ZOOM engineers

جامعة عفت
EFFAT UNIVERSITY

From Effat University

Jeddah, Makkah Region

Saudi Arabia

Presenting ***Casper*** to

2017 MATE ROV Competition

Company Employees

ZAINAB KHAN, President & Finance Manager

Electrical Team

SARAH TOONSI, Vice President & Safety Manager

Electrical Team

KOWTHER KAHIN, Design Manager & Logistics Manager

Mechanical Team

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Abstract

Zoom Engineers ROV Design Co. is a company that believes in safe, efficient and effective Remotely Operated Vehicle design and build. It has worked on a new ROV called Casper while keeping in mind the MATE ROV Competition criteria. Casper was created after studying the current ROVs and finding the best solution for the competition requirements. Casper has overall dimensions of 50cm*34cm*26cm and a weight of 17kg. Made from acrylic material, this frame holds two capsules and allows the smooth maneuver of Casper. It is positively buoyant, supports two robotic arms and has a 360 degree gripper to allow faster handling of the competition tasks. Its six powerful thrusters can reach up to 130 Watts. This ROV can move around in all directions easily. Power distribution is also well-managed for Casper. Two 48 to 12 DC-DC converters support the thrusters and remaining components. The underwater camera is powered by 12 V to 5 A converter. Using QGroundControl software, the topside controls movements underwater as footage is observed. The integration between the Raspberry Pi and the other modules enables complete control over Casper by the pilot and engineers. In their journey so far, Zoom Engineers have become more adamant to continue and win. With hopes and faith in their team work, determination, support system of mentors, supervisors, friends and family, Zoom Engineers is proud to introduce itself in the MATE ROV Competition for 2017 with their ROV called Casper.

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1. Introduction

Zoom Engineers is excited to be a part of the 2017 MATE ROV Competition for the first time and present its own ROV system called Casper. It hopes to perform well because of its dedicated members and clear objectives.

1.1. Mission and Objectives

Zoom Engineers aims at achieving the requirements of a Remotely Operated Vehicle (ROV) for the Port of Long Beach as per their Request for Proposals (RFP) and design and build their own ROV that can complete all the tasks required by the 2017 MATE Explorer ROV Competition.

1.2. Organizational Chart

Given below in Figure 1 is the organizational structure of Zoom Engineers ROV Co.:

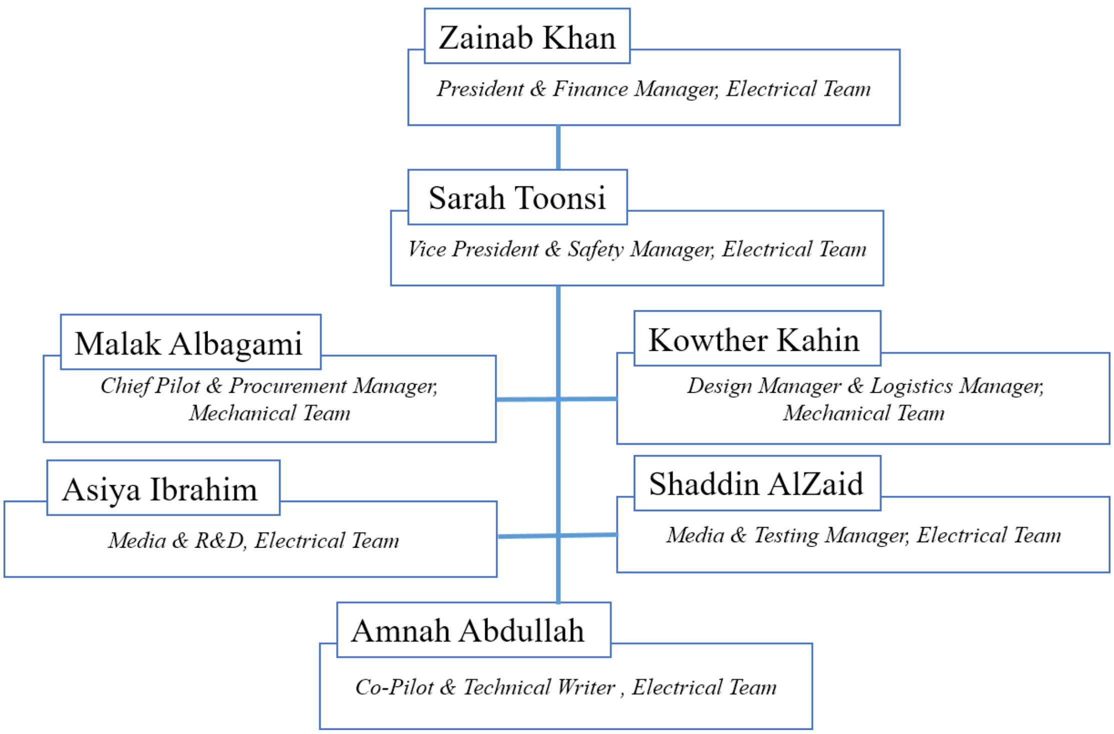


Figure 1 Organizational Chart of Zoom Engineers ROV Co.

