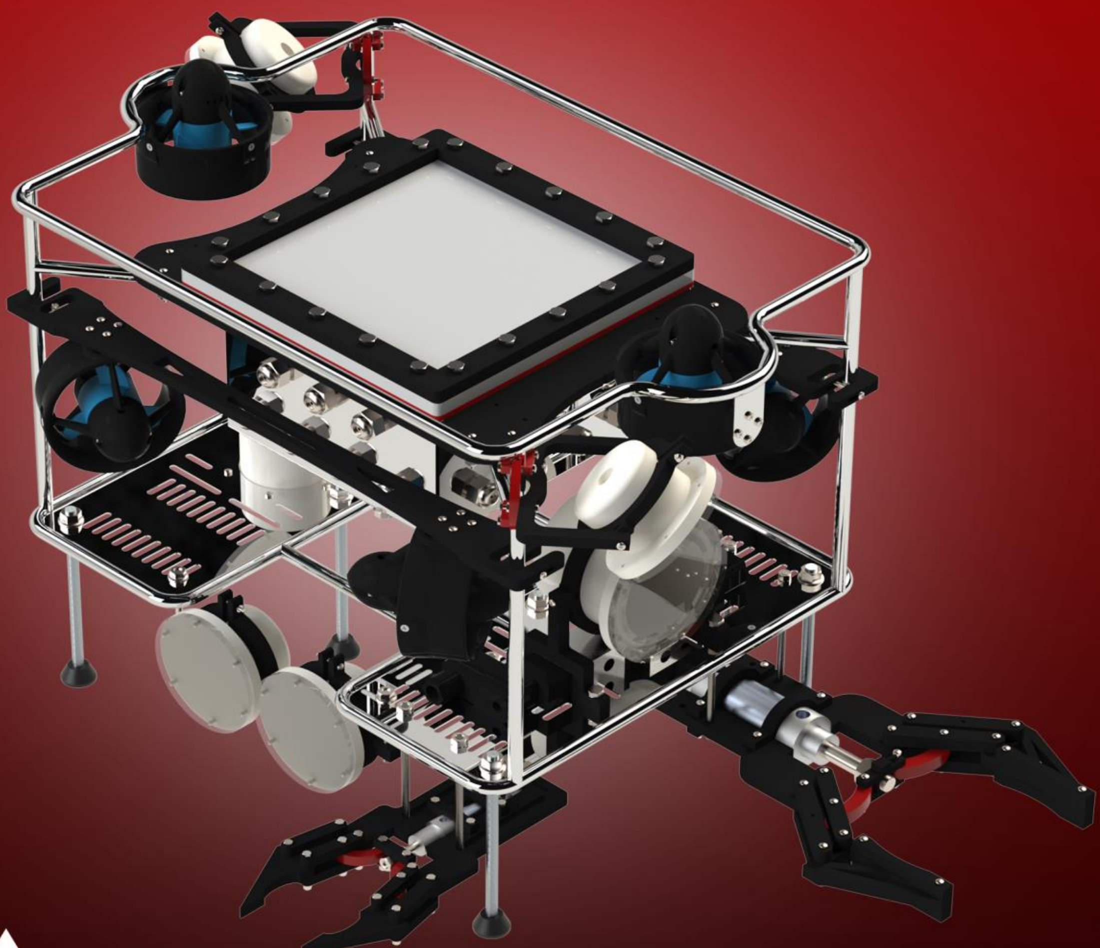

TORPEDO PROPOSAL

2 0 2 3

Contents

0.1 Abstract

We are tied to the ocean. And when we go back to the sea, whether it is to sail or to watch, we are going back from whence we came." — John F. Kennedy For 9 years, Torpedo has aimed to provide individuals with the right ambition, passion, innovation, and skills to explore our homeland Egypt which overlooks two wonderful seas: the red sea and the Mediterranean. And so, after rough days and long nights of brainstorming, designing, prototyping, and fabrication, we are proud to reveal our newest product, Polaris. Our ROV is named after the north pole star, and as sailors used it to illuminate their darkness, Polaris is going to be the centerpiece of our set of ROV's, proving our dedication to the field. We started designing Polaris with the help of CAD software (Solid Works), equipping it with 2 manipulators to achieve high functionality, and six Blue Robotics T-200 thrusters which give high efficiency at low cost. When delivering Polaris, we made sure it met all safety standards and the required specifications, making it ready for field work. This document illustrates the technical abilities of our final system, and decisions made throughout the development process. It also shows how our project management methodology has helped us achieve our goal in the most effective wiz possible.

