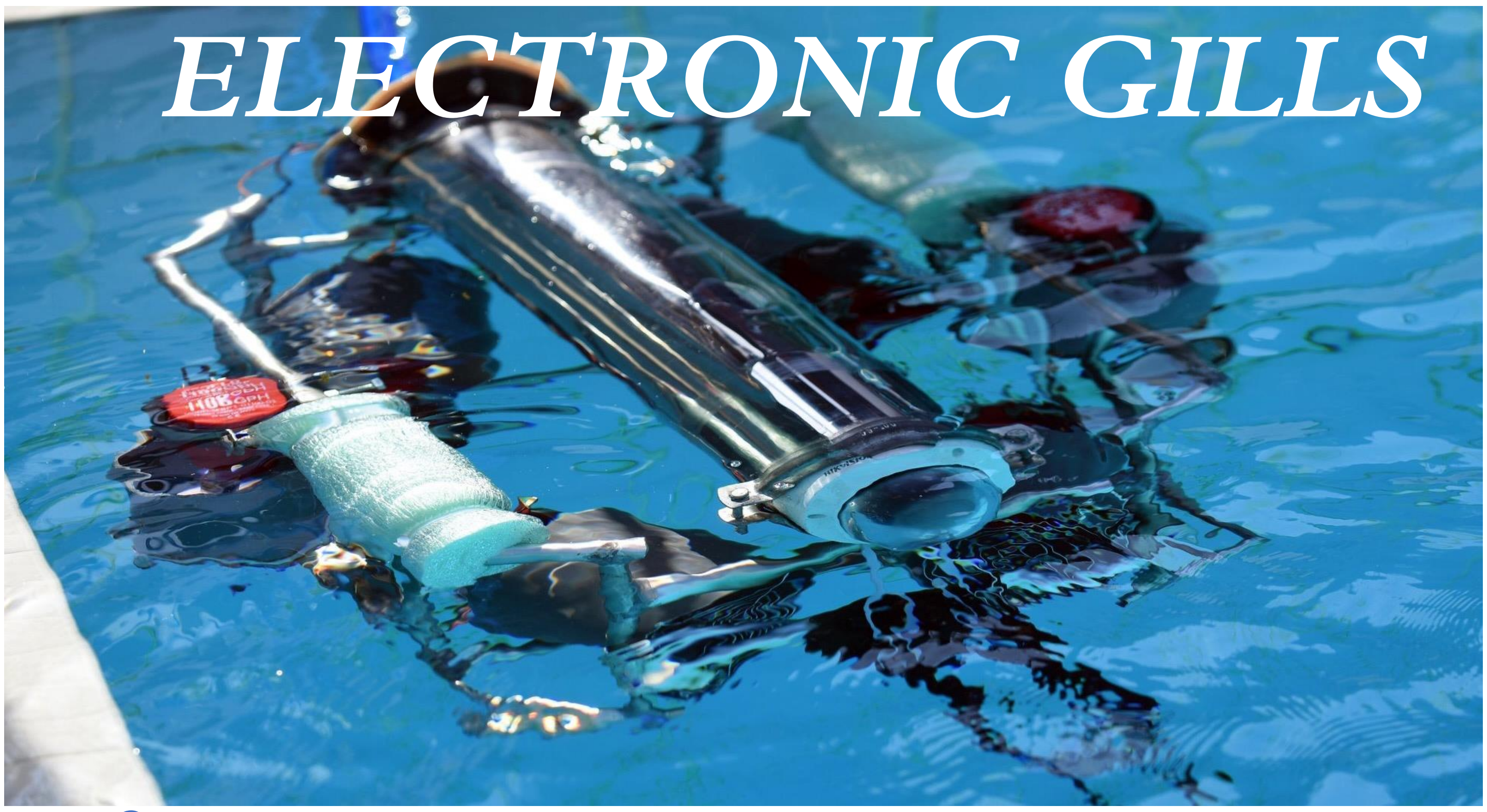
ELECTRONIC GILLS



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ELECTRONIC GILLS

Thanks to

MATE ROV COMPETITION
Arab

Content table:

1-Abstract:

Depending on the cultural background, a company starts out with a different mindset and with a specific view of reality. Ours has forged its axioms:
Resourcefulness and plan B. That way, we designed OXOMLS, a ROV that meets Eastman expectations according to the tasks mentioned in this present RANGER Manual.

As a first step, we tried to imagine ourselves into a completely new environment. Then, instead of plunging into the product we scrutinized the specifications and utilized Microsoft project as a tool to organize our work. Soon after, we used Engineering Design Process to find solutions and Design Thinking Process to make innovation alive and conceive specialized tools for our ROV.

Some tools are derived from leveraging scientific knowledge: we increased stability by maintaining a neutral buoyancy of the ROV to precisely measure distances especially in task 3.
Others derive from transformation: we transformed water pumps into waterproof motors since they are unavailable in Tunisia. We also designed and created specific propellers through 3D printing to complete task 1 faster.

Because our goal is to provide a safe and secure working and living environment in an eco-friendly way, we need to monitor dam's temperatures and phosphate levels through our sensors. And since species diversity is another indicator of water quality and environmental health, we need to recognize them by visual recognition and replace degraded rubber tires by reef balls with our gripper. Finally, preserving the city's history and by marking any shells to safely remove them afterwards using our sensors.

Figure (1): Team members

2-Understanding the context

Dams are known by their regulation of the flow of water and their storage. Almost the majority of dams have serious problems because of the amount of polluted water that passes every minute and carries with it negative consequences which are a bit complicated to repair.
However, many experts have questioned the risks of using human divers and have turned to ROVs as a solution because ROV can be used to efficiently and safely perform tasks and tests, even in areas that are inaccessible by human divers.

In October 2014, experts found water and sediments were weeping from the riverbank. Therefore, ROV's mission is to deploy a secondary micro-ROV for possible dam failure and to locate the muddy areas.
Besides that, it is designed to maintain the water quality by measuring the pressure of the dam, temperature every 15 minutes, movements every 30 minutes and to insure the surveillance of the dam using specialized sensors. It is also designed to locate and repair structural issues for instance inserting grout to fill voids beneath the embankment or changing and old, broken trash rack and replacing it by a new one.

More than 1500 degraded rubber tires contribute to the imbalance of water quality, but these rubbers represent a habitat for fish. Our ROV will place reef balls to ensure a normal life for these trout fries and to increase the number of these fish.
As far as the preservation of history is concerned, the role of our underwater robot is to recover the cannons to preserve the history of south fork Holston River since the battle during the civil war.
As intelligent as human pilots, as valuable as their machines, ROVs incorporate the best of both words to go beyond the intentions of human divers. For the Boone Dam or other dams in the world, ROV is a significant advantage of technology and a boon to economy nearly anywhere in the world and for any underwater tasks.

