INTEGRATE ORCA

2015 REPORT

ALEXANDRIA, EGYPT

TARGET ACQUIRED

Name:
Killer Whale v2.0

Status:
THE NEXT BIG THING

MATE 2015 INTERNATIONAL COMPETITION

CREATORS:

K. El Ghandour
A. AbouelKhair
M. El Rayes
A.. El Assar
A. Mashaly

MENTORS:

Ashraf AbdelAziz (Comm. Eng.)
Ahmed Fouad (Comm. Eng.)
Mahmoud El-Said (Comp. Eng.)

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Who Are We?

We are Integrate Orca. We are a team of 6 people of different ages, different schools and different interests, but we all have one common passion, the passion of pushing the limits. We will never stop pursuing our goal, even if it means getting out of our comfort zones and with the help of our mentors and advisors, we were able to do so.

***Karim El Ghandour**, CEO, Head of Mechanical team, 18, 1st year participating*
Grade 12, Riada International School

Ghandour always loves to check and be up to date with the newest technologies. He also likes writing, designing, programming and video editing and most importantly volunteering to help the misfortunate. He aspires to become a professional programmer and have his own multinational company one day, and later becoming the President of Egypt and achieve world peace.

***Amr Abouelkhair**, Pilot, Head of Electrical team, 18, 1st year participating*
Grade 12, Riada International School

Abouelkhair likes to program and learn new programming languages. He also likes to invest his free time in boxing and working out. Upon graduation from college, he hopes to work his way to leading the android development team in Google and afterwards become a university professor.

***Abdelrahman Assar**, Co-Pilot, R&D team, 17, 1st year participating*
Grade 12, Riada International School

Assar enjoys listening to music and watching the TV during his free time. He likes hanging out with his family and friends. He wants to become an engineer when he grows older.

***Marwan El Rayes**, Tether man, Mechanical team, 16, 1st year participating*
Grade 10, Alexandria International School.

Rayes likes watching sci-fi and horror films. He also enjoys hanging out with his friends. Unlike a lot of people he actually loves physics and mathematics. He wishes to continue his studies in one of the top universities in the world and then becoming a professor there teaching the following generation.

***Adham Mashaly**, CFO, Operation and Outreach activity, 15, 3rd year participating*
Grade 10, El Quds American School

Mashaly likes going out with his friends during his free time. He likes getting to know new people and learning new things. He wants to become an engineer later in his life.

***Youssef El Telbany**, Safety Specialist, Electrical team, 9, 1st year participating*
Grade 3, Sidi Gaber Language School

Telbany unlike many kids his age likes science and mathematics. But his true love is playing and watching football, and his idol is Messi. He wants to become an important person when he grows up.

Abstract

It is our motto to push the limits, and come up with something new and serve its function with high efficiency. We worked together and we made "Killer Whale" – named after one of the strongest and most vicious creatures in the ocean. It featured a polypropylene body with 8 motion thrusters, 2 arms and H-Bridges -based control system. Not only were we able to compete against other teams during the Egyptian Regional's of 2015, but we were able to come in 1st place which reserved for us a spot in this year's International Competition held in St. John's Canada.

For the internationals we wanted to come up with something better, something that will be able to maneuver well under the water with a wide range of motions for the optimum control, and with a good visual capability to be able to identify creatures from a large distance. Throughout this technical report we will present you with the process that we went through to design the ROV, the difficulties we faced and the troubleshooting process we went through, the improvements that we had to make, and with the various skills we learned during this competition.

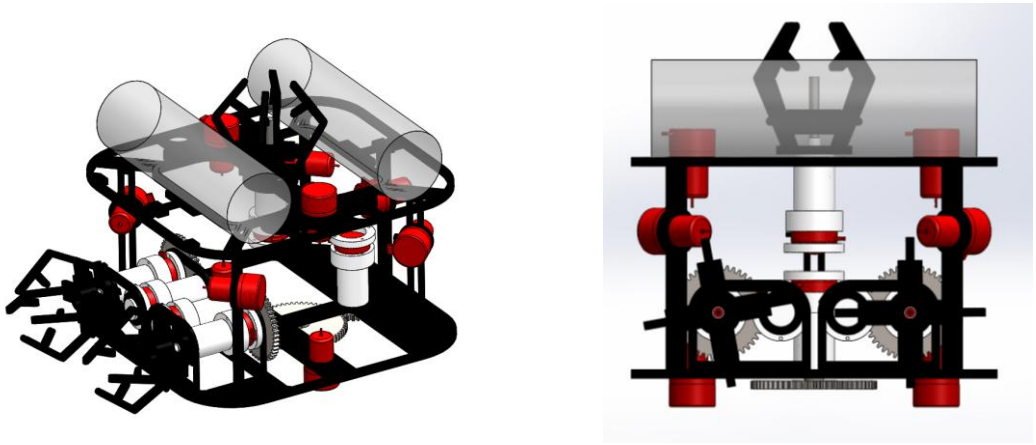


Figure 1 and 2 showing the Isometric and the front view of the ROV as sketched in SolidWorks

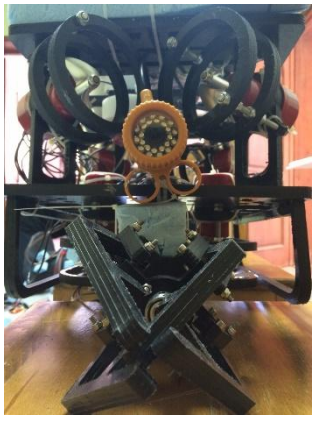


Figure 3 showing the ROV's front assembled and tested with one front arm

Team Briefing

After the regional's, we knew that in order to be able to compete in the Internationals we had to discuss the difficulties and problems we faced and tackle them during the short period of time that we have. However, with the majority of our team members being in High School facing their Final Examinations of the year, we knew that the free time we had before will be cut down dramatically.

The team was able to meet up on Saturday the 2nd of May 2015 in our workshop to sketch up how we will be able to invest the time we had left until the start of the competition in St. John's, Canada. We knew, however, that with proper role distribution and team organization we will be able to be ready.

After catching up and remembering some of the funniest memories that we shared in Port Said, where the Egyptian Regional's were held, the serious part of the meeting started. All the team members made a list of the weaknesses and we then talked about how we can improve them.

a) Challenges faced:

1. **One control board fitting all 20 relays in it which was hard to edit and troubleshoot.**
2. **Small range of motion for the arm since it wasn't made to rotate.**
3. **More torque was needed**
4. **Even with the help of our sponsors we still faced financial issues and the lack of money led to some delays in terms of ordering items required to complete the ROV.**
5. **Small time-frame due to end of year examinations.**

b) Improvements:

1. **Improved On-surface tether end.**
2. **HD TV Tuner for higher frame rate visuals.**
3. **Booster motor to add more torque.**
4. **Replacing the simple relay-based control system with a more advanced Arduino control system.**

c) Roles distribution:

We saw the significance of finishing the basic overall chassis, selecting the best materials, the number of thrusters that we will use, and the controller that the pilot will use. After sketching the proposed designs we started to get to work.

We decided to assign the team members the following:

1. **Ghandour will be responsible for designing the chassis on Solidworks, leading the mechanical team. He will also be responsible with designing and writing up the technical report and the spec sheet.**
2. **Rayes will help with the 3D designing process working in the mechanical team and sketching up the design parts on paper.**
3. **AbouelKhair will be leading the electrical team. He is responsible for drawing up the electrical circuits, setting up the SID (System Interconnection Diagram) and programming the way the Arduino will work.**
4. **Assar works in the Research and Development team, researching and writing up the pros and cons of each material as well as the most suitable controller that will be used for the navigation of the ROV underwater.**
5. **Mashaly works in the Financing team. His task resides in finding sponsors and financial sources, as well as finding the best prices for the materials. He also helps Telbany in the safety measures that we will take.**
6. **Telbany is responsible for the safety procedures that we will have to follow, making sure that we follow all the guidelines in the mechanical and electrical designing process.**

Figure 4 shows Assar researching the materials

Design Rationale

After several sketches that we drew up on paper, and after many team meetings and discussions we wanted to make a compact ROV that will be able to fit in the 75cm x 75cm hole, while still being able to lift and transport objects under the water and handle large pressures and depths. We succeeded in making an ROV measuring 60cmx45cmx40cm (LxWxH).

Frame:

When it came to designing the frame, we wanted make an easily assembled and disassembled chassis, and at the same time can withstand high pressure, and is easy to cut.

For the overall frame we decided to use polypropylene as the main material. Polypropylene is famous for its lightweight and strong durability. It also has low water absorption and is easy to cut making it one of the best materials that we can use for our ROV.

To ease the process of assembly and disassembly, we used the polypropylene as sheets of thickness 1cm each. After we finished the designing process on Solidworks, we used CNC to cut the sheets down to fit the ROV design. For the assembly process, we decided to use a technique known as "Finger Joint" made by cutting rectangular cuts in the polypropylene sheets. You can visualize this technique by interlocking the fingers of your hands at a ninety degree angle, hence the name "Finger Joint". By doing so we were able to form the chassis of the ROV from sheets without having to crave in a block of polypropylene which helped save costs. It also allowed us to make separate sheets for each part, which made it safer to transport without worrying of taking a lot of space. In addition, by cutting rectangular cuts for the motor mounts like displayed in the following figure, we were able to change the direction of the motors according to the task we assign it to do which added more flexibility.

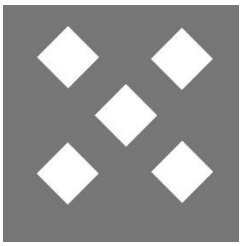


Figure 5 showing an illustrator sketch of the finger joint technique we use

The Chassis consists mainly of 2 main sheets, the top and the bottom.

- The top sheet measuring 50cmx45cm is used to house two thrusters directed vertically downwards. On top of the sheet the insulation tube, where we place the below shore control system, is placed, in addition to an additional tube to help with the buoyancy and balance of the ROV. At the center of the sheet lies an arm facing upwards used to grab objects above the ROV.
- The bottom sheet measuring 50cmx45cm houses two thrusters directed vertically upwards. At the center of the sheet a rotating arm facing downwards is placed.
- 5 small sheets measuring 27cmx25cm placed perpendicularly on the bottom sheet, joining both, the top and the bottom, sheets together. Each small sheet holds a thruster, with 4 of them aligned at an angle of degrees of 45 degrees.

Propulsion System:

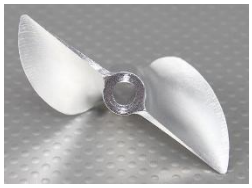
One of the most important aspects of building an ROV is its propulsion system. We wanted to use a propulsion system that:

1. Is Safe
2. Is Fast
3. Is Powerful
4. Is Water Resistant
5. Provides the ROV with versatility and maneuvering capabilities.

Our propulsion system consists of 4 parts. The Motor, the coupling, the propeller and the guards.

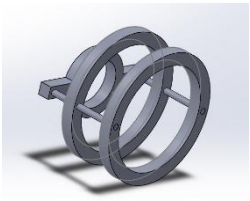
Motor: We needed a motor that is powerful, cost efficient, and more importantly that is insulated. After writing down the pros and cons of the different types of motors we discovered that going with a Bilge Pump (1100GPH) was the best option. It provided a good speed and a high torque and at the same time it required only a supply of 12V and 5Amp. In addition, the bilge pump used is already waterproof, and is easily adjustable to attach propellers or bolts. We modified the Bilge Pump by removing its cover using a saw and then removing the impeller to expose the motor shaft.