0.2 Design Rational

0.2.1 Mechanical System

A- Design Evaluation

Before starting the process, we wanted to make sure the team had the adequate knowledge to embark on this adventure, and so a training phase was allocated, where the old members passed on all their knowledge and experience to the new members. After the training phase, we begun the brainstorming phase, where we held several meetings, attended by both the old and new members. We started thinking of solutions to problems we faced before, improvements we can add to our system, and a way to integrate these ideas together. We decided to reuse previous designs due to their proven performance, in addition to avoiding the problems we had faced before and adding new features we had thought of before,At the end, we came out with Polaris, an ROV which topped all our previous products, passed all safety and quality standards, and satisfied industrial requirements.

B- Innovation System

Table 1: Innovation System

Mechanical	Electrical
Compact and light frame	Inserting leakage sensors in our box
Flexible camera fixations with multiple view.	bullet connectors to connect the ESC's to thrusters.
Pneumatic levels of gripper.	Using an ESP32 as our main controller.
Manually rotating gripper.	
Assembled electronics house structure for easy maintenance.	

C- Mechanical Structure

This year, the design focused on three main goals: improving stability, making better use of spaces, and molecularity, all while taking in the manufacturing process in mind.

1- Frame

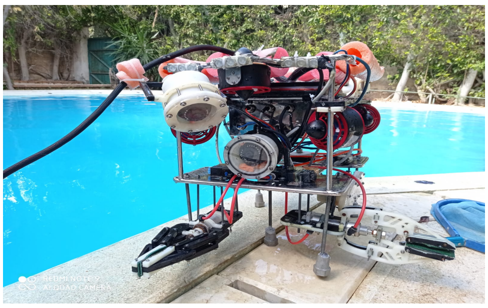

Figure 1: Polaris.

The frame consists of a structure made of stainless-steel tubes and four plates, two of which are of HDPE material, which are fixed to the sides and are responsible for fixing the thrusters. This design allows us to change the level of thrusters to make the center of thrust at the same level as the center of drag, which ensures the horizontal stability of the vehicle. The other two are responsible for installing the rest of the tools, and are also made of stainless steel, which is resistant to rust, to provide high durability and reduced weight. This design allows us to control the position of tools in two different directions and gives us the ability to lower the center of gravity of the vehicle (which improves balance), ensures the stability of tools during operation, and eases dismantlement,which in turn simplifies the maintenance process. To keep these tools at a high level, we used the help of topology science this year to make the design cost-effective. Moreover, stress analysis was made to ensure frame strength.

2- Electronics Box

In the last 2 years, the electronics housing took a cylindrical shape and was made of HDPE, which resulted in the irregularity of the ROV's weight and the waste of materials, which cost us loads of money. This year we decided to go by a different approach, which was to use a cubic stainless-steel box, which was lighter and sturdier than HDPE housings. A comparison was made between choosing stainless-steel or Aluminum, but we decided to go with stainless-steel due to its high strength which would allow us to use a thinner sheet. Moreover, it will help dissipate the heat from the internal electronics to the surrounding water.

Figure 2: Polaris Box.

3- Camera

We wanted to provide clear vision for our pilot and eliminate blind spots as much as possible, so we modified camera fixations to achieve that purpose.

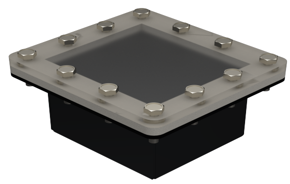

Figure 3: Polaris Camera.

4- Thrusters and Propulsion System

Our RND unit has been making major accomplishments concerning the propulsion system. Since 2021 we have used T200 from Blue Robotics, which have provided us with adequate thrust force. We are currently working on manufacturing our own thrusters, using waterproofed DC brush-less motors and 3d printed thyroidal propellers. This year, our goal was to design a propulsion system with the highest efficiency and the lowest possible cost, so we reused the T200 thrusters we had from previous years. The parts were damaged and needed proper maintenance before being integrated into our ROV. Regarding the positioning and configuration of the thrusters, we agreed on using 6 thrusters, and to achieve stable vector drive, the propulsion system was configured in a way such that two thrusters are used to move the ROV in its vertical plane. Four other thrusters are used to move the ROV in the horizontal plane. Each of the four horizontal thrusters is fixed such that its center axis of rotation is placed with an inclination of a value of 60°/30° relative to the surge direction of the ROV in the horizontal plane. This configuration allowed all thrusters to contribute to the total propulsion in 5 cardinal directions (surge, sway, heave, yaw, and pitch), gave priority (in terms of speed) to forward and backward motion, and minimized flow interference with the electronics housings in the center of the vehicle.For the safety of personnel and equipment, thrusters guards are mounted on both sides of the thrusters' core nozzles to prevent foreign objects from entering the thrusters.

D- Computational Fluid Dynamics

Drag refers to the resistance encountered by an object as it moves through a fluid medium, such as water. By accurately calculating drag forces, we managed to optimize the performance of our ROV. We visualized the shape of artery vertices, and accordingly, the main components of Polaris were modified to obtain the lowest drag coefficient, and all this was done by conducting CFD analysis using ANSYS Fluent. The final design is shown in the figures, where we visualized pressure contours, velocity contours, and streamlines. The final drag coefficient was 0.9 as printed from the Fluent drag force and coefficients report.