3-Design rationale

Although the solutions to the mentioned problems in the Manual are infinite, the existing contraints in terms of circumstances and ressources led us to the concept of «design thinking» in which validation was there in every step of the process.
We first did what we call « EMPATHY ». In this step, we first tried to have a holistic view of the situation that MATE competition depicted in the Manual. All the members of the team read it entirely. But two of us were in charge of scrutinizing and making a summary out of it. At that moment we had a clear picture of what we need to emphasize and highlight. The second part is «IDENTIFICATION OF THE NEEDS». At that point, we made several meetings in which we discussed about the missions that Eastman requested. We scrutinized the missions in depth and started to work down on the easy ones.
And now, comes the best part of our teamwork: our philosophy. Our motto is: Reflect Transform and Create. And the first step was «BRAINSTORMING» in which we try to destroy our ideas to make innovation alive. And it was there where we divided ourselves into subgroups. Each one has its own concern: safety, stability, sponsorship, organizing events to raise funds or to create a media outreach, adequate coding, and solutions to task 1, 2 and 3...
And as the experienced MATE judge Marty Klein: «First, you look at the tasks...instead of plunging into the product. » we took his advice into serious consideration. We also defined the role of each like that was responsible to find a way to measure precisely the distances in step 1 but mainly in step 3 or who has the responsibility to make the idea that we want to convey to people clear, who was in charge of the safety during the whole process...
And after weeks of research, we started to make our ideas alive by « PROTOTYPING ». And as Markus Cicero said: « The safety of people shall be the highest law ». Therefore, we called on our two mentors to supervise us and check that we meticulously followed the guidelines they gave us and follow the right procedure and protocols for safety. They supported us a lot in that stage.
But how do we valid the solution to a certain task and know that it is the right one? We could not have any better response with «TESTING». Although leveraging and

developing scientific knowledge is one of the best ways to solve our problems, we could not negate that we need to check that our equations were right. We could give you the example of our "conceptual group" who wanted to maintain a neutral buoyancy to provide high stability for OXOMLS, our ROV. They first calculated the right amount of foam of plastic to add. However, the ROV in water seemed to have positive buoyancy. They forget to take into consideration Archimedes principle. This is how we find the solution to our problems.

FRAME OF OXOMLS:

The frame of OXOMLS as shown in figure 3b must be rigid and light as it provides the space to host all of the components. Therefore, the choice of its material shall be a wise and sensible decision. In fact, members of OXOMLS team spent a whole week deliberating on the usage of the variety of materials to construct the chassis like carbon fiber, iron and epoxy resin. Aluminum was the final decision, as it is durable, lightweight, recyclable (eco friendly), resistant to corrosion (important for dam's inspections) and cost effective.

The frame consists of two parts: core part and actuator part.

The core part is the upper layer and it hosts the electrical chamber (central unit of OXOMLS). Although the lower part mainly hosts thrusters, it was meant to support interchangeable and detachable tools to complete the different tasks. Another deliberated choice was its likely rectangular shape. As you noticed, the frame was not a block but rather a emptier chamber. This is due to the first law of Newton: inertia. Because if we close the frame, the ROV would have difficulty to change its motion since inertia would be bigger. We also thought about hydrodynamic. As some members of our team practice swimming, they have a great understanding of drag forces. For this reason, we tried to curve a bit the structure but not too much to prevent any weakness in bearing the stresses. We also wanted to use less material while preserving its properties (less expenses) by piercing the structure of the tube (to become an empty tube). We were inspired from the mechanism of the body to counterbalance the air pressure, and it is clearly explained through figure 3. However, it makes the ROV heavier and let the water penetrates easier. Being aware of this, we precisely added, using equations and Archimedes principle, foam of plastic and made a special safe wire compartiment, a path only for wires with thicker cable covers on purpose to prevent any harm to anyone. Plus a tube filled with water is less heavy than one filled with aluminum.

4-Buoyancy:

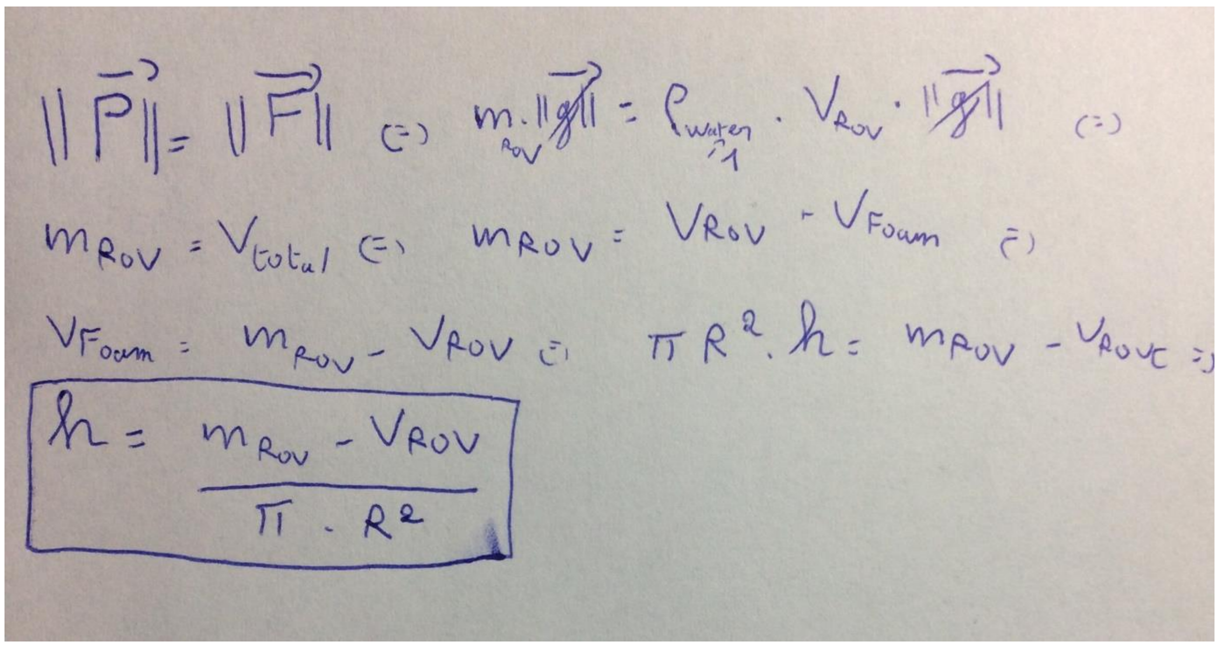


Figure 2: Equation to calculate the high of the foam by Yasmine Kerkeny

To achieve higher stability, we need to get closer to neutral buoyancy. And it is achieved by using foam of plastic, found everywhere, as the buoyancy material. To precisely measure the right amount of this later, we applied this formula as shown in figure 2 by applying Archimedes principle. However, we want it the ROV to have a slightly positive buoyancy to rise upwards in case of a hardware failure so that it does not damage the environment by releasing any harmful chemical reaction after its degradation. Therefore, in our formula, we neglected the adding volume of the foam in the equation to achieve this slightly positive buoyancy. Furthermore, the foam is placed at the top of the frame which allows the center of mass of OXOLMS to inline vertically with its center of Buoyancy.

5-Propulsion system:

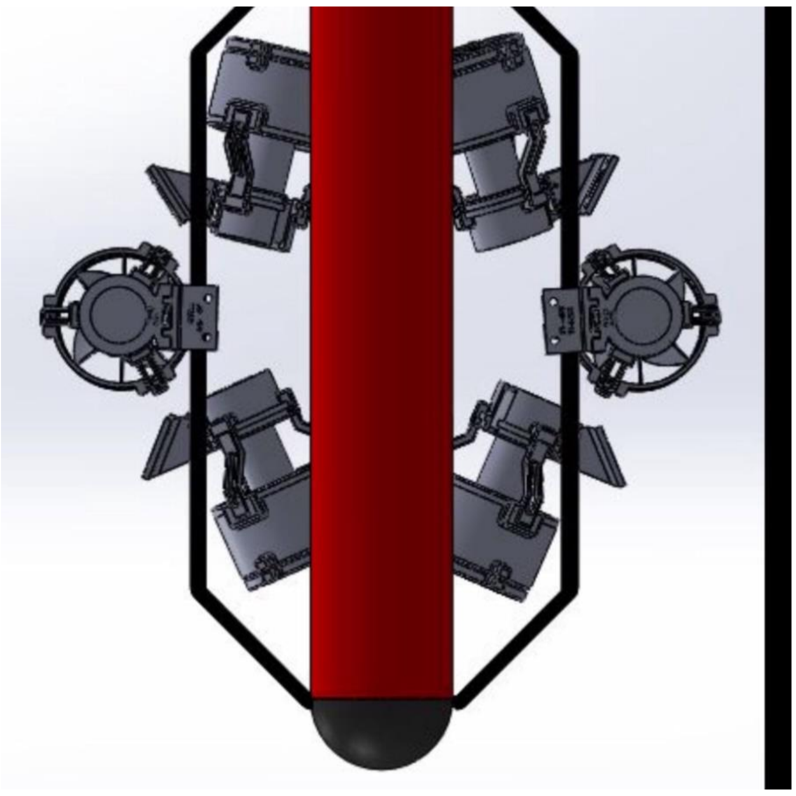


Figure 3: a- The displacement of thrusters done/credit: Khalil Mattar/ Solid Works

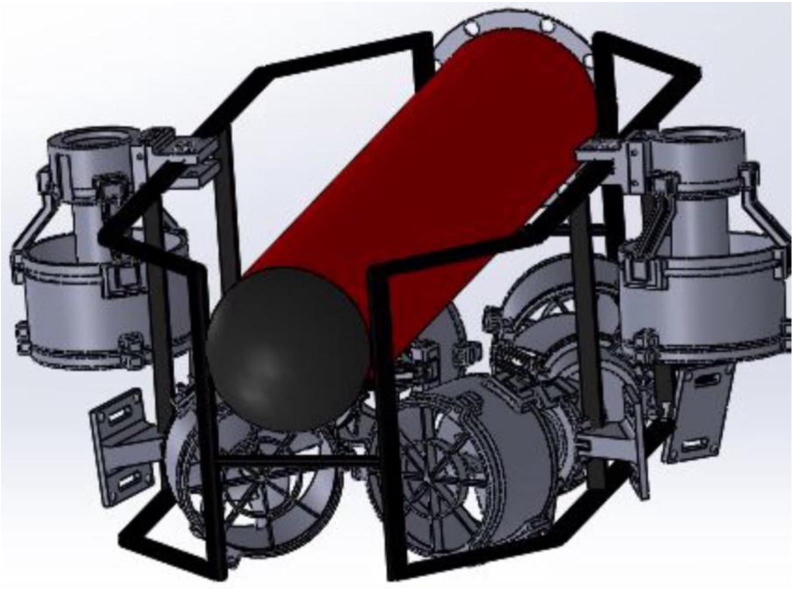


Figure 3: b- 3D model of OXOMLS using Solid Works done by Khalil Mattar

4 thrusters are meant to control both rotational and transversal (forward and backward motions) and 2 thrusters are used for upward and downward motion fig3a. Water pumps are selected for this task because waterproof motors are unavailable in Tunisia (our country). Therefore, we applied our philosophy*: if you cannot buy, reflect, TRANSFORM and create*. For this reason we transformed water pumps into waterproof motors. As well as creating 3D printed 2 bladed propellers to speed up the velocity of OXOLMS. The propulsion system consists of 4 horizontal thrusters in a vector configuration and 2 vertical thrusters. Therefore, we can manœuvre with 6 degrees of freedom. Assuming the forces produced by these propellers are identical, the angle of each should set a 45° to control the magnitudes of the forces in each direction to achieve the optimum stability during maneuvering. As mentioned, we are currently using the 45° angle as shown in fig3a which gives us sufficient proportions of thrust to fulfill stability to the rotational motion. We also realized from our past experience that an «O» shape configuration facilitates the rotation of OXOMLS.

6-Tether:

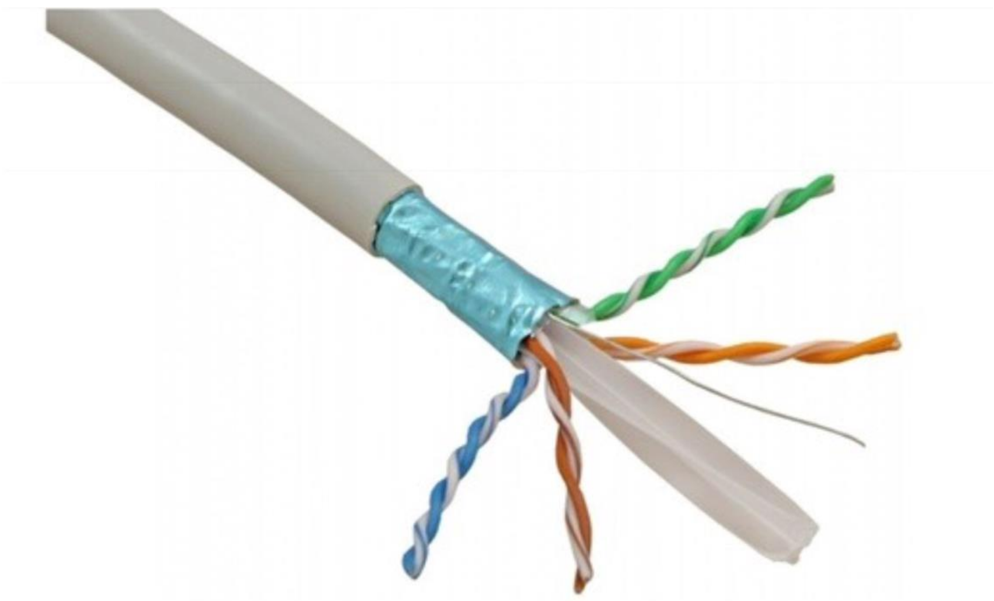


Figure 4: the protection of the Ethernet category 6 (FTP)

a- Communication:

The signal is transmitted from the station to the ROV through 20 meters Ethernet Category6 FTP Solid Cable as shown in fig4 which have 8 cores which supports data rates of 10G up to 100 meters (this is what we need for real task missions). The cable can handle speed performance of up to 250 MHZ. This fast performance makes it

possible to use with a fast ethernet network including Gigabit Ethernet and 10-Gigabit Ethernet. After long discussions we learned that a twisted pair reduces electromagnetic radiation from the pair and crosstalk between neighboring pairs and improves rejection of external electromagnetic interference. We also learned other strategies to deal with interference.
The tether also consists of a USB cable that is connected to the Arduino Mega cable in which we learned two essential rules: the longer a wire is, the stronger is its resistance - the finer the wire is, the greater is its resistance.
We also discovered through tests that the tether is negatively buoyant since it adds more drag to OXOMLS. Therefore, we planned to add some foam every 50 cm (this is an area of improvements).

$$VDI = \frac{Current\ (Amperes) \times Length\ of\ wire\ (feet)}{\%Voltage\ drop \times Voltage\ (volts)}$$

$$= \frac{12.3 \times (25 \times 3.28)}{4.2 \times 48} = 5$$

VDI (5) —AWG wire sizing chart→ AWG (10)

Figure 5: Voltage drop index (VDI) and American wire gauge (AWG) calculation example

b- Power transmission:

The tether measures 20m in order to have a wide range of motion. But our goal was to minimize the voltage-drop (10%) across the tether's terminals and subsequently providing the DC-DC converters with a stable voltage-fig (5). To reach this goal, we utilized calculations by working out the VDI (10), and through that we discovered an area of improvement.
Based on the AWG wire sizing chart, we must use in theory a 7AWG (3,665mm diameter). However, we faced hiccups to find those right dimensions. Therefore, we planned to buy the right range of cables as soon as we find them. Albeit, we learned through that process new concepts and realized all the engineering and mechanical knowledge needed to realize a professional operated vehicle.

7-Power Distribution

The current supplied from the 12 volt power supply passes through a 12V/20A fuse and located 20 cm from the power supply to be sure that we will not have any interruption, then reaches the main electronics enclosure where it’s distributed among six cytron cards as well as supplying the 6 thrusters, the Arduino Mega, the camera, the gripper and the micro ROV.
A 7805 voltage regulator is used to regulate the voltage from 12 volts to 5 volts and from 30A to 12A.
Maximum power is never reached because of our software interlocking system which limits the speed of each thruster individually. Therefore, it prevents the thrusters to operate at their full speed simultaneously. This results in a preservation of the performance of them so that they operate longer.

8-Electronic chamber and its sealing:

This year, another of our main concerns from a mechanical point of view was creating a robust and durable design for the electrical housing, since main electrical components are hosted inside this tube; we need a system that prevents water seepage. In addition to this, we have to deal with the ressources that we have because in Tunisia, components are either unavailable or overpriced; or worst: defective equipments. Therefore, all of the team and especially the mechanical team members have to deal with all these constraints in head. The canister is made out of a stainless steel tube since it is the only material found in our country OXOMLS' electronics enclosure. It is a 21.5cm long flanged cylinder with an inner diameter of 15cm and a wall thickness of 5mm.

The cylinder is made of Inox as it is a non-porous, high strength, shock-resistant material as well as cost effective.
Both of the ends of the 5mm-thick chamber used an O-ring instead of epoxy to avoid polluting the underwater environment and assure with great reliability that no water penetrates. In fact, we realized after the safety check list and during the retrieval phase that water seepage occurred only once which is due to the old O-rings that we used last year and tested countless of times. Therefore, we changed it to a new one that fits in a suitable groove to assist in the sealing process. It was then fixed by 8 bolts to ensure its enclosure. All wires connecting the electronics within the canister with outside components are passed through 5 plastic glands which are used to seal between the cables and the cable holes through the enclosure as well as providing stress-relief for the cables. Those glands can withstand a pressure difference up to 5 bars(5x105Pa).
Those wires are then gathered by a 3D printed fragment to track their paths so we replace them easily in case of a dysfunction in the electrical network. However, electrical components are not fixed in the EC but are rather fixed in a customized support that aligns with the cylinder central axe so that the components will be in a secured place even if water seepage happens.

9-Electronic disposition and choice:

The number of cytron cards inside the electronic chamber is 6 and it is fixed on a 3D printed fragment that represents the support of all the electronic cards which passes through the central axis of the cylinder. These cards are linked by cables to interconnect the motors. Their role is to change motors' direction by changing the electrical circuit's path. Initially, we used relay cards until we saw its flaws by doing tests. At first glance, they seemed to match the requirements since they are available in Tunisia and very affordable. But during the tests, we concluded that this type of card was not the best choice, because there is a downtime of 5 seconds to react to the pilot's commands. This was very inconvenient, since we need accurate and real time reaction for our tasks. Although cytron cards are much more expensive, we chose them since they are more efficient, faster and easier to install and program (especially when it comes to programming them) and capable of controlling motor for Start, Stop, Brake, Direction and Speed. Therefore, this analog input card was a better and well appropriate choice.
Each of the 54 digital pins on the Arduino Card Mega 2560 can be used as input or output using the functions pinMode (), digitalWrite (), and digitalRead (). It also has 16 analog inputs, each of which has 10 resolution bits (ie 1024 different values). This card has a number of ways to communicate with a computer: another Arduino or other microcontrollers. In addition, we have an Arduino UNO card that controls the sensors.

10-Vision system

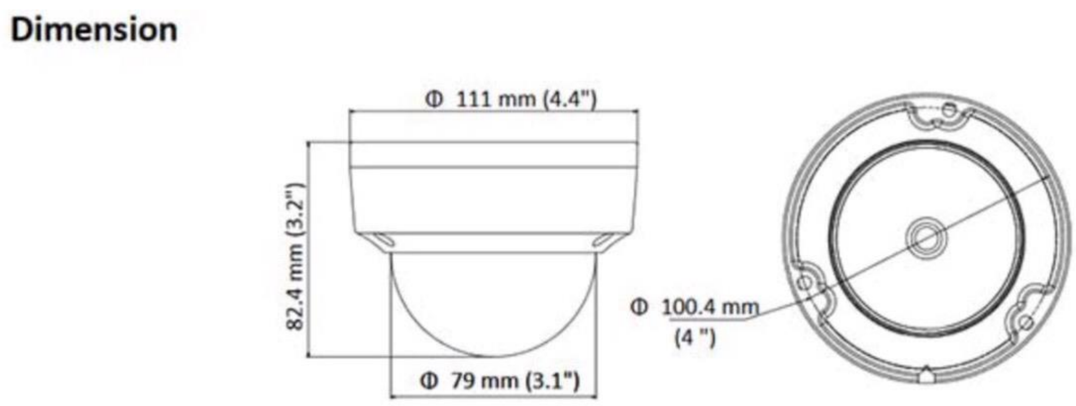


Figure 6: Dimensions of the main camera

Main Camera:

Since all of the tasks require a camera and need a lot of image processing, we thought that we need a decent camera. Therefore, we chose an IP Hikvision DS-2CD1141-I Ultra HD 4MP PoE camera as it provides features needed for missions. This camera has a focal length of 2.8mm and a decent angle of view of 105.8^. It is already waterproof and can deliver a high quality image up to 4MP. Therefore, it almost gives the pilot a perfect view ahead. Another of its features: a nocturnal vision up to 30m since it is an infrared camera and it incorporates advanced image processing technology needed to calculate distances. This sponsored device could work under relatively tough conditions from -30 to 60 c which is perfect for Eastern Tennessee climate.

It is also powered through an RJ45 cable that we already have.

11-CONTROL PANEL:

Figure 7: Our control box panel

Our control panel consists of two main components: the first one is the monitor that displays the readings needed by the pilot while controlling OXOMLS through a graphical user interface. The display is divided into four sections meant for the cameras in both the main ROV. During the testing phase, our pilot suggested that we should use only one screen instead of two ones for convenience purposes in terms of carrying, removing and monitoring. Our meticulous pilot wants a neat and organized working place environment without loose components or unsecured wires. Therefore, our co-pilot ensures this request by applying a special protocol before

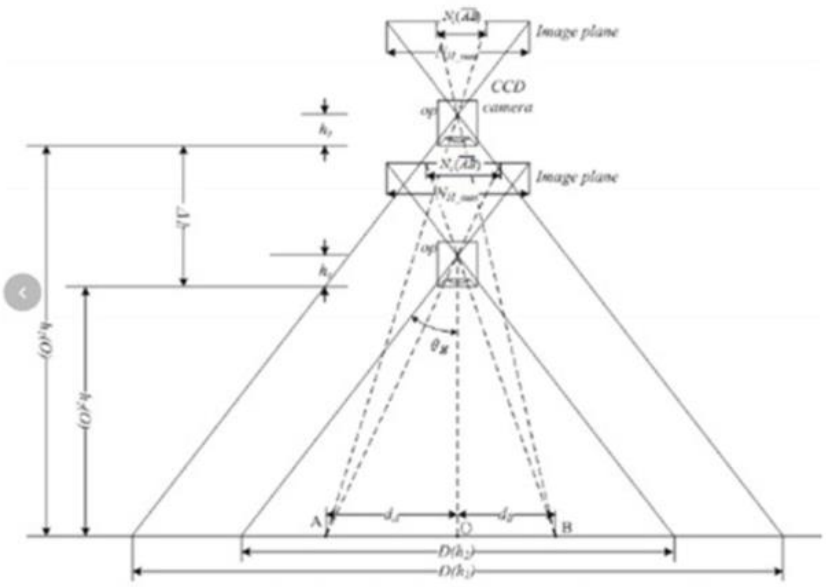
starting the maneuvers of OXOMLS. The second one is the joystick as shown in figure 45 and it has a couple of interesting features: flexibility and stability at the same time. The pilot and co-pilot mutually agreed upon this quote: There is no chance to lose control while doing the tasks.
Moreover, our joystick contains a myriad of other buttons which can be a godsend, since we need to add more options to the ROV according to the tasks. Therefore, the Joystick was used to ensure the easiest and best control for the pilot as well as providing different vehicle speeds to achieve the mission in the least time possible

12-Software:

The Arduino controller on the ROV is programmed using National Instruments LabVIEW software. LabVIEW is a graphical programming language that allows users to create programming code through control block diagrams rather than traditional line code. Since most of the team did not have much experience, the graphical format of LabVIEW allowed the team to focus their efforts on the actual content of the program, rather than learning the syntax.
In a nutshell, this program acts as the center of the whole control system that gives commands to the main ROV. Before that, it receives data from the pilot commands and collects inputs from the user through the joystick and conrtol panel. We chose to work with this program because we can automate the capture, validate signals and take measurements with less effort than traditional programming environments. We have also got hardware options (controllers, measurement modules, control modules, communication modules), real-time applications and desktop applications are developed in the same environment and series of add-ons and plug-ins to help get the job done faster; without the mention of its parallel processing that enables us to do multiple tasks at once such as monitoring water's temperature while displaying status of any benthic species with the image processing like in task 1. LabVIEW is our friend. It is a graphic programming, therefore, easier than textual programming (coding) and it also contains an interface for the pilot to control other subsystems, such as lighting or manipulating.

13-Mission specific tools:

Measuring distances to calculate the volume of the canon:
Using the main camera of the ROV, a photo is captured and imported to the image processing software. A scale is set to a known distance in the captured photo and using the concept of relative distance measuring based on pixels counting, a relation between the number of pixels and the unit length could be established which is used to calculate the required distance accurately while calculating the volume. -**fig(8)**



Schematic diagram depicting the relationship between distance and variation of pixel counts at different photographing distances.

Meanwhile, other parts of the team were trying to find the equation that gives the volume of the canon based on :
-Overall length of the cannon (L)
-Outer radius of end 1 of cannon (R1)
-Outer radius of end 2 of cannon (R3)
-Bore radius (R2)
Therefore we created an algorithm that automatically works out the volume of the canon as shown in figure 38
((3.14xL)/3)x(R3*R3+R3*R1+R1*R1-(3*R2*R2))

Monitoring dam's temperature:
We used a PT-100 temperature probe whose sensing element is platinum (PT).
The material of the cable is made out of Silicone rubber with an Accuracy of +/- (0.15 + (0.002*t)) which is a perfect range of precision needed to monitor dam's temperature. Its cable temperature ranges from -55°C to 125°C
As the temperature changes the resistance of the platinum changes.

Figure (9) : Temperature testing

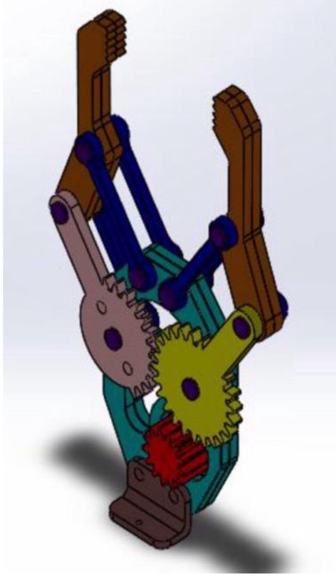
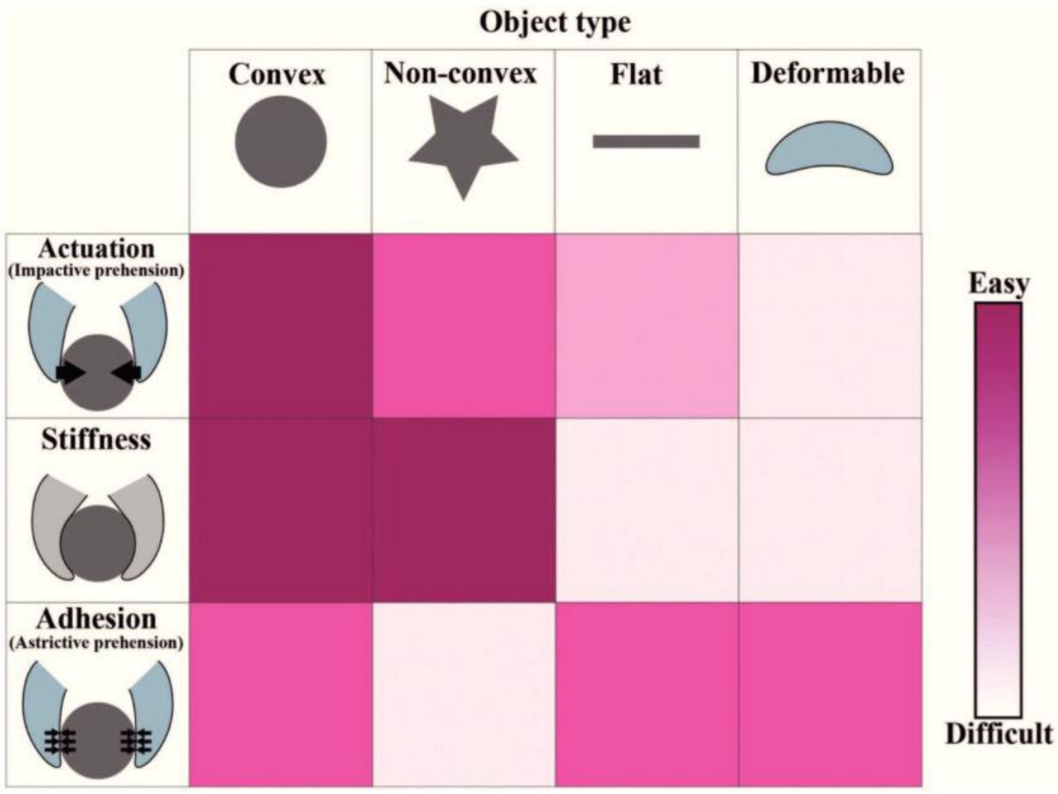


Figure (10): The 3D gripper model using Solod Works

14- The gripper:

Gripper has two claws in plexiglas, is fixed with gears and works with servo motors who have the power of 20Kg / cm as shown in figure 10. This is what we call a type A since it works with actuation by applying opposite forces. This deliberated choice was the result of days of research to know more about the different types of gripper.
As you probably know, there are 3 types of gripper: actuation, controlled rigidity and adhesion. And based on this diagram and according to the tasks we chose the first one. However, we utilized and applied this knowledge to create our homemade universal gripper using a ballon and coffee grains. We used it for the National Science Fair in which we learned Fluidization non Newtonian fluids and the jamming effect.



One possible classification of the characteristics of soft grippers for different gripping technologies and object types.

Figure (11): table classification of different gripping technologies and object types

15-New vs Reused:

We did not want to compromise waterproofing and safety of our ROV and hence we strictly purchased new components used in waterproofing, penetrators, and cables. Fuse, etc. We choose to reuse the thrusters as they performed well in multiple tests. Microcontrollers like Arduino rarely tend to fail unless blown due to power surges or a short circuit. In fact, we always try to «recycle» what we have by applying our motto: REFLECT, TRANSFORM and CREATE. By doing that, we encourage people to reuse instead of just throwing and buying new ones; this is what we call: all together for a greener place.

16-Build vs buy:

There were multiple instances where the employees had to take build vs buy decisions. This is very crucial as our prime motive was to develop a powerful and innovative ROV but on a tight budget. We choose to build most of the ROV components such as the Electronics chamber in a price which was almost 7 times cheaper than a similar option for purchase at Bluerobotics. In addition to that we save up to 8 times the frame of OXOMLS by leveraging the second law of Newton and the mechanism of the body to counterbalance air pressure. Although, we want a better deal, we face a dilemma: Safety vs time. Indeed, we preferred to buy already waterproof components such us the cameras because of the urge to meet deadlines. However, we shall also keep in mind that there im some cases we could not create them by ourselves since we do not have ressources. But, in many other cases we made components waterproof instead of just buying them. We chose to 3D print the propellers instead of buying them because we wanted them to adapt to the motors. And as a first prototype, we crafted our own 3D gripper to understand more its concepts. Therefore, we learned to use 3DS MAX in order to design our models. In fact, we took 3 information sessions to have a decent understanding of the program. And as mentioned previously, since we do not have T-100 motors in Tunisia, we decided to transform water pumps into waterproof motors.

17- Safety:

Company safety philosophy:

According to the adage: better be safe than sorry. Therefore, it is about providing a safe and secure working and living environment for our teammates. In fact, following the guidelines is not a priority but a law, a commitment that we guarantee to all of our members. A commitment not only applied in manufacturing OXOMLS but also in OXOMLS itself.

Lab safety protocols:

Our team follows the following protocols for safety:

See the danger
Alert the danger
Follow the guidelines
Ensure that the guidelines are well understood
Try to operate while respecting those guidelines
Yardstick for safety report

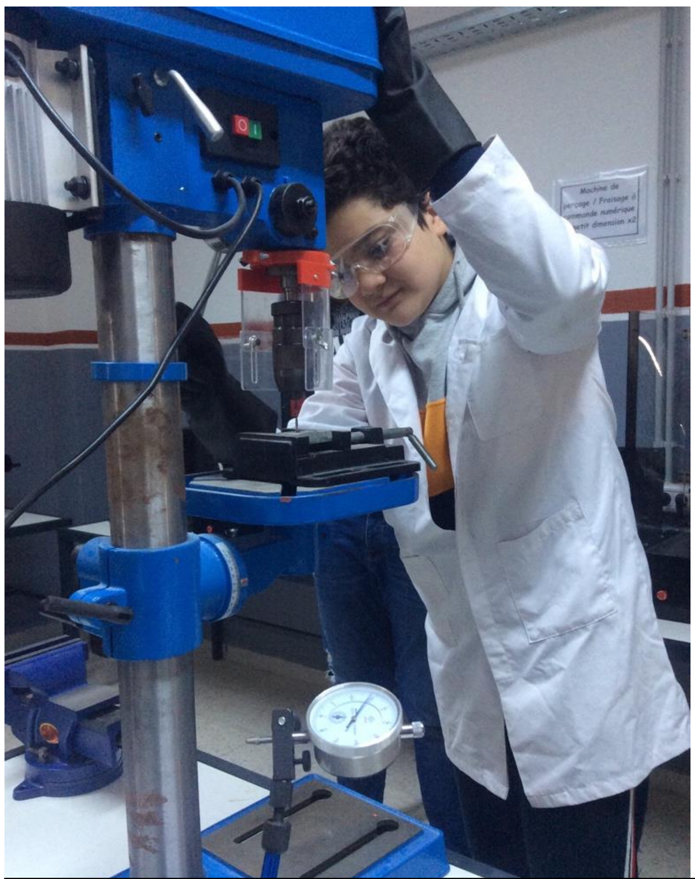


Figure (12) :Following the safety protocols

For the sake of our team members' safety, our company followed this protocol. And to ensure that we all understood the guidelines of the safety checklist provided by MATE competition, we asked our safety inspector to read the Oceaneering Americas Region HSE Employee Handbook as well as summarizing and highlighting the key words in it. In addition to that, we asked our two mentors to monitor us while operating some dangerous operations. And during the workshop in our school we also applied those top 3 golden rules:

1) Always bring those elementary safety tools: safety goggles, appropriate gloves, ear protection, safety shoes, masks and appropriate attire.

2) No member shall work alone to prevent any mishap.

3) Remove what you left behind because one could slip or trip on some debris left on the floor.

As mentioned in our safety philosophy, we want to ensure safety on the actual ROV, itself: OXOMLS. Therefore, the vehicle incorporates in each thruster's cable a 12V/5A fuse because the electrical system was equipped with high drive motors performance which are able to support 13A of Ac current. Therefore, we wanted our system to be highly protected. In addition to that, we placed a 12V/20A fuse after 30 cm of the power supply to be sure that we will not have any interruptions.

18-Project management and teamwork

- Our first initiatives:

Many of the points have already been established in the initial meeting in which we saw the availability of each. And every team member has the freedom to select the committee in which he/she wants to be part of. Then, to become more organized, we structured different types of meetings: information meetings, brainstorming meetings, work meetings, event planning meetings, information sessions, assessment meetings...

For the project management, we called on an expert who explained to us, in one setting, the different phases of the project: preparation, planning and managing.

He also showed us how to conduct a project by explaining to us for example that in the preparation phase we have to define the goals in term of quality, time, production costs and communication (media outreach). Moreover, we have to define each role's actor, identify the challenges and hiccups we might face and look for those who have experience.

But to go more in depth, the methodology we used for the project management was mainly inspired for the «Office Project Platform» due to its ubiquitous success. This deliberate choice allowed us to leverage its tools and therefore organized the work.

We have listed 4 steps:

1) Preparation phase allowed us to set the boundaries of the project, set the goals as mentioned previously, elaborate good communication strategies, define the roles of each and analyse the risks (identifying the obstacles).

2) In the planification phase we cut the project into smaller tasks and affected ressources.

3) The managing phase was structured essentially by conduct steps meetings, realized arbitrages and especially constant updates of the scoreboard and the planning.

4) The assessment phase is the important if not the crucial step because it is there where we see the potential improvements that we will make and capitalize on the experiences acquired.

Additionally, we followed a support process that consists of:
-organizing in the preparation step the ressources that must be mobilized to achieve the missions tasks and the relations between the different actors of the missions since the beginning of the project until the end.

-optimizing the resources management in the planning phase by implanting tools like: identify and coordinate the tasks, estimate the workload of each task, plan the different tasks, monitor the progress, anticipate and manage the disruptions, capitalize on the experiences and the expertise

-Controlling at the managing step the probable deviations from goals and contraints.
-Communicating throughout the process the progress of the project

It is necessary to mention that everything could not be solved only with techniques, methods or tools. However, teamwork and the symbiosis within the group are the ingredients for success. Our quote is: « we cannot achieve a dream work if we do not have a strong teamwork. »
Notable: We divided ourselves into subgroups: programming and coding group whose main mission was to find an efficient program that measures precisely the length of the longest crack in task 1 but also the lengths of the canon to find its volume like in task 3 as well as an image processing software for task 2. The mechanical team focused on transformation. Since there are no waterproof motors in Tunisia, they transformed water pumps into desired propellers. The Design group was in charge of crafting all of the unfound needed pieces in Tunisia by using a 3D printer. Our last example is the conceptual group whose goal was to increase stability by maintaining a neutral buoyancy of the ROV.

- The schedule as follows:

Preparation: 320 hours
Planification: 484 hours
Managing : 696 hours
Assessment and report: 24 hours
Total hours: 1524 hours

19-Identification and Solution

One example of a troubleshooting method used on our ROV involves an apparently faulty connector in the canister. Six connectors were installed, but only five of them worked properly at first. The thruster matched with the bad connector would not run. To identify the core problem, the company created a list of components potentially at fault. One possibility was that the connector itself was faulty, which was a possibility since the part was donated and had been used previously. Another problem faced was that after we installed the camera and fixed them tightly, it experienced problems in video streaming as the image quality was distorted and it even broke down after the regional competition. We bought a new camera and we sealed it around the canister where exist the electrical components entering the camera from the back to seal them completely. The third was that the controls had been wired up incorrectly. To solve the problem, the careful troubleshooting methods described in the previous section were applied to remediate the situation.

Troubleshooting has helped us wonderfully to solidify our teamwork, to push us do more research and look for more information to highlight and improve each ROV system.

It is through hiccups that we seek innovation. For example, our ROV used to have a rectangular design so that it is not very hydrodynamic, but this is no longer the case because it has become more curved and easy to orient.
We have also discovered that the positioning of the motors slows down the speed and orientation of the ROV, where the O-shaped motors are set up as shown in the figure below to ensure the efficiency of the different movements.
No matter how much careful planning goes into a project, human or machine failure is always a possibility .This is why doing tests is the best solution to identify problems, or at least to eliminate what the problem might cause.
Therefore, OXMOLS has been tested in pools to show if it can complete with the specifications of safety, stability and hydrodynamics balance the tasks provided by MATE correctly and brilliantly.

We have prepared the testing tools and as security is crucial, we insist on wearing personal protective tools and taking precautions while doing any testing.
Throughout the testing phase, modifications never stopped in order to increase OXMOLS efficiency.

We identified the problem correctly then we brainstorm the causes and categorize them. Finally the chosen solution was implemented.

20-Challenge:

We have to conduct simultaneously 2 different competitions (MATE competition and the National Science Fair) that have different missions and mindsets while using the same ROV. Therefore, we have to make adaptations that work for the 2 projects. It was an organizational, redactional and technical challenge.
To solve the organizational issue, we formed an ad hoc composed of 3 people whose roles were to respect the deadlines of the two events, provide the right documentations and realize the follow-up missions.

For the redactional challenge, we have to use 2 languages (English and French) and eventually a third one (Arabic) because some of the judges were foreigners. Thus, we presented the ROV in three languages in both of the events. Therefore, to overcome this issue, all team members spent a whole week preparing in those 3 languages to be more at ease during presentations and during the redaction of the different documents needed.

For the technical challenges, we faced a contradiction: the solution to a problem is in itself a problem to the solution. Due to the different mindset that MATE competition and the National Science Fair have, we obliged ourselves to make 2 different models of the gripper. For the National Science Fair, we built a gripper that works with controlled rigidity. Why? It is because we want to take samples of debris that have different shapes,materials and properties while making the gripper as easy as possible to be built using everyday tools. As a result, an amorphous universal gripper was the solution. However, for the Mate competition, a gripper that works with actuation seems to match the needs of the missions asked in the Manual. It was more suitable to use servo motors than using the jamming effect with the universal gripper. Thus, we used two detachable grippers according to our needs.

21- Future enhancements:

- Doing a platform web where customers can interact and give their opinions about our company so that we can take that into consideration and work to improve our company, increase our customer service & sell our product using this platform web
- Using the AI; for example, the display of a detailed report concerning the quality of water
- Involve with research laboratories to keep up with the latest developments
-Using this time the design thinking as a tool to solve problems and missions tasks not only for the MATE competition but now, for our other clients.
- Attending more difficult training courses for the mechanical & electrical team to improve and make our product more efficient.
- Making a neutral buoyant tether
-Increase safety by using thicker cables
-Doing more events related with the ROV

22-Corporate responsibilty:

What do we do with OXOMLS:

-we organized 2 Rubik's cube competitions in which we talked about our ROV and the MATE competition to kids, collected funds, and made a media outreach for our sponsor Idéale schools. In the first competition, we broke the record of the smallest competition in the world: 7 competitors. However, we showed to WCA (World Cube Association) our professionalism. Consequently, it gave us the permission to organize the first African Rubik's cube competition. For the second one, 30 people arrived and many kids learned mathematical concepts as well as gaining 200$.

Figure (13) : Rubik's cube competition in Idéale schools in the 17th and 18th of novembre 2018

-we did information and awareness sessions to high school students in the Idéale school. We organized for them a mini competition to foster them to participate in this field and be involved in our underwater technology club. We gathered approximately 23 kids. At the end, they were able to design their own frame. Initially, we gave a challenge in which one should be the winner to foster them into the STEM world and convey the knowledge we acquired. At the end, we decided that all of them are winners since we saw passion and interest in their eyes.

Figure (14 a/b): Information session in the 18th of December 2018

-we participated to national science fair and we won the second prize. The title was: the invisible pollution of seawater. We want to raise awareness among people about the millions of tons of debris leaked into the oceans. Therefore we tried to create a ROV that is cheap, doable and easy to reproduce at a large scale so that people are more involved in it.

Figure (15): Our participation on the science fair in the 7th-9th on February 2019 at the CIFFIP in Tunis

-For the 24th of April, we are going to present our ROV to the industrial world for energy transition missions that will be held in ESPRIT College.

23-Lessons:

We learned to cooperate and work harmoniously as a whole team without wasting time by respecting this following rule:
A horizontal organization with shared responsibilities within the group, where communication is done through respecting the following basic protocols:
-When it comes to write an Email to all of your team mates, WRITE THE OBJECT of your writing, the PURPOSE.
-when you want to set a meeting, ALWAYS DEFINE its TYPE, CONTENT and DURATION.