Coupling: We decided to use copper alloy joint coated with an isolation pain to avoid rusting and corrosion on long term basis, fitted on rotary axe of motor using 2 bolts for stable fixation.



Propeller: When it came to the propeller we had to select one that will offer the best thrust flow possible. We decided to go with a CNC 2 blade aluminum propeller providing a stable and efficient thrust flow.

Guards: Here in Integrate Orca we believe that safety is important. We wanted to come up with a design that will provide safety and at the same time offer a good water flow. We decided to use 2 sheets of polypropylene joined together by 5mm screws which achieves our goal.



Assembly: The propeller was fitted on the coupling head. It was then tightened using a locknut to avoid the unscrewing of the nut when the motor rotates both ways.

Figures 6,7,8,9 shows the ruler bilge pump, the coupling, the propellers and the guards used respectively

Configuration: After experimenting and through various trial and errors we discovered that one of the issues we faced during the regionals was we needed more torque underwater. So instead of using 8 thrusters like in the regionals, we decided to add a booster motor having a total of 9 thrusters. We wanted to add more mobility to our ROV, and so we decided to align our lateral motion motors in an angle of 45 degrees which will give us a greater freedom of motion. Doing so will allow the ROV to move forwards and backwards, sideways, diagonally, and giving it the ability to rotate as needed whether clockwise or anti-clockwise. As for the vertical motion motors, we will be placing 2 thrusters in the top sheet and 2 thrusters in the bottom sheet as shown in the following figure.

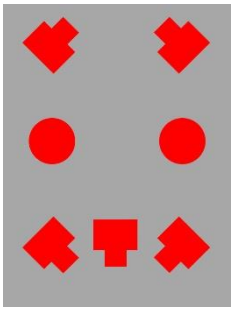


Figure 10 showing the motor configuration used in Killer Whale

Control System: Our control system is divided to two parts, On-shore and Below-shore.

Figure 11 showing the Playstation 3 Controller

- **On Shore:** Our research and development team was assigned with the task of choosing a suitable controller that will provide all the buttons we need while still being familiar enough to the pilot. After narrowing down our options, we decided to go with the well-known Playstation 3 Controller which was suitable for our objective.
- **Below Shore:**
    - **H-Bridge:** An H-bridge is an electronic circuit which enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards with variable speed according to PWM signal generated from control board. The team chooses Dual Channel 10A DC Motor Driver which is designed to drive 2 brushed DC motor with high current up to 10A continuously. Its supports locked-antiphase and sign-magnitude PWM signal. It is using full solid state components that result in faster response time and eliminate the wear and tear of the mechanical relay.

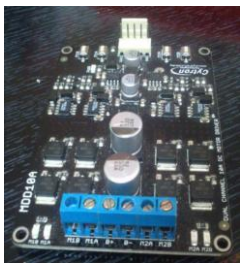


Figure 12 showing an H-Bridge

    - **Relays:** Using the input signals given by pressing a button on the joystick it connects the ground signal to close a specific relay which is normally connected to the positive and closing the circuit as the relay coil is magnetized turning on the relay switch causing the corresponding motor to work. By this concept we connected each button on the joystick to be responsible for a single motor in the case of the 4 lateral motors; however, the vertical motors each 2 are connected to a single button for an efficient performance.
- **Tether:** The ROV's tether is used to transmit power and data between the ROV and the piloting station. We had to put into consideration distance that the ROV is expected to swim underwater and the distance from the surface till the piloting station. A 33 meters 4 mm power cable was used, because it will provide the least resistance and will handle more than the double of the ampere usage providing a great safety factor. As for the data cable a 16 wires tether was used with a rubber coat and a metal shield to protect it from scratches and cuts which provide maximum safety.

Isolation: The electronics can is composed of one optically clear acrylic tube. With an outer diameter of 13cm and a length of 35cm the acrylic tube is attached to two polypropylene stoppers sealed by rubber O-rings that are incorporated in the stoppers forming three-stage water isolation. The thickness of the tube is 1cm which makes it endure very high pressures. Such a setup was optimal since we were able to fit all the electronics inside without a single drop of water entering the tube after several tests underwater at relatively large depths.

Figure 13 showing the Camera used

Camera: It is our priority that we provide the best solutions for our pilot and co-pilot to be able to finish their objectives. We needed to choose a camera that is isolated and water proof, and still offering a high quality picture. It was also necessary to attach LEDs to increase the line of the sight of the pilot. We ended up selecting a camera that featuring a lens angle of 92 degrees, and a built in LEDs.

With its waterproof body, we knew that it was the best possible solution. Our ROV features 3 cameras. One that views the front arm and is used as the eyes of the ROV so the pilot can navigate through the obstacles faced. The second is positioned on the bottom sheet so that it adds vision to the arm looking downwards, and the third is positioned on the top sheet of the ROV where the pilot will be able to view the third arm pointed upwards.

Specifications
Image sensor: 1/4 inch color Sony CCD
TV System: PAL/NTSC optional
Effective Pixels: 628x582/628x512
Sensing Area(mm):3.6x2.7
TV lines: 420TVL
Horizontal Sync.Frequency(KHZ): 15.625/15.734
Vertical Sync.Frequency: 50/60
Video Output: 75Ohm
S/N ratio: Betterthan45DB
Gamma Consumption: 0.45
Lens: 3.6mm
Lens Angle(Deg): 92
Current Consumtion (MA): 500MA
Power Supply (DCV): 12V
Leds: 24 LEDs
Minimumillumination: 0.8Lux/F1.2
Underwater visual distance(m): 0.5~1.5m
IP rating: 4Kg/cm2
Operating Temperature(Deg): -20~+75 (RH95% Max.)
Storage Temperature (Deg.): -40~+85(RH95%Max.)

Figure 14 showing the specifications of the camera

Payload Tools: Having a good camera and good maneuvering abilities is not everything. We had to think of the next big thing.

An Arm capable of finishing the task at hand, ranging from grabbing small objects, to long objects, to closing and opening valves, and tying in screws. After several sketches, we decided to build 3 different end-effectors, each serving a specific purpose.

All the grippers have the same mechanisms. Our grippers have a mechanical and an electrical mechanism, and by using a ball screw and rotating it clockwise we were able to open the arm and reversing the rotation allowed us to close it. Polypropylene was used in building our arm giving us a strong and easily shaped arm end factors.

Figure 15 showing the 4-end effectors gripper we are using

- Front arms: We wanted to make an arm capable of rotating. We were able to do that with the use of 2 gears and 2 bilge pumps. By turning on the bilge pump, the small gear rotates, rotating the second larger gear which in turn rotates the arm either clockwise or anticlockwise. By having 4 end effectors we guarantee that we are able to safely hold objects of different sizes safely.
- Top Arm: One of the challenges we faced in the regionals was that grabbing the object near the surface of the ice-sheet required tremendous effort, having to move slowly to make sure that we succeeded in grabbing it. After a team discussion we came up with a solution of wrapping a "net" around the arm which in turn will make grabbing objects easier.
- Bottom Manipulator: The first question we asked ourselves as a team was "We want to be able to close and open valves. How will we work around to find a solution?" We started by replicating this 'motion' with our hand. We wanted to know how the human joints worked. We then came to the idea of fixating 2 sticks to a sheet at a good enough distance them to provide enough torque, and then rotating the sheet as necessary. Such a technique is similar to the way you fixate your wrist and fingers and rotate your arm all the way to your elbow. Following the method the way the front arms rotate with gears, we were able to achieve the same effect we wanted.

Buoyancy and Stability:

When creating an ROV that is supposed to dive underwater, you cannot just think about its power. You have to put into consideration its ability to actually move underwater and not just sink down like a lump of rock. Here is where studying the buoyancy and adjusting the stability came in handy.

Buoyancy is the principle given by Archimedes which states that the body experiences an upward force when it is partially or completely immersed in liquid. Buoyant force given by the following formula:
In terms of pressure, buoyant force Fb is given by:
$F_{b=PA}$
Where (Fb: buoyant force, P: pressure, A: area)
In terms of volume, height and area it is given by:
$F_{b=gpV=pghA}$

Where (Fb: buoyant force, *ρ is* the density of the fluid, g: gravity,
V: is the volume of the immersed part from the body in water,
h: height of the immersed part from the body in the water, A: area)

We managed to achieve this by using two insulation tubes (including our control tube) placed on top of our ROV. Their whereabouts help position the center of buoyancy at the top aligned with the center of gravity present at the bottom making sure that maximum separation is present between both forces ensures utmost stability. The ROV is then tweaked further using additional loads or extra variable tanks (water bottles) or extra foam to achieve critical floating.

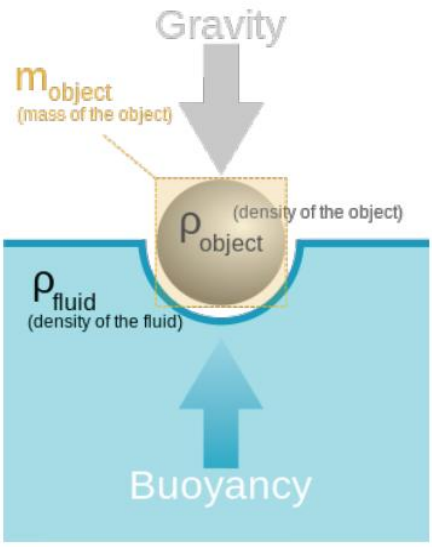


Figure 16 showing the buoyancy forces that the ROV Experiences

Figure 17 Integrate Orca team adjusting the buoyancy of the ROV.

Teamwork and Organization:

"The strength of any team is measured by the strength of its weakest link", and here in Integrate Orca we believe that winning or losing, if by the end of the day we felt like we didn't benefit the team with something new then it wasn't a successful day. That is why even though the team is divided into specialized divisions, we had to make sure that we have good communicational skills and that we had good chemistry.

We can't deny that in any team there is bound to be some arguments or a difference of opinions. However this we are responsible to work out our differences and look at what is best for the team. That is why we follow a democratic system where we give the spotlight to each of the team members to speak his mind, stating the pros and cons of their point of view and then we all vote on what we find best.

We also believe that trusting each other is important. With the many commitments we each have, there comes a time when there is someone who cannot finish the job. That is why we always offer a helping hand knowing that we can depend on each other to get the job done.

Troubleshooting Techniques:

An ROV consists of a lot of different mechanics and parts that are required to work together to achieve our goal, and as a result everything is not expected to work from the very first time. We are bound to face problems. We start by making a list of the probable causes of the problem, and through the list of elimination we figure out what is the specific cause. Then we walk through the solutions as a team until we find what is best. An example of such a process is when we faced a problem designing our board. We wanted to make a circular board having a certain radius. But every time we fail to draw it. We made a list of the probable causes, including the width of the wires, and the position of the connectors, until we came up to the conclusion that we were using a larger than required connecter which required a larger space.

Figure 17 Troubleshooting Techniques

Skills Gained:

Throughout our lives we gain skills over the years. Some are technical, focusing mainly on the scientific knowledge we learn and some are interpersonal. Joining such a competition helped us as team members to gain several skills that can help us for the rest of our lives whether in the field that we will work in later on in life or even when it comes to day to day encounters.

- **Interpersonal:** Can you imagine a team assembled less than 10 months before the competition with most of the members not even knowing each other, trying to dive into a field that they have almost no background of and still planning to win? Having to transform the team from strangers to become more like family within such a short period of time is almost impossible, but again here in Orca we love pushing our limits and defying the impossible. Through the several encounters we had, and through the many problems we faced together we gained many interpersonal skills. We gained a lot of communication skills which allowed us to understand our differences and increase our chemistry. Our presentational and public speaking skills increased drastically allowing us to increase our self-confidence. Last but not least, being chained down by a lot of deadlines and time limits we learned to manage our time wisely and efficiently which is surely going to help us in our social and work life.

- **Technical:** One of the things that a lot of people complain about when it comes to the normal educational system was the lack of practical work. What will people gain from learning theoretical knowledge if they can't practice what they have learned and know its relevance and how to use it in their lives. Participating in the ROV Competition greatly helped us understand principles we might have been told about in school but we didn't comprehend until we put it to practice. We gained invaluable knowledge ranging from learning basic physics principals such as buoyancy and stability, to the minute properties of industrial materials. We learned the process that any product goes through from the basic early hand-drawn sketches through the cutting until the final assembly. We all learned how to transform those sketches to accurate 3D designs on Solidworks, and how the circuit boards are designed in Eagle. Furthermore we learned how to program an Arduino chip which gave us a glimpse of low-level programming languages providing invaluable knowledge before entering university.

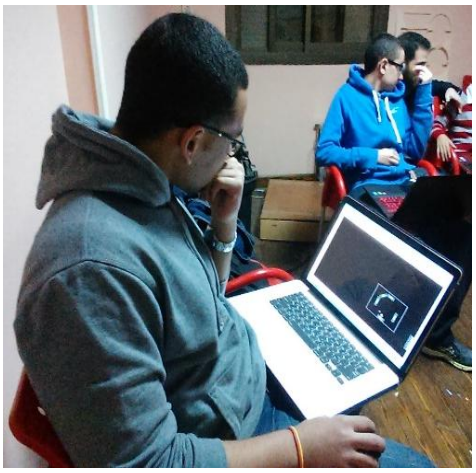


Figure 18 Amr designing on Solidworks

Safety and Security:

Our top priority is the safety of our customers and only through intensive researches and tests we were able to do that.

- **Staff Safety:** We started our manufacturing process following strict guidelines when it came to the safety of our staff.
    - Wearing eye goggles during cutting and building the mechanical body.
    - Using insulated tools while working
    - Using fixed tools like the drill station instead of the drill to avoid any injuries.
    - The workshop also contains a first aid box for any injuries.

Figure 19 Mashaly wearing eye goggles and gloves

- **Mechanical Safety:**
    - We designed the ROV with smooth edges making sure that there are no sharp edges that might accidently harm anyone.
    - Motor guards are attached to the motors to prevent any accidental contact with the propellers during motion.
    - To alert for moving objects such as thrusters, we attached cautionary signs to the motors and wrapped the end effects of the arms with red water-resistant tape.

- **Electrical Safety**
    - After intensive research about the current our ROV requires, we found that using 25Amps fuses connected to the power line of the tether placed in the driving stat ion seemed optimal. 25 Amps allows us to operate the cameras, and up to 4 thrusters all at the same time.
    - An emergency button is placed in the driving station to shutdown the system in case of any emergencies.

Future Improvement:

We always seek to improve our products with the latest features and technologies. We believe that a product needs constant developing and improving. Our research and development team is working day and night to come up with the best solutions and improvements for the near future. Some of the ideas suggested so far:

- Providing Tilting capabilities to the ROV to add maneuvering abilities.
- Increase publicity in the community. A lot of people in Alexandria, Egypt still don't know what an ROV is. Next year, we will have a campaign early in the year to acknowledge citizens with the competition.

Reflections:

"Joining this competition was one of the best decisions of my life. And I hope to make my country proud this year in the internationals" –Amr AbouelKhair.