F- Buoyancy

Achieving good stability configuration and smooth suspension of our ROV underwater has always been one of the goals for our mechanical team. Also, for safety purposes, it was decided to make the ROV slightly positively buoyant. To achieve these goals, we started by locating the center of buoyancy (CB) relative to the center of gravity (CG) with the help of CAD software (Solid Works), we intended to put bigger weights at the lower base and floating material at the higher base to increase the distance between (CB) and (CG) which provided better stability for the whole system. At the end, mechanisms were mounted on Polaris' frame, and the result was that Polaris was negatively buoyant by 1.25 Kg, so we decided to put rigid Polyurethane (Foam) with a density of 36 Kg/m3. On calculating the required volume, we decided to put cylindrical foam around the electronics housing.

G- Wire Selling

We tried many methods for wire sealing, however we decided to use cable glands to pass cables through safely easily and guarantee maximum sealing against water infiltration.

0.2.2 Electrical System

A- TCU(Tether Control Unit)

The biggest advantage about our TCU is its plug and play feature, where you only need to power it up and you're good to go in no time. To connect the TCU to the ROV through the tether, polarized connectors are used. For the power connection, the XT-60 connector is used, due to its firmness and being polarized, avoiding any miss wiring during setup. In addition, wire terminals are covered with heat shrinks avoid unexpected shorts in the TCU. For communication, a single RJ-45 Ethernet connector is used since it provides a firm and stable connection.

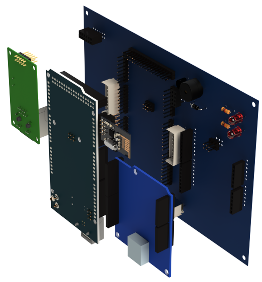

Figure 4: Polaris Console Board.

1- Main Controller

As for controlling Polaris from the TCU, we've decided to reuse our PS3 connectors. game pad since it has enough buttons that satisfy our needs. The game pad is connected to Arduino Mega -the micro controller we use topside- via a USB host shield. The micro controller reads the game pad's readings, applies a vector algorithm, and then sends the required thrusters' direction and speed to the ROV.

2- GUI (Graphical User Interface)

GUI is a vital tool for the co-pilot so they can monitor Polaris' status and view feedback from the used sensors so that they are always aware of any problem before it is too late. This is why we made sure our GUI is not at the risk of crashing or malfunctioning and chose PyQt5 to implement the interface. For additional ease of use, each task is separated into its own tab so that the co-pilot would not be distracted while performing a specific task.

B- Tether

We incorporated a CAT6 Ethernet cable in the communication between the box and the TCU by connecting it to a network switch to communicate with the Ethernet module connected to our TCU micro controller. We preferred the CAT6 type over CAT5e because of the greater transmission performance and better immunity from external noise. CAT6 is also more malleable and can handle harsh conditions. We also covered the tether with a Tec flex cover to maintain cable management and provide the tether with more protection As for the power tether, we decided to go with a 13 WG stranded cable as this gauge can stand the rated current draw, while also having the least voltage drop and smallest cross sectional area (which meant the least affected by drag) among all other options. The tether also includes a pneumatic cable to supply air to all pneumatic contraptions mounted on the ROV.

C- Electronics

1- Power Conversion

This year, we utilized seven DC-DC converters to step down 48VDC to 12VDC, four of which can draw a maximum current of 30A, and two others can stand a maximum of 20A. They are used to power our thrusters. The seventh, with a 5A maximum current, is used for powering our control circuit, six cameras, lights, and solenoids. This configuration was proposed to solve 2 major problems that had occurred in the previous years which are the camera feed lag and communication distortion due to the transient effect of thrusters when the cameras and electrical unit were connected to the same converter, but this year we decided to use the seventh as mentioned before. This made the power distribution more efficient and better distributed than before.

2- Electronics Box System

This year, our focus for the electrical system was the ease of maintenance and modularity, as well as decreasing the size as much as possible so as not to cram the electrical housing. Our system mainly consists of one double layer control board. Polaris' control board is centered around an ESP32 as it offers many features, such as its small size (compared to other micro controllers offering the same number of pins), built in Wi-Fi (that enables communication and integration with other devices and networks), and its high performance. One challenge that arises when working with ESP32 is the limitation of the pins, but by using a shift register, we were able to expand the number of pins available for connecting different components to our control board. For the thrusters' operation, we decided to use ESC motor drivers to control the internal brush less DC motors. We chose to buy it over making our own for many reasons, such as the small size, better efficiency, the lack of need for a heat sink, and it has current protection. Also, a bullet connector is used to connect the ESC with the thrusters to be easily detached and pass through the glands and separate the thrusters from the system for troubleshooting and debugging. At the end, