral L	-100	-100	100	100	0	0	0	0
		Rotating R	100	-100	-100	100	0	0	0	0
		Rotating L	-100	100	100	-100	0	0	0	0
	Vertical	UP	0	0	0	0	100	100	100	100
		Down	0	0	0	0	-100	-100	-100	-100
		Pitching F.	0	0	0	0	100	100	-100	-100
		Pitching B.	0	0	0	0	-100	-100	100	100

Table 2: PWM Output

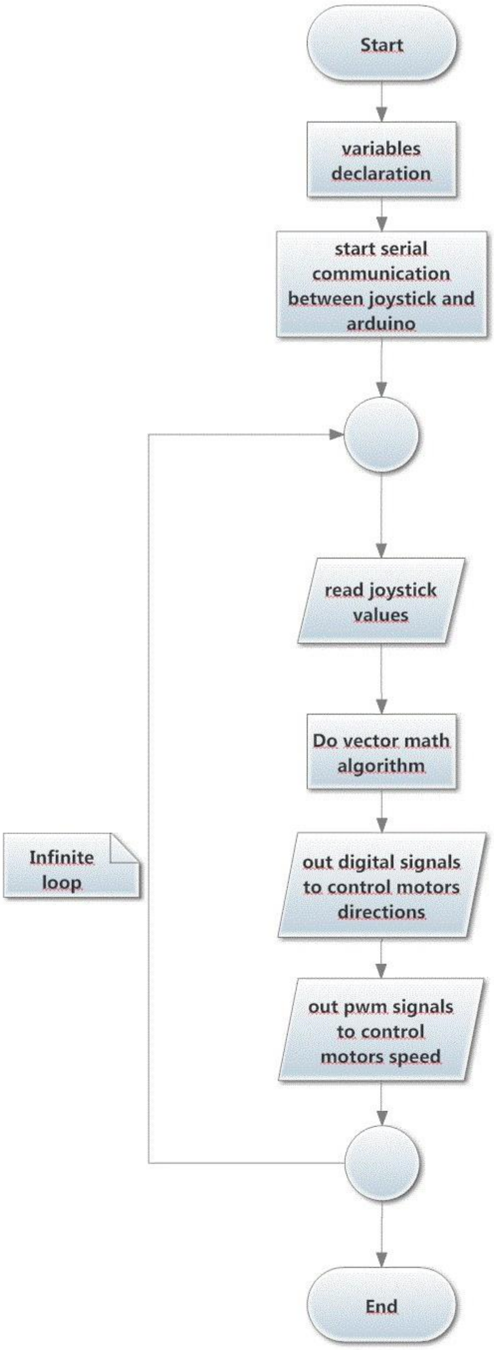
3.2. Software

Dolphin ROV software is simple but effective; it consists of two main parts; the base-station software at the pilot side and the on-board underwater software. Base-station software uses input from a joystick the Logitech Extreme 3D Pro Joystick (Figure 12), written with open source available Arduino software.

Figure 12: Logitech 3D Pro Joystick

On-board electronics consist mainly of an Arduino Mega ADK board. This exact brand of Arduino microcontroller was chosen although it was expensive compared to its counterparts as it has a powerful processor ATMega 2560and it features an ATmega8U2 programmed as a USB-to-serial converter.
Its length and width are 10.2 cm and 5.3cm respectively operating at 7-12 input voltages and DC current of 40 mA having 54 Digital I/O pins, 15 of which provide PWM (pulse width modulation) output, and 16 Analog input pins and equipped with a boot-loader to upload new code to it without the use of external hardware programmer.

Software Layout:



This table that shows the impact of a full-scale deflection of the joystick:

			Joystick input (full deflection)		
			X	Y	Z
Dolphin ROV	Horizontal Motion	Forward	512	612	128
		Backward	512	0	128
		Lateral Right	612	512	128
		Lateral Left	0	512	128
		Rotating Right	512	512	260
		Rotating Left	512	512	0

Table 3: Joystick Readings

3.3. Communication

According to our believe in continuous evolution, this year Torbini Company decided to use a new method of communication between the joystick and the ROV under water. It is a kind of serial communication called "UART communication" which uses two Arduino™ Mega ADK boards, one of them is located on the shore connected to the joystick. It takes the signal which consists of bytes and sends it to the other Arduino™ Mega ADK board which is located inside the ROV. The one which is inside the ROV receives these bytes and starts to analyze them, then it moves the signal as instructions to the H-Bridge motor drivers to implement the instructions and control the motors.