1.3. Budget

Table 1 Budget for Casper

CATEGORY	AMOUNT ALLOTTED
ELECTRICAL PARTS	$1,500
POWER SUPPLIES	$1,000
MECHANICAL PARTS	$1,200
SOFTWARE	$4,000
REMOTE CONTROL	$200
ACCESSORIES	$200
ROBOTIC GRIPPER	$300
WIRING	$150
TRAVEL	$15,000
ACCOMMODATION	$5,000
COMPETITION	$400
TRANSPORTATION + FOOD	$3,000
TEAM SUPPLIES	$250
SHIPPING COSTS	$500
TOTAL BUDGET	$32,670

1.4. Costing

Table 2 Total Expenses

ROV EXPENSES						
ELECTRICAL PARTS	Raspberry Pi 3 Computer	with Camera board	Purchased	1	$60.00	$60.00
	Arduino Uno R3		Reused	1	$30.00	$30.00
	3DR Pixhawk Autopilot		Purchased	1	$240.00	$240.00
	Fathom-X Tether Interface Boards	Set of 2	Purchased	1	$159.00	$159.00
	T100 Thruster		Purchased	6	$119.00	$714.00
	Electronic speed controller		Purchased	8	$25.00	$200.00
	Heatsinks	for Raspberry Pi 3	Purchased	1	$6.79	$6.79
	KK-Mini flight control board		Purchased	1	$20.00	$20.00
	Lumen Subsea light		Purchased	1	$99.00	$99.00
	Underwater camera		Purchased	1	$60.00	$60.00
						$1,588.79
POWER SUPPLY	48V 30A AC-DC Power Supply	For testing phase	Purchased	1	$270.00	$270.00

	48V to 12V DC-DC Converter		Purchased	3	$133.00	$399.00
	48V to 12V Buck Converter		Purchased	1	$38.14	$38.14
	48V to 24V Buck Converter		Purchased	2	$38.70	$77.40
	12V to 5V DC-DC Converter		Purchased	2	$22.00	$44.00
	2200mAh 3S Lipo Battery Pack	For testing phase	Borrowed	1	$10.00	$10.00
	Power distribution boards	Octo and Quad	Purchased	2	$4.50	$9.00
	Fuse Assortment kit	5A - 30A	Purchased	1	$7.39	$7.39
						$854.93
CONNECTIONS AND WIRING	Cable - 18 AWG	by the meter	Purchased	7	$7.00	$49.00
	Cable - 20 AWG	by the meter	Purchased	1	$7.00	$7.00
	Fathom ROV tether - 26 AWG	by the meter	Purchased	25	$5.00	$125.00
	Servo extension cable wire	Female to male	Purchased	1	$8.25	$8.25
	Gold connectors 2mm	20 pc	Purchased	1	$2.30	$2.30
	Live video out A/V cable	For camera connection	Purchased	1	$3.00	$3.00
						$194.55
MECHANICAL PARTS	300mm Acrylic capsule		Purchased	2	$54.00	$108.00
	Acrylic end caps		Purchased	4	$24.00	$96.00
	Cable penetrators		Purchased	26	$5.00	$130.00
	O-Ring flanges		Purchased	4	$29.00	$116.00
	Enclosure clamp		Purchased	2	$39.00	$78.00
	Enclosure vent and plug		Purchased	2	$8.00	$16.00
	Mounting brackets		Purchased	6	$5.00	$30.00
	Screws M3*16mm		Purchased	30	$2.00	$60.00
	Screws M4*60mm		Purchased	15	$2.00	$30.00
	Hex nuts M4		Purchased	20	$2.00	$40.00
	Acrylic body	Laser cutting	Purchased	8	$25.00	$200.00
	Power box casing and clamps	Laser cutting	Purchased	1	$90.00	$90.00
						$994.00
ROBOTIC GRIPPER	Waterproof Servo motor		Purchased	4	$43.00	$172.00
	Claw Gripper		Donated	2	$20.00	$40.00
	Metal brackets and supports		Donated	1	$25.00	$25.00
	Shaft extension	3D printed	In house	4	$10.00	$40.00
						$277.00
SOFTWARE	SolidWorks		Borrowed	1	$0.00	$0.00
	QGroundControl		Free	1	$0.00	$0.00
	Mission Planar		Free	1	$0.00	$0.00
	Cura Slicing Software		Free	1	$0.00	$0.00

						$0.00
REMOTE CONTROL	Flight Stick	Thrustmaster T-Flight	Purchased	1	$50.00	$50.00
	Logitech Gamepad	F310	Purchased	2	$19.96	$39.92
						$89.92
ACCESSORIES	Subsea buoyancy foam	12x6x1"	Purchased	2	$25.00	$50.00
	Silica gel desiccant		Purchased	1	$10.00	$10.00
	Epoxy		Purchased	1	$19.00	$19.00
	Pliers and wrenches		Purchased	1	$30.00	$30.00
	Metal plates		Purchased	4	$5.00	$20.00
						$129.00
TOTAL ROV EXPENSES (WITHOUT SHIPPING)						**$4,128.19**
SHIPPING					$356.18	$356.18
CUSTOMS CLEARANCE					$133.67	$133.67
TOTAL ROV EXPENSES						**$4,618.04**
OTHER EXPENSES						
TRAVEL	Accommodation	4 nights		7	$80.00	$2,240.00
	Flight tickets	Jeddah to Alexandria Roundtrip		9	$230.00	$2,070.00
	Food and transportation	4 nights		7	$40.00	$1,120.00
	Flight tickets	Jeddah to Long Beach, CA		7	$1870.00	$13000.00
	Accommodation	5 nights, CA		4	$140.00	$560.00
	Food and transportation	5 nights		7	$50	$2000.00
	Team shirts			7	$30.00	$210.00
	Poster			1	$20.00	$20.00
COMPETITION	ROV Arab Regional Registration			1	$150.00	$150.00
	MATE International Registration			1	$100.00	$100.00
TOTAL TRAVEL & COMPETITION EXPENSES						**$21,470.0**
GRAND TOTAL EXPENSES						**$26,088**

Table 3 Total Income

INCOME		
	Effat University Office of the Provost	$5,700.00
	Effat University Office of Student Life	$5,400.00
	Effat University College of Engineering	$5,700.00
	Sponsor	$10,000.00
TOTAL INCOME		**$26,800.00**

2. Design Rationale

The following section describes all the thoughts given to the mechanical, electrical and software systems of Casper and why we chose the design methods as we did.

2.1. Mechanical System

After much brainstorming, discussion and consideration of all the members' ideas, the design of Casper was determined and it was decided to model it using SolidWorks. The 3D modules eased to structure and were cut into acrylic pieces. The prototypes were then tested under the conditions similar to the competition missions.

2.1.1. Structure Design

The frame has important functionality in the ROV as it carries all the components of the vehicle. Considering its significance, the frame design was the first to be planned. The initial design was a cube of PVC pipes with 50*50*50 cm dimension. However, this design was discarded as it was not well balanced when tested in the water. The second structure was planned more carefully based around satiability and efficiency; hence, Casper is stable enough to complete all the required tasks, yet compact and light. Casper consists of two side frames rectangular in shape with 50 cm in length, 34 cm in width and 26 cm in height. They have many holes to reduce the water pressure coming for the six thrusters. Their rounded edges ease the movement of the ROV under water. A horizontal plate at the bottom holds the two side frames. Moreover, Casper is held together by four horizontal pieces which are designed to place the bouncy foams. One more piece was deigned to hold the robotic arm. The material used to create the structure is acrylic and 10 mm thick. See Figures 2-6.

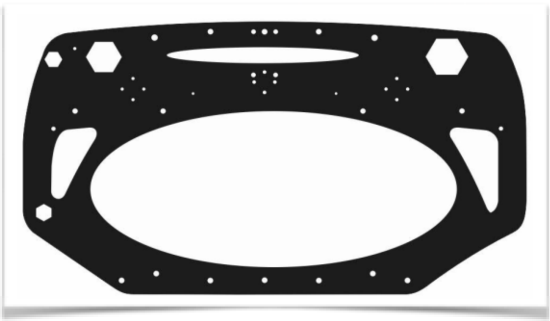


Figure 2 Side frames

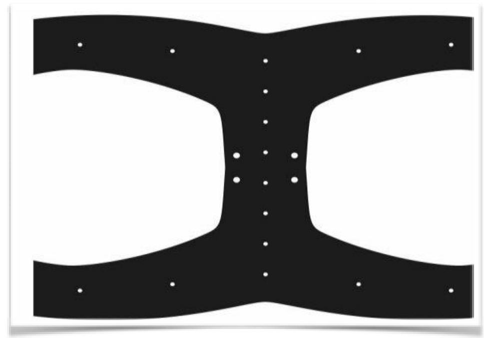


Figure 3 Bottom Piece

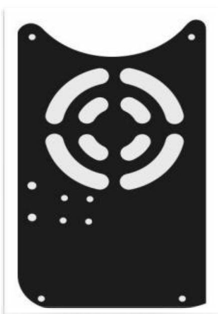


Figure 4 One of the four horizontal pieces

Figure 5 Front piece for the robotic arms

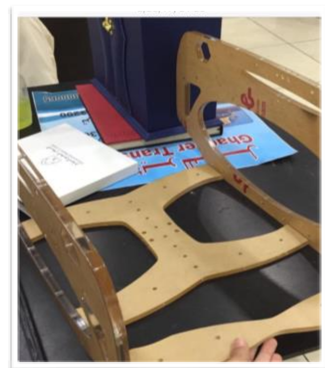


Figure 6 Frame pieces

2.1.2. Electronics Capsules

The ROV is powered by delicate electronic components, thus, needing a host to isolate it from the water. Casper has two capsules which are 30cm long cylinders. The first enclosure hosts the following parts: Raspberry Pi with camera, Pixhawk, light, Fathom-X, six ESC's and PDB. The cylindrical shape helps inherit strength under pressure. The second capsule holds three 12V Buck converters. Both enclosures are made from acrylic with a machined aluminum coupling epoxied to each end. The couplings prevent the two enclosures from bending and provide a constant sealing surface for the end cap O-rings. The end caps house the O-ring and provide a mounting surface for the electronic system. The circular shaped tube was purchased from Blue Robotics, see Figure 7..

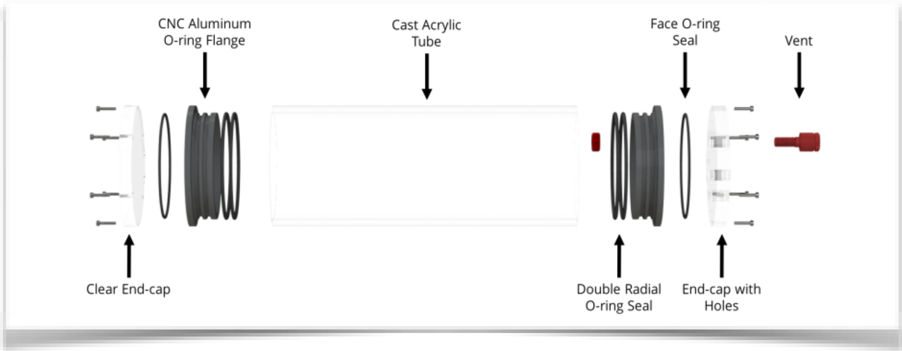


Figure 7 Commercially purchased capsule

2.1.3. Buoyancy & Stability

Most ROV's, being naturally negatively buoyant, require foams to restore their buoyancy. However, Casper is positively buoyant because of its two acrylic tubes. The two capsules facilitate the ROV to float in the water; thus, the foams which were purchased initially were discarded. Since Casper can easily float, we added two 0.25 kg weights at the rear end of the bottom frame which assist it to dive and spare the thrusters to work on full load. The weights also increase the stability as they prevent the pitching caused by the two robotic arms placed at the front of the ROV.

2.1.4. Propulsion System

The T100 thrusters are brushless electric motors with an attached propeller (both clockwise and anticlockwise) and waterproofing mechanism. Six thrusters were used: two for diving up and down and four for underwater movement. This was done to have more flexible driving and faster movement. Their orientations are shown in figure 3. In order to operate them at different speeds, an ESC (Electronic Speed Controller) was connected to each. Additionally, the power of these thrusters can reach up to 130 Watts, enough to fight water drift and ensure the smooth movement of Casper underwater.

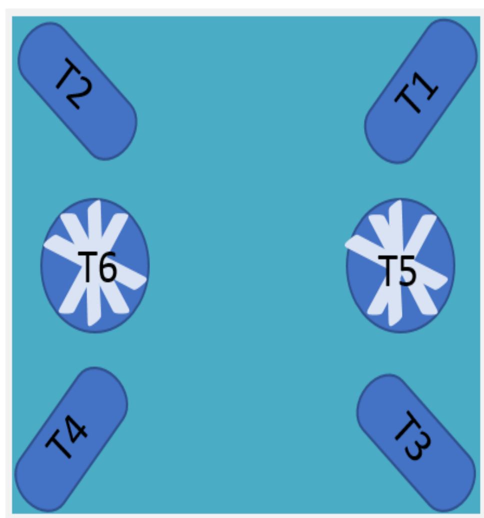


Figure 8 Thruster Formation

2.1.5. Robotic Arm and Rotational Claw

The gripper is controlled by a continuous DC motor and two gears placed in the center of the gripper's structure to open and close it by using infinite screws as shown in Figure 8. It is connected to a small gear to turn a bigger gear to produce a 180-degree movement. It allows Casper to easily turn while it is deployed in the water. The rotational claw is also controlled by a continuous DC motor. Its main purpose is to rotate the valve in the entertainment mission so it is designed to rotate 360-degrees.

Figure 9 Gripper

2.2. Electrical System

The following section explains all the aspects of the electrical system.

2.2.1. System Integration Design and Power Distribution

Casper is powered by three 48 to 12V DC-DC Buck converters. One converter is responsible for feeding 12V to four T100 thrusters and the Pixhawk controller, which is connected to a power module. Current was limited to a maximum of 2A for each thruster. Therefore, a 7.5A fuse was placed after this converter for safety. Another converter supplies power to the remaining two thrusters, two Fathom-X boards and the Raspberry Pi. The Raspberry Pi receives its required 5V through a UBEC. Finally, a third converter is used to power an underwater camera, two DC motors, and two Arduino Uno Atmega234 microcontrollers. A DC-DC converter with a rating of 5V 5A is used to step down the 12V for the Arduinos. The DC motors are given the required voltage through UBECs. The power distribution is explained in Figure 10.

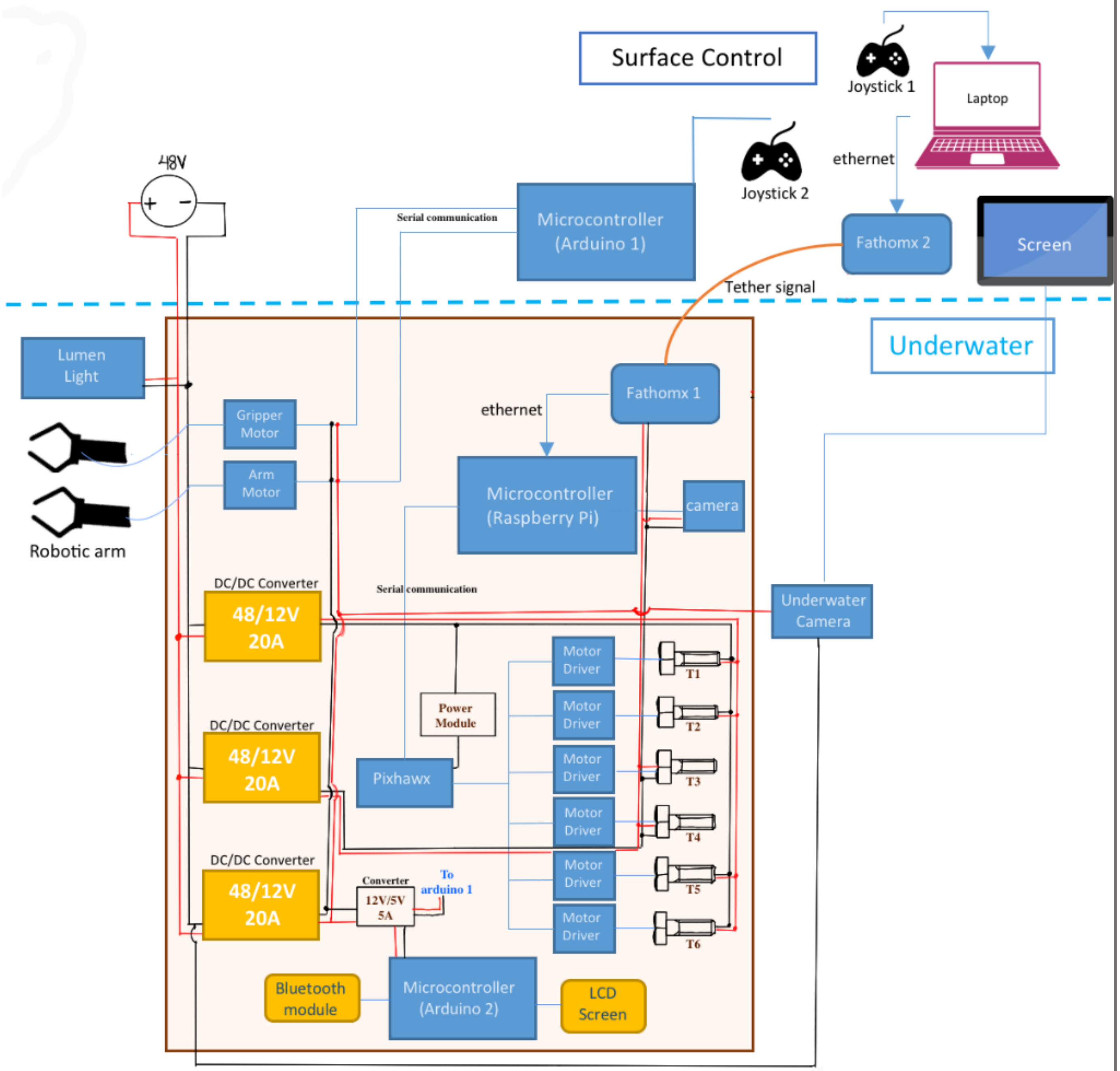


Figure 10 *System Integration Design* and *Power Distribution*

2.2.2. Control System

The whole ROV system is remotely controlled on the surface by the Pilot and Co-pilot. QGroundControl (QGC) software is used to communicate with Casper from the topside. It is open source software that supports remotely operated vehicles running on platforms such as ArduSub. QGC is the medium used to interface between the control unit and Casper's movements. The software takes inputs from the user-controlled joystick, the Logitech USB Gamepad F310. It allows control over ascend, descend, bidirectional strafe, bidirectional yaw, forward and reverse. It also lets the user arm or disarm the ROV, turn ON/OFF the lights and control the angle of the camera. These signals are sent to Casper's electronics unit which includes the Raspberry Pi interfaced with the Pixhawk PX4. The Raspberry Pi also controls the analog camera for rear view. The Pixhawk PX4 sends signals to the Electronic Speed Controllers (ESCs) to control movement of the 6 thrusters.

At the same time, a separate pair of thimbles is used to send signals to an Arduino Uno microcontroller to control the robotic gripper and the rotational claw. The signal from the thimbles is passed using the Fathom-X boards through the tether. Also, another underwater camera transmits signals via a 20m HDMI cable to an LCD screen on the topside. The two cameras give the pilot front and rear view as well as an eye on the claws to navigate Casper underwater.

2.2.3. Navigation & Video System

A clear view of the surroundings is necessary to fully pilot an ROV. Casper uses two cameras. Firstly, the ODRVM WIFI underwater camera, as shown in Figure 11, was used to capture underwater shots and record live video action via the smart DV app in the smartphone. It features full-HD 1080p video resolution to 20M for high quality videos, a 170-degree wide-angle lens for wider footage coverage. It can go up to 30 meters under water thanks to its water-resistant casing and record for about 121 minutes per battery. The second camera was the Raspberry Pi Camera as shown in Figure 12 to provide high quality videos, 110-degree-wide angle lens and 8-megapixel native resolution sensor-capable of 3280 x 2464 pixel static images. The Raspberry Pi with the camera delivered the live video feed via Ethernet cable inside the capsule. [1]

Figure 11 ODRVM WIFI underwater camera

Figure 12 Raspberry Pi Camera

2.2.4. Tether Systems

A naturally buoyant tether was bought and combined with two pairs of wires for video transmission. The main tether consists of four pairs of 26 AWG wire, see Figure 14. Pair A is used for signal interfacing with the Fathom-X. The Fathom-X is a board that uses the Rak Wireless LX200V20 module, as shown in Figure 13, to transmit Ethernet connections along only two pairs of wire. Pair B is used to transmit the joystick signals for the robotic gripper and rotational claw.

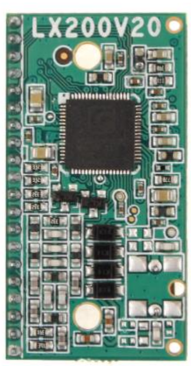


Figure 13 Rak Wireless LX200V20 module

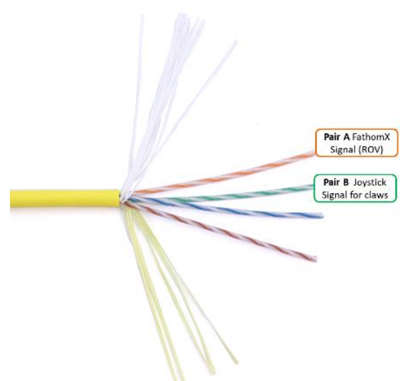
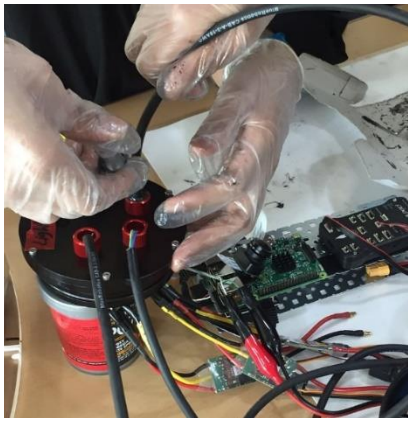


Figure 14 Tether Connections

3. Safety



Zoom Engineers strongly believes in safety precautions for both its employees and customers. Maintaining a safe work environment during the designing, manufacturing, handling, testing and while working with chemical materials.