A surefire way to find a solution to a problem is done by first making a background research as we have done for the conception of the gripper.
We first read articles about the history of the types of gripper so that we have a holistic understanding of it. We learned that there are 3 types of gripper: actuation, controlled rigidity and adhesion. Where in each special features or solution to a problem exist. And while finding the easiest way to create an amorphous gripper, we learned through that process: fluidization, non-Newtonian fluids and fluid dynamic using also Archimedes principle.
Now, we have a better understanding of these phenomenon, concept and properties. The technical lessons are thusly a leverage of scientific knowledge from creating a gripper to stabilize the ROV using math which is truly the essence of this experience.

24-Accounting

The budget was discussed in the start of the process to ensure as this is one of the most important aspects. Team members made sure that the components in good shape are reused instead of purchasing. However components which are crucial for safety such as fuse, etc. are brand new. We were able to achieve our target: making a robust and innovative ROV while keeping a lower budget.
Therefore, by following “Office project “and by setting meetings to clear our goals we were able to meet our goals in term of budget. The total cost is 661$. However this actual cost is 215.5 $ since many components are either reused or sponsored.

Components	Nb	Price $	Cost $	State	Cost $
Frame	1	30	30	BUILT	30
Thrusters	6	17,5	105	BUILT	105
Arduino Card Mega 2560	1	10	10	REUSED	10
Cards cytron	6	12	72	REUSED	72
Gripper	1	25	25	BOUGHT	25
Propellers	6	4	24	3D PRINTED	24
Hik Vision Camera	1	110	110	SPONSORED	110
Digital Video Recorder	1	80	80	SPONSORED	80
Electronic cards' support	1	12	12	3D PRINTED	12
Thrusters support	1	3	3	BOUGHT	3
Tether	1	10	10	REUSED	10
Electrical chamber	1	150	150	SPONSORED	150
Joystick	1	13.5	13.5	REUSED	13.5
Servo Motor	1	12	12	BOUGHT	12
PT-100 temperature prob	1	4.5	4.5	BOUGHT	4.5

TOTAL w: 661$

25-Reflection

Selim Makni :

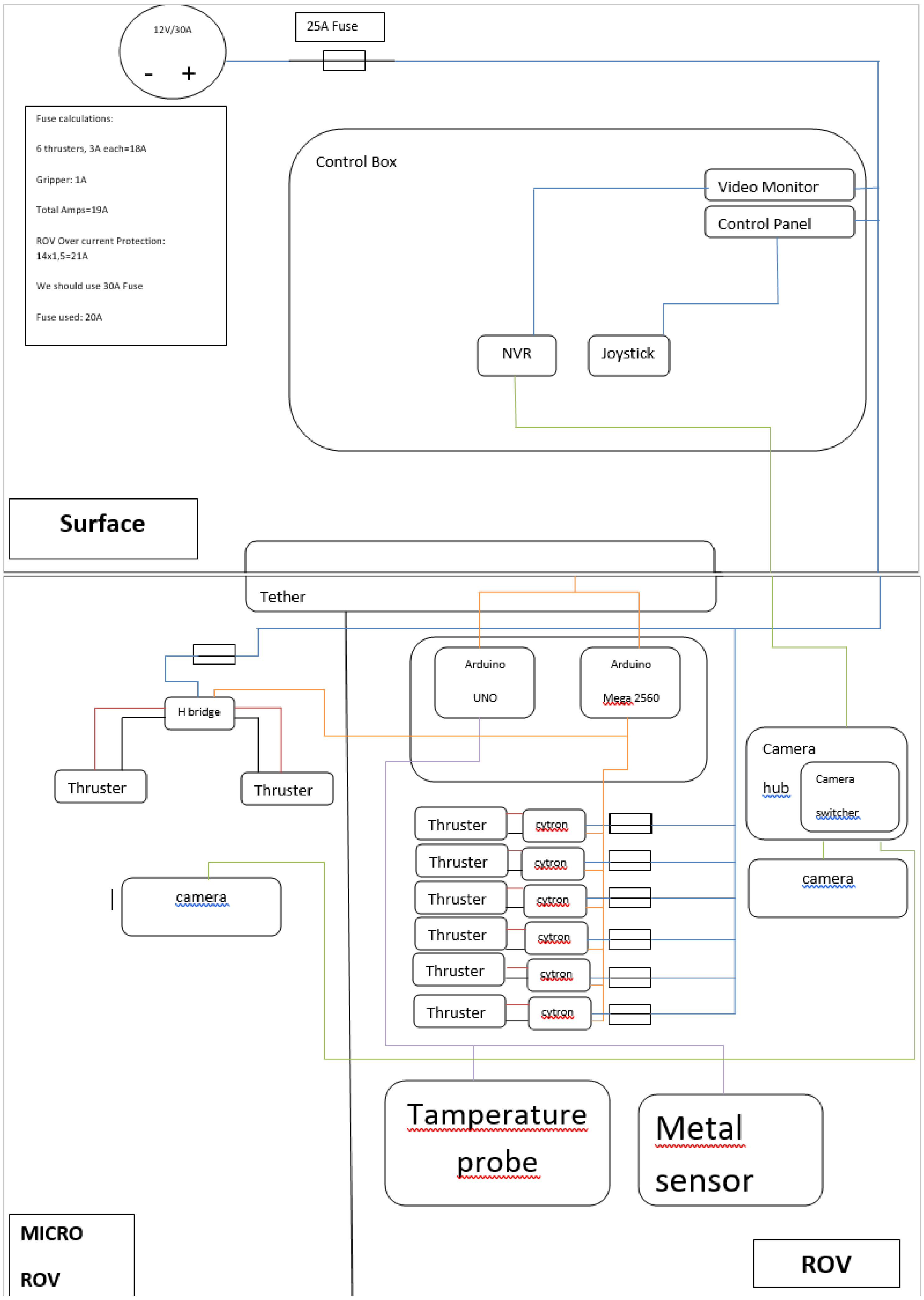
« Well, with the only modicum of rest I have, I still feel the urge to deepen my knowledge when it comes to STEM applications. Through that process, no one could claim that he/she was the most hardworking person in the group because truly we cannot achieve a dream work if we don't have a strong teamwork. I realized that sometimes our hands are tight and we need to admit our limits. However, with my team I can move mountains; they are the ones that I could count on in the future. Indeed, moments of fatigue, stress and feelings of failure happened during the 4 phases of the project but when I remember all the efforts my team did, I forget all of those hiccups: solutions are designed to solve problems; it is up for us, as a team, to find it. »

Yasmine Kerkeny :

« We can not taste the success If we did not put so much effort. And our success was synonymous with teamwork. The search for information, the perseverance, and the attendance allowed us to have as result OXMOLS. It was a wonderful experience that allowed me to see Technology's world in a different way and further my curiosity to deepen. »

26-Appendix :

a-SID



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27-Safety checklist

Phase	*Topic to check*	*Check mark*
Pre-mission	Make sure deck crew is in place	
	See the quality of the équipements	
	All wiring is secured	
	Tether connected and secured to ROV	
	Tether is properly untangled	
	Test all motors and attachments before putting the ROV in the water	

	Main power is switched off until all electronics are properly connected and checked
	Pilot calls out when power is turned on to alert deck crew
	No exposed wiring or propellers
In water	Check for bubbles
	If there are large bubbles, pull to surface immediately
Retrieval	Switching the power off
	Control unit shutdown
	Check if the thrusters stopped running before taking the ROV out of the water
	Pilot informs deployment members that ROV needs retrieval
	ROV is retrieved by two members

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UTC Tunisia for organizing the regional competitions
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- To our sponsors

DANA Equipements

TBS security systems

Les écoles Ideales

SoNAFIC

SAFRAN