Figure 13: Arduino™ Mega ADK board

Figure 14: Fish finder Camera

4. Cameras

Dolphin is equipped with 3 waterproof fish finder underwater cameras. The main camera is positioned to view the gripper, the second to view the object held by the gripper and the last camera is positioned at the back of the ROV to view a wide area of the pool to aid the pilot in finding specific tasks underwater. The cameras have built-in LEDs to help the pilot to perform the required tasks in dim light.

5. Mission-Specific Tools

- **Pressure and Temperature sensor**

To be able to determine the thickness of the ice and the depth of the ocean in mission to Europa's task, The Bar30 pressure sensor is attached to Dolphin. The sensor is already waterproofed, which saved the company the time to isolate it. This sensor also includes a temperature sensor accurate to ±1°C to enable the ROV to measure the temperature of the venting fluid.

Figure 15: Pressure Sensor

- **The collecting box**

This year's missions require that several items are collected and carried to the shore. Therefore, due to the depth of the NBL pool, a collecting box was made to ease the missions for the pilot. Instead of ascending and descending the 12 meter pool several times, the pilot can collect all items that should be gathered in the box and ascend to shore only a single time saving time and energy.

III. Mission Strategy

In order to perform the mission in the least time possible, the pilot and co-pilot developed a mission strategy. First, they will descend the collecting box on to the pool floor, then they will start collecting the oil samples and the coral samples. While collecting the samples the co-pilot will photograph the corals and determine its state. The pilot will then take the box back to the shore using the manipulator. After that, the tether man will attach the pressure sensor to Dolphin and will deliver the oil samples to the co-pilot in order to identify it. The pilot will then measure the temperature of the venting fluid, then measure the thickness of the ice and the depth of the ocean. The pilot will then collect the cubeSats and then connect the ESP to the power and communication hub. Finally, the pilot will install the flange, bolts and the wellhead cap to the top of the wellhead and retrieve the ROV to the surface.

IV. Safety

Safety is more important than convenience, therefore Torbini is extremely concerned with the safety and health of its employees. The company’s workshop and ROV comply with all safety regulations stipulated by Oceaneering HSE handbook and OSHA regulations. A safety officer is always present in workplaces ensuring that employees are following safety precautions while doing their jobs. The officer also uses the company's safety checklist daily to conduct routine inspections (refer to appendix A.) Furthermore, the safety officer is responsible for investigating accidents to prevent them from occurring in the future. Safety is not only limited to the workplace but also to Dolphin itself. These are some of Dolphin’s safety features:

Figure 16: Following Workplace Safety

Figure 17: Safety equipment

Figure 18: Kort nozzles

- Safety electrical labels on vehicle.
- Kort nozzles surround each propeller (Figure 18).
- Heat shrinks used on welded wires (Figure 19).
- No Sharp edges.
- Curved and rounded edged frame.
- Housing is made from acrylic which is non-conducting
- Fuse board-withstanding 10A inserted before each motor drivers.
- LED indicators on the Arduino shield.
- A high sensitivity water detection sensor module is used to detect liquid leakage.

Figure 19: ROV Cables, in heat shrink

V. Cost Analysis

Before starting to build Dolphin, the company's CFO conducted a CBA (cost-benefit analysis) and a detailed estimated budget (see appendix B) for the project. The CFO considered re-using some components to reduce the overall cost as the company's budget was limited. After referring to the mechanical department to ensure that the thrusters and the propellers are in a suitable condition, the company decided to re-use them as they were all in perfect condition and buying new thruster would have been an unnecessary cost. The pilot has also checked the condition of the joystick and it was functioning properly, so the company was not obligated to buy a new one. Some other electrical components were also re-used after consulting the electrical department which confirmed that these components were in a good condition to be used again without reducing Dolphin's efficiency. The CFO also ensured that the new components purchased are up to our company's quality standards with a suitable cost.