"The value of the skills and knowledge I learned is priceless. Worth every sleepless night I spent working on this project." – Karim El Ghandour

"There is no better feeling than feeling like you accomplished something. Win or lose this feeling means everything to me" – Marwan El Rayes

"Dipping my hands in the dirt for once and really learning the value of knowledge changed the way I look at science." – Abdelrahman El Assar

"People my age are out there playing with plastic toys. They can't believe that I am making a robot!" – Youssef El Taybany

"I learned a lot of things throughout my journey and I can't to learn more" – Adham Mashaly.

Budget Sheet:

*All Prices in USD.

ROV budget:

Description	Amount	Cost Each	Total Cost	Status
Bilge Pumps	15	48	720	New
Cameras	3	131	393	New
Acrylic Tubes	2	13	26	New
Tether Wire	2	40	80	New
Joystick	1	46	46	New
Propellers	10	40	400	New
Gold Plated Connector	30	0.40	12	New
Electronic Components and PCBs			100	New
Stainless Steel Bolts and Locknuts			27	New
H-Bridge	8	36	288	New
Arduino	2	46	92	New
Ball screws	5	30	150	New
Artilon Stopper	4	30	120	New

Total ROV Cost	**2454 $**

Travel budget:

Description	Amount	Cost Each	Total Cost
Flight tickets	12	1300	15600
Accommodation	12	300	3600
Vehicle and Gas	1		1800
Team T-shirts	12	17	204
Transportation from Integrate to Airport			300
Visa Fees	12	190	2280

Total Travel Cost	**23784 $**

Total budget:

Total budget	**26238$**
Donations from RLS	**4300$**
Donations from ALS	**1500$**
Donations from IBM	**2000$**
Newly Paid	**18438$**

Acknowledgements:

Killer Whale wouldn't have made it this far without the generous help of these individuals and organizations:

- The MATE Center for providing us with this opportunity.
- Hadath for organizing the regional.
- Arab Academy for Science and Technology (AAST) for hosting the regional.
- Integrate for being our main technical supporter.
- Eng. Ashraf AbdelAziz, Eng. Ahmed Fouad and Eng. Mahmoud El-Said technical advisors.
- Eng. Mahmoud ElSaid graphic design advisor.
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- Channel two national TV for media coverage.
- El Mahrousa for allowing us to use their pool.

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- 2015 MATE ROV Competition Manual – Ranger Class http://www.marinetech.org/ranger_2015/
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- Arduino http://arduino.cc/en/Main/arduinoBoardUno
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Appendix A: Development Schedule

Tasks	Aug	Sep	Oct	Nov	Dec	Jun	Feb	Mar	Apr	May	June
Learning Solidworks											
Learning Eagle											
Sketch design											
Finalize Solidworks drawing											
Buy materials											
Manufacture isolation tube											
Test isolation tube											
Buy Electrical components											
Complete electrical control											
Assemble											
Prepare pool											
Testing ROV											
Troubleshooting malfunctions											
Regional Technical report											
Pilot training											
Regional Sales Presentation											
Regional Poster display											
Regional Competition											
Re-designing											
Technical report											
Re-assembling ROV											
Sales Presentation rehearsal											
Poster Display											
International Competiton											

Appendix B: Safety Checklist

Electrical	
	NO wires near motors
	25A fuse present
	NO exposed wires
	Circuit board isolated
	Wires properly attached to tether

Mechanical	
	NO exposed motors
	Propellers fitted in coupling
	NO loose screws
	Caution signs present
	NO sharp edges
	Gripper securely held
	NO cracks in tube
	4 O-rings present in each polypropylene stopper
	Camera fixed properly

Drilling and cutting	
	Wearing eye goggles
	Keeping sharp and drilling tools in the tool box
	Wearing safety gloves

Appendix D: System Interconnection Diagram (SID)