3.1. Safety of Employees

Safety precautions were always taken while working. When epoxying wires, the employees wore masks, gloves and goggles to avoid direct contact with the chemical. When using the drill,

Figure 15 Epoxying parts with gloves on

they ensured its stability on the surface and wore protective gloves. Extra care was taken while testing with electricity near the swimming pool and they had assigned a member to be responsible for isolating the water from the electronics. Furthermore, the soldering procedure was safely carried out while using a solder stand, wearing protective gloves and masks and making announcements whenever the solder was being used. The safety checklist is in Appendix A.

3.2. Safety of Casper

Figure 16 Cable penetrator

Underwater operations are dangerous as 100% isolation from water is required for all electronics. To be able to achieve that, all small electronics were placed inside a capsule sealed with O-rings. Cable penetrators, shown in Figure 16, were used to allow cable access to both the capsule and the box. These penetrators were sealed with epoxy to close all small openings. For further protection, a double casing technique was used for all electronics. All open cables were covered by isolating tape and were separated from each other. Also, heat sinks were placed on the ICS of the Raspberry Pi and both Fathom-X interfaces to protect them from overheating. A

25A fuse was used after each 48 to 12V DC-DC converter to cut the circuit in case of overload of current. A SBS 50 Anderson connectors, shown in Figure 17, were plugged in properly to the tether for providing a compact connection with a touch safe interface.

Figure 17SBS 50 Anderson connector

4. Testing and Troubleshooting

After the first trial of underwater testing, we encountered issues with the ROV. It was struggling to sink, which was due to the lack of weight at the bottom of the robot. To solve this issue we decided to place four square stainless steel parts, see Figure 17. The structure of the ROV was modified and the position of the thrusters was changed. After facing issues while installing the DC-DC converters enclosure, the acrylic pieces seen in Figure 1, were raised 5 cm from their original position to add space. Also, the robotic arm's position was lowered to give it flexibility. The epoxy around the wires was breaking so we ordered a stronger type and sealed the wires again. The underwater servos provided 180 degrees rotation, which did not serve our application. They were replaced with continuous DC motors to provide 360 degree rotation for the robotics arm joint.

Figure 18 Stainless steel squares

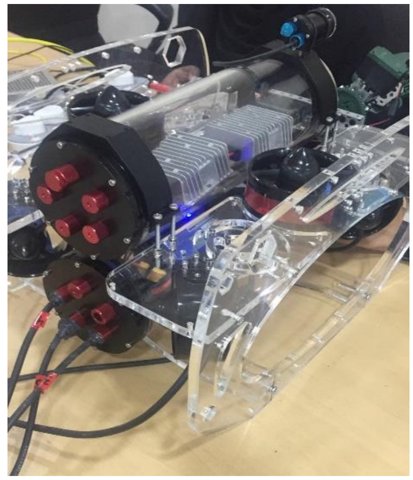


Figure 19 Acrylic piece

5. Payload Tools

5.1. Commerce: Hyperloop Construction

The demonstration of this task depends on the stability of the ROV underwater and the robotic arm. Casper is equipped with six powerful thrusters that can handle high pressure underwater. The inner part of robotics arm claw, as shown in Figure 19 includes a rubber material to move efficiently and firmly hold objects.

Figure 20 Vex Claw

5.2. Entertainment: Light and Water Show Maintenance

The entertainment task requires the turning of a valve. For that purpose, we added a 360 degree rotational joint. This mechanism was created by adding two gears; a small one that is attached to the shaft of the motor (driving gear) and a bigger one that is driven by the smaller gear as shown in Figure 20.

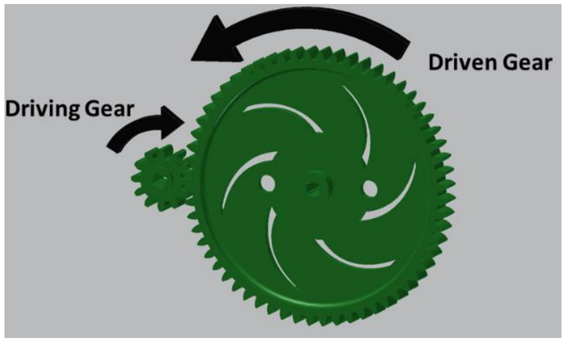


Figure 21 Vex gears

6. Challenges Faced

6.1. Technical

We required a 48V-30A power supply to test our power distribution but could not find any within our budget in Saudi Arabia. We finally found a vendor in Egypt with the right specifications. The underwater camera did not have a port in its casing to carry a signal to the topside, so we made custom holes and water proofed it. Stability of the robotic arm was a main challenge that took time to solve. This was done by redesigning the support pieces on SolidWorks for a firmer hold on the arm. The Lumen light drew a lot of current, around 15A, and this was causing other components in the circuit such as servo motors to overheat. The Lumen light was then connected directly to 48V power supply to avoid overcurrent draw.

6.2. Interpersonal

A lot of thought was put into forming a quality team of individuals who could work together to solve problems. In the initial phase of the company, problems were faced in balancing work load among members. To solve this, each member was given a designated role and a number of tasks to focus on. As residents in Saudi Arabia, getting around is a little harder for girls. So the team members improvised by carpooling and making special arrangements for team meet-ups which were suitable to all members of the company. For ordering parts, some vendors do not ship to the country, so we had to find alternative ways to get what we needed. We had to rely on the local market and request individuals to bring the components with them.

7. Lessons Learned

The MATE ROV competition is an unforgettable experience that all competitors share. The challenge of designing and building our own robot from scratch with limited supplies and assistance was no easy endeavor. The team of Zoom Engineers agrees that the most important lesson learnt was patience- whether it was when struggling to get Casper to work or trying our best to cooperate with each other. The experience also taught us the importance of communication, cooperation and sharing a common goal as a team.

8. Future Improvements

In the future, Zoom Engineers plan to add sensors to Casper to detect harmful chemicals in the sea. This can serve oil and gas companies to inspect their off shore oil rigs and help in providing a sustainable environment for marine life. Other sensors will help it move and keep its orientation.

9. Reflections

Ever since the employees of Zoom Engineers heard of MATE, they could not stop raving about the ROV. Being a part of this challenge has piqued their passion in robotics and allowed them to work with wonderful people. Seeing Casper come to life is a highlight moment in their lives which they would not take for granted. From the President down to every member, each engineer has worked towards gaining knowledge and putting it to practice.

The journey of making Casper a reality has been truly exciting and amazing. The team has not only learnt new things but improved its previous skills. They experienced challenges and felt the thrill of overcoming them. Such competitions are indeed truly useful for engineers, teamplayers and passionate robotics enthusiasts. Although this is Casper’s first year at MATE Competition, it is most definitely not its last.

10. Acknowledgements

Casper could not have been accomplished without the best wishes of our families and friends. We are highly grateful to all those who guided us and our special thanks go to the following organizations for their continuous support and valuable help to Zoom Engineers ROV Design Co.:

- Effat University (financial support)
- Dr. Haifa Jamal Al-Lail and Dr.Malak Abunar (financial and moral support)
- Dr.Akila Sarirete (providing workspace and continuous encouragement)
- Our Mentor Dr. Mohammed Shahata (guidance)
- Eng. Fadel Abdellatif (guidance and training)
- Mr. Ernie Geslani (design support)
- Mr. Rushdi Al Azzah (technical and logistics support)
- All MATE Competition officials and volunteers, regional competition supervisors [2]
- All our parents and families for support

11. References

[1] "Teach, Learn, and Make with Raspberry Pi." Raspberry Pi. Accessed January 10, 2017. https://www.raspberrypi.org/.

[2] "Marine Advanced Technology Education :: Home." MATE. Accessed December 19, 2017. https://www.marinetech.org/.

12. Appendices

12.1. Appendix A: Pre-Launch Safety Checklist

- ☐ Check and replace broken fuses
- ☐ Check the following connections:
    - Raspberry PI to power supply
    - PIXHAWK to power supply
    - PI to PIXHAWK
    - Signal wires of ESCs to Pixhawk
    - ESCs to power
    - Servos to power
    - Signal wires of servos to Raspberry PI
    - Light to power
    - Second Camera Signal to PI
    - First camera to Power
    - First camera signal to IPAD
    - Bottom Fathom-x to power
    - Top Fathom-x to power
    - Tether connection to both Fathoms
    - Tether connection to power
    - Tether power to both 48 to 12 DC-DC converters
    - 12 to 5 converter to 48 to 12 converter
- ☐ Check epoxy on all cables
- ☐ Grease O-rings with silicon
- ☐ Ensure tight enclosure of end-caps
- ☐ Check all screws

12.2. Appendix B: Post-Launch Safety Checklist

- ☐ Check screws
- ☐ Check for leakages
- ☐ Dry Test for all thrusters
- ☐ Check Fuses