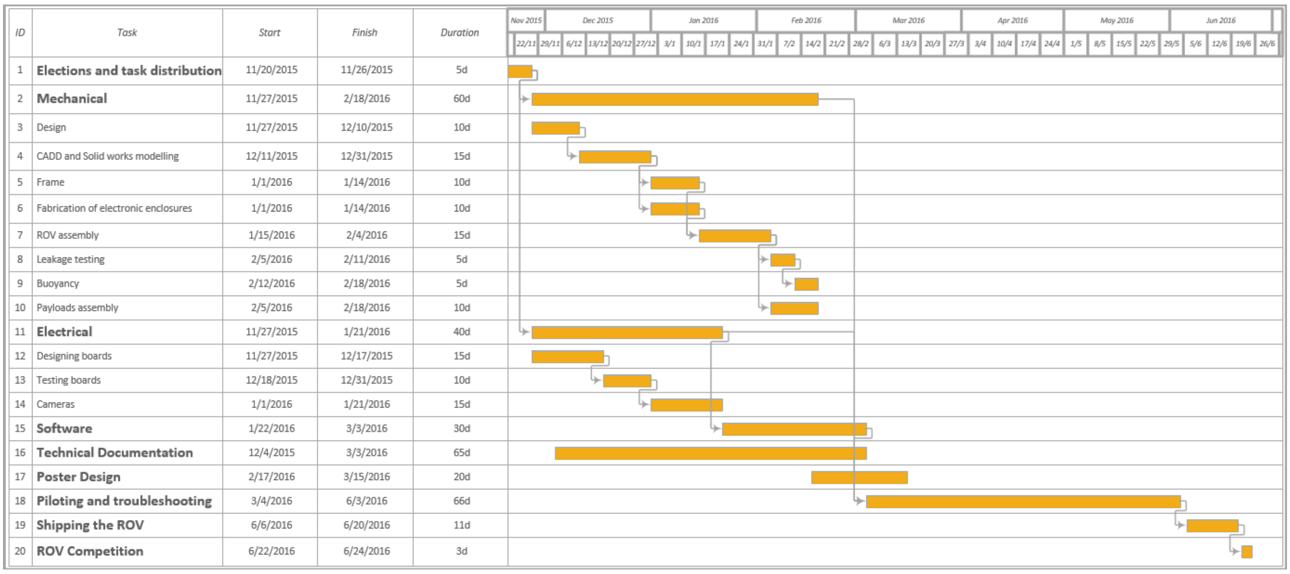
VI. Project Costing

University Name:	Arab Academy for Science, Technology and Maritime (Torbini)				Reporting period	From:	1/25/2016
Sponsor:	Arab Academy for Science, Technology and Maritime					To:	6/1/2016
	ATCO PHARMA						
Date	**Type**	**Category**	**Expense**	**Description**	**Notes**	**Amount**	**Running Balance**
1/20/2016	Purchased	Hardware	Body frame	Polyethylene material	The material needed for building the body frame	-100	-100
1/25/2016	Purchased	Service	Vehicle body frame	Polyethylene frame	Machining cost	-50	-150
1/25/2016	Re-used	Electronics	DC/DC converter	SD-500L-12	3X 48V/12V 20A	-120	-270
1/25/2016	Re-used	Electronics	DC/DC converter	SD-500L-24	1X 48V/24V 20A	-40	-310
1/25/2016	Re-used	Electronics	Joystick	Logitech	Logitech extreme 3D pro	-90	-400
1/25/2016	Re-used	Electronics	DC motor drivers	6 motor drivers	10A rating current	-100	-500
1/25/2016	Donated	Hardware	Electrical tools	Donated by AASTMT	Soldering iron, glue gun, driller and cutter machine	-170	-670
1/25/2016	Re-used	Electronics	Control unit	Arduino™ Mega ADK	2 Arduino Used as a control unit of the vehicle	-80	-750
1/25/2016	Re-used	Electronics	Arduino shield	Signal distribution board	Used for distributing the signal to the motor drivers	-6	-756
1/30/2016	Purchased	Electrical	Cables	Electrical cables	30 meters power cable + 5 meters power cable for inner wiring	-20	-776
1/30/2016	Purchased	Hardware	Cable	4 cores control cable	30 meters cable for the communication between the two Arduinos	-15	-791
2/1/2016	Purchased	Electronics	PCB	PCB, Connectors	Used for supplying the motor drivers with power	-5	-796
2/7/2016	Re-used	Mechanica	Thrusters	SeaBotix® thrusters	2 SeaBotix® thrusters	-1400	-2196
2/7/2016	Re-used	Mechanica	Bilge pumps	Johnson® Pumps	4 modified bilge pumps used as thrusters	-160	-2356
2/7/2016	Re-used	Mechanica	Propellers	3 blades propellers	4 propellers	-22	-2378
2/20/2016	Purchased	Hardware	Thruster holders	Stainless steel holders	Used for fixing thrusters on the vehicle	-9	-2387
2/20/2016	Purchased	Hardware	Tie wraps	Plastic tie wraps pack	Used for tying up the inner wirings inside the enclosure	-2	-2389
2/27/2016	Purchased	Hardware	Stainless steel screws	50 screws	Used for assembling the body frame parts together	-3	-2392
2/27/2016	Purchased	Hardware	Stainless steel nuts	50 nuts	Used for assembling the body frame parts together	-3	-2395
2/27/2016	Purchased	Hardware	Cable gallands	6 gallands	Sealed gallands used for conneting the tether to the control enclosure	-20	-2415
2/27/2016	Purchased	Hardware	Scotchcast	3 packs of schothcast	Used for sealing purposes	-70	-2485
2/27/2016	Purchased	Hardware	Polyethylene	Cylindrical polyethyelene		-25	-2510
2/27/2016	Purchased	Service	Machining	Control Enclosure machining		-15	-2525
2/27/2016	Purchased	Hardware	O-Ring	Rubber O-Ring	Used for Sealing the control enclosure	-2	-2527
3/10/2016	Purchased	Sensor	Video Cameras	3 Cameras	3 fish finder cameras	-350	-2877
3/10/2016	Purchased	Electronics	ION Video 2 PC™		Video to PC converter	-50	-2927
3/10/2016	Purchased	Hardware	Epoxy	10 packs of epoxy		-15	-2942
3/26/2016	Re-used	Electronics	Controlled A/V selector		Used for having a full view of all vehicle cameras and selecting a specifi	-40	-2982
3/26/2016	Donated	Electronics	Laptop	Samsung® laptop	Donated by one of the team's memebers	-600	-3582
3/26/2016	Purchased	Electronics	Pressure and temperature sensor	Bluerobotics®	Used for taking pressure and temperature measurments	-60	-3642
3/26/2016	Donated	Electronics	External monitor	LCD monitor	Donated by AASTMT	-65	-3707
4/1/2016	Purchased	Mechanica	Air compressor	Air compressor	30L air compressoe	-140	-3847
4/1/2016	purchased	Mechanica	Air pressure regulator	Air pressure regulator	Used for regulating the pressure at 40 PSI	-7	-3854
4/7/2016	Purchased	Pneumatic	Pneumatic Piston	1 pneumatic cylinder	Used for the gripper	-10	-3864
4/7/2016	Purchased	Pneumatic	Pneumatic line	40 meter pneumatic line	used for	-8	-3872
4/7/2016	Purchased	Pneumatic	Pneumatic solenoid valve	1 Pneumatic solenoid valve	Used for controlling the pneumatic piston	-40	-3912
4/15/2016	Purchased	General	Technical documentation		Hard copy of the technical documentation	-10	-3922
4/15/2016	Purchased	General	Marketing Pisplay		Printing the poster	-30	-3952
4/15/2016	Purchased	General	Team's member T-shirts	15 T-shirts	Team member's Uniform	-170	-4122
5/19/2016	Purchased	General	Air fare for team members	6 Tickets	6 round and trip airfare ($850 each) donated by AASTMT	-5100	-9222
5/19/2016	Purchased	General	Air fare for team members	3 Tickets	3 round and trip airfare ($850 each) donated by ATCO PHARMA	-2550	-11772
5/27/2016	Purchased	General	Accomodation	9 Members	The estimate cost of the accomodation for the team members	-3500	-15272
6/1/2016	Cash donated	General	Fund	Funds donated by AASTMT	Used for general vehicle construction and travelling affairs	16000	728
						Total Raised	16000
						Total Spent	-15272
						Total Balance	728

VII. Teamwork and Project Management

Dolphin is the product of the hard work of each member of the company as the cooperation between the employees of Torbini has led to this fruitful outcome. Elections were made at the very first meeting to choose a CEO and then a full company hierarchy was made by designating a role to each member. The CEO made a general time plan and each department was assigned tasks. Consequently, each department head assigned tasks to the employees and put deadlines according to the time plan. The technical report and the poster, although only the technical writing director was in charge of them, each department have written and sent their sections to ease the work of the technical writing director.

Weekly, a general meeting is held for department heads to report the progress of the week. In addition, every department held its own meeting for members to report the progress of their specific assignments and to ensure that everything is still on schedule. Occasionally there were delays and straying from the schedule but by the motivation of our CEO everyone managed to finish the work within the set time frame. To set an effective and efficient time plan, the company used Gantt chart (Figure 20), Critical path method (CPM) and Program Evaluation and Review Technique (PERT) to guide their decisions regarding resources and time. The company also employed a heavy usage of flowcharts and networks to plan and coordinate activities. Figure 21 shows the Torbini team assignments diagram.



ID	Task	Start	Finish	Duration
1	**Elections and task distribution**	11/20/2015	11/26/2015	5d
2	**Mechanical**	11/27/2015	2/18/2016	60d
3	Design	11/27/2015	12/10/2015	10d
4	CADD and Solid works modelling	12/11/2015	12/31/2015	15d
5	Frame	1/1/2016	1/14/2016	10d
6	Fabrication of electronic enclosures	1/1/2016	1/14/2016	10d
7	ROV assembly	1/15/2016	2/4/2016	15d
8	Leakage testing	2/5/2016	2/11/2016	5d
9	Buoyancy	2/12/2016	2/18/2016	5d
10	Payloads assembly	2/5/2016	2/18/2016	10d
11	**Electrical**	11/27/2015	1/21/2016	40d
12	Designing boards	11/27/2015	12/17/2015	15d
13	Testing boards	12/18/2015	12/31/2015	10d
14	Cameras	1/1/2016	1/21/2016	15d
15	**Software**	1/22/2016	3/3/2016	30d
16	**Technical Documentation**	12/4/2015	3/3/2016	65d
17	**Poster Design**	2/17/2016	3/15/2016	20d
18	**Piloting and troubleshooting**	3/4/2016	6/3/2016	66d
19	**Shipping the ROV**	6/6/2016	6/20/2016	11d
20	**ROV Competition**	6/22/2016	6/24/2016	3d

Figure 20: Gantt chart

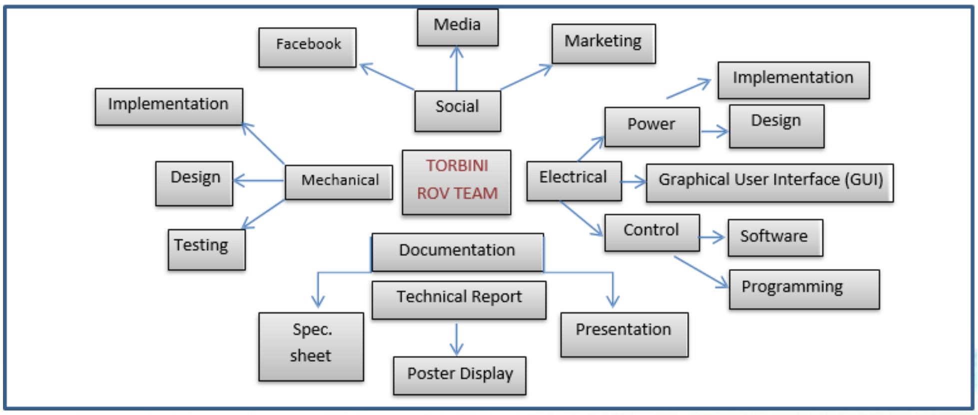


Figure 21: Torbini Team Job Diagram

VIII. Challenges

A. Technical Challenges:

As a company which believes in innovation, Torbini always encourage its employees to get out of their comfort zone and to try new methods and techniques instead of the guaranteed traditional techniques. Accordingly, the employees encounter some technical challenges while working.

- **Electronic enclosure**

The mechanical team decided to use acrylic instead of polyethylene for the electronic enclosures. As they were not used to this type of material, one of the enclosures was cracked and leaked water. Having limited time to make a new enclosure as this type of material was not present in Alexandria and the mechanical engineers had to travel to be able to manufacture a new one, the mechanical team decided to manufacture a polyethylene enclosure instead.

- **Pneumatic**

Our mechanical team had a very little experience with the pneumatic systems since the company has always used a motor and screw motion in controlling the motion of the gripper. Therefore, the mechanical team faced some challenges in their attempts to make a successful pneumatic manipulator. First, the mechanical team had to read about pneumatic systems to gain enough knowledge to build one. And after few trials, the team was able to build a functioning pneumatic manipulator.

B. Non-Technical Challenges:

Beside the technical challenges, our company also faced some non-technical challenges. One of the major challenges that we have encountered was that the lab that we used to work in was unavailable and our college could not provide us with another place to work in. Thus, the work was delayed for a while until one of our mentors offered to give us an empty apartment to work in. Another challenge was that most of our company members are graduating this year and they were busy in their graduation projects and had a very limited time to work in. Consequently, new members had to adjust their daily schedule to comply with the graduates' schedule and tasks were redistributed so we can be able to finish our product on time.

IX. Troubleshooting

Although each part of the ROV was separately tested and the ROV was tested after integrating all of its parts, Torbini has encountered several problems in the process of building Dolphin. These situations were handled through the company's troubleshooting and problem solving techniques shown in figure (22).

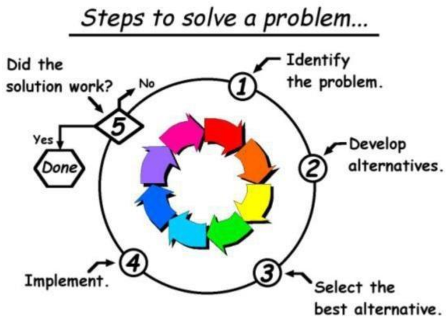


Figure 22: *Our methodology of problem solving, courtesy ofwww.thecollaboratory.wikidot.com*

A problem that the company faced was that in one of our product testing, two motors stopped working. The pilot then retrieved the ROV, and the team began the troubleshooting process. After making several short-circuit tests, the company's electrical engineers identified the problem which was that a ground wire of one of the DC converters was cut. As the regional competition was after almost a week, the solution of replacing this wire was almost impossible as that would mean that the company would make a new endcap for the enclosures that would be isolated and tested again within less than a week. Hence, other alternatives were considered, and the electrical team settled on powering these two motor from another DC converter, the converter which powers the Arduino. After trying the system with the new modifications, the pilot discovered that when he operates these two motors, the everything stops and he has to restart the whole system for everything to start functioning again. Since the applied solution did not accomplish the job effectively, other alternatives were considered again and the electrical team connected the two motors with the ground of another DC converter as they all have common ground and the Arduino was again connected to a separate DC converter. The pilot the tested the modified system and no other problems were detected.

X. Future Improvements

Our company believes that there is always a way to do it better, thus, although our ROV is stable and efficient there are some future improvements that the company is willing to apply in the coming years.

1) As a result of carrying heavy objects, Dolphin can sometimes have an undesirable tilt. Since Dolphin has an open-loop control system and it gives no feedback, this tilt could not be detected and thus could not be avoided. As a future improvement, our team is willing to make a closed-loop control system instead by putting sensors such as: compass, gyro and accelerometer to monitor the motion of the ROV. Hence, the team could automatically prevent the ROV to tilt while carrying heavy objects and auto-stabilization could be applied if the pilot wanted to stay in a certain depth for a certain period of time. Also, our team is willing to use motors which can give a feedback in order to use PID control to reduce the errors in the thrusters and to increase the efficiency of the whole system. This will ease the job of the pilot in performing any task our future customers will request.
(closed-loop diagram)

2) Another future improvement is replacing traditional copper cables with Fiber-optic cables to transmit information over a much larger distance and with a much higher bit rate. Digitized information is placed onto light pulses for transmission using a laser and travels along the glass fiber at the speed of light. This will allow us to receive and transmit data faster which will increase the efficiency of the vehicle for our future customers. (fiber optic cable)

XI. Lessons Learned

A. Technical lessons learned:

In an attempt to improve the overall efficiency of our ROV, the mechanical department implemented a new mechanism for Dolphin's manipulator. For the first time in their career, the company's mechanical team had to build a pneumatic manipulator. As they were not acquainted with pneumatic systems, they had learnt a lot from this experience. From learning about the mechanism to knowing all safety precautions needed, the team was eager to gather all possible information about pneumatic systems to be able to apply it effectively.

B. Interpersonal Lessons:

While building Dolphin, our team gained some interpersonal skills beside the technical ones. The experienced member did not only pass their technical knowledge but also their organizational and problem solving skills to the new members. Our tight time plan in building Dolphin forced us to manage our time more professionally to be able to balance between our studies and the ROV work. Furthermore, sudden problems taught us how to think for solutions together without panicking in critical times. This project has also enhanced our presentation and technical writing skills.

XII. Team Reflections

"This is the first time I participate in a serious project. Thanks to that I've learnt much more new information about mechanics, learnt how to design mechanical components, electrical isolation and also motion and buoyancy calculations. The most important thing that I consider as an addition to me is teamwork. We have changed from being strangers with one unifying passion for ROV to a family of 12. This has brought us closer and had helped us to overcome the challenges."

Ahmed Abdulfattah-

"As far as your dream goes the earth will get bigger so I consider that being a member of Torbini Company a year ago to be one of the most rewarding experiences in which I have ever participated and also it is the first step towards my targets. Following my curiosity and wish for something new I chose circuit engineering as my field of study. As a senior member in the team, just having a working ROV and achieving average results at the competition will not be enough for me. I thought a lot and set new goals for the upcoming competitions on the individual level, hoping that the goal would grow on a team level. "

Omar Badra-

XIII. References

1. Harry Bohm and VickiJensen
   (1997) "Build your own underwater Robot and other wet projects".
2. Robert D-Christ and Robert L.WerlniSR (2007)"The ROV Manual: A User Guide for Observation Class Remotely Operated Vehicles".
3. MATE – Marine Advanced Technology Education “www.marinetech.org”
4. http://www.marinetech.org/underwater-robotics-textbook-2/
5. Oceaneering Americas Region HSE Employee Handbook

XIV. Acknowledgments

We would like to thank the following organizations and individuals:

- **AAST** (Arab Academy for Science, Technology and Maritime Transport) for the financial support, hosting the local competition and allowing us to use the pool for ROV testing.
- **ATCO PHARMA** for providing the company three travelling tickets.
- **Prof.Dr.Ossama Ismail** for mentoring and providing technical support.
- **Dr. Ahmed Elshenawy** for facilitating the working environment and co-coordinating our logistical issues.
- **Dr.Rania Assem** for providing us with a fund to aid in building the ROV
- **Engineer Mohammed Fouad** for providing engineering consultations and for providing us the Mechanical work shop.
- **Industry Service Complex** at AAST for being such a great machining resource
- **MATE Center** for organizing the international competition and bringing together so many
- competitors and organizations in one think tank.
- **Hadath** organization for helping and organizing the regional competition.
- Our mentors **Engineer Ahmed Ramy**, **Engineer Mohamed El Bana, Engineer Abdelrahman Aboulkheir** and **Engineer Mai Faramawy** for their continuous help and support.
- **Noran Mohamed** for her spectacular efforts in the technical documentation

XV. Appendices

A. Safety Checklist:

Date of Inspection: / / Time of Inspection:

	Workplace Safety	
1	No loose or entangled wires	
2	Electrical Equipment tested prior to usage	
3	People working with electrical equipment have been given proper training	
4	All power points, light fittings and switches in a safe place	
5	Staff are using safety goggles	
6	Medicine cabinet is adequately filled with all necessary first aid kit	
7	All exit routes free from obstacles, including furniture and electrical equipment	
8	All Team members have been given full instructions and training in escape and assembly points, and fire precautions	
9	All team members wearing life jackets on pool	
10	Appropriate shoes are worn on pool	

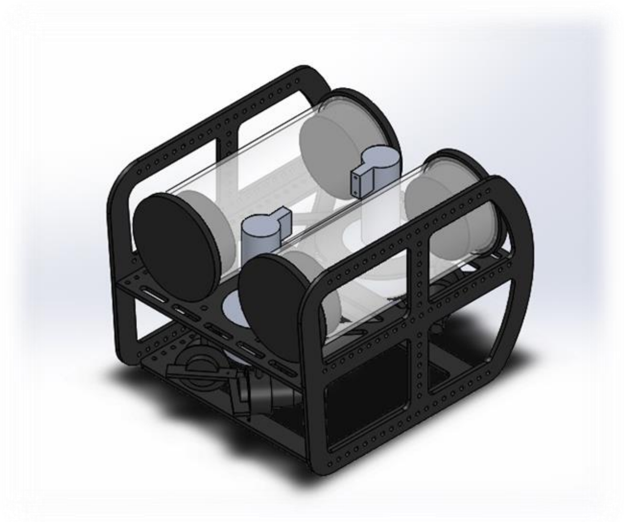
	ROV Safety	
1	Safety Labels	
2	Propeller Kort nozzles fixed	
3	Fuses in place	
4	Connections are secure	
5	No leakage	
6	No live wires	
7	No sharp edges	

Safety Manager: Signature

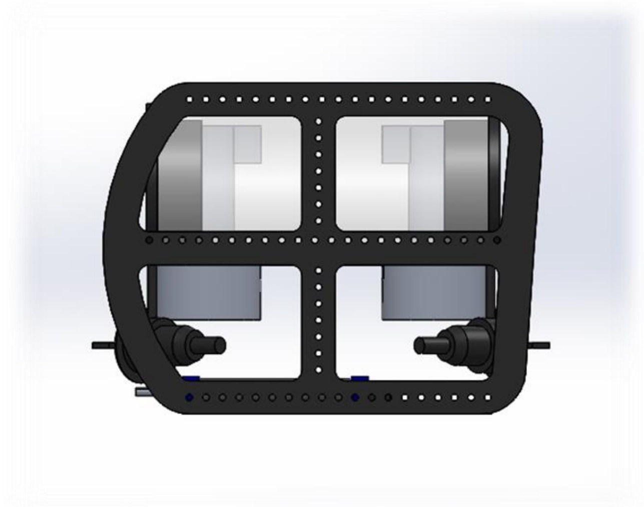
B. Budget

	Required itmes	Total (USD)
Electrical	Electrical Tools	300.00
	Motor drivers	3960.00
	Control unit	80.00
	Thrusters	1560.00
	DC/DC Converters	160.00
	Joystick	90.00
	Cameras	350.00
	Sensors	60.00
	Tether	50.00
	Electronics components	100.00
Mechanical	Enclosure	150.00
	Buyouncy foam	5.00
	Sealing Tools	10.00
	O-ring	10.00
	polyethylene sheets	100.00
	Hand tools	50.00
	Machining/CNC/Drilling	50.00
Printings	Technical Documentation	10.00
	Marketing display	30.00
	T-shirts	170.00
Travelling	Aifare to Houston	7350.00
	Accomodation and meals	3500.00
	Total	18145.00

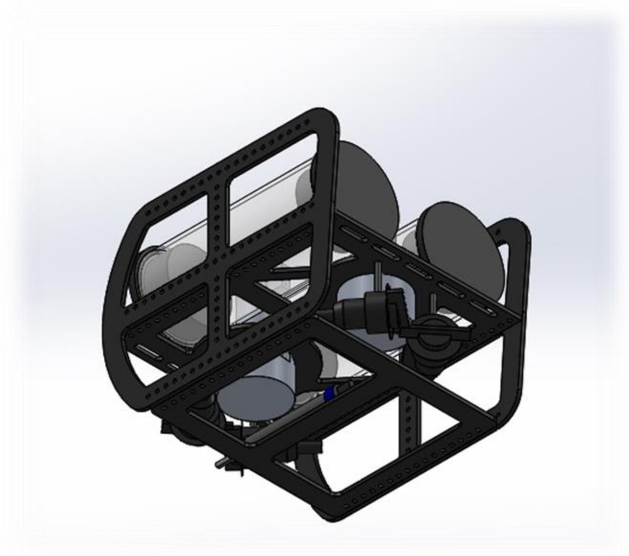
C. Dolphin ROV SolidWorks™ Design Views



3D assembly Top View



3D assembly Side View



3D assembly Back View

3D assembly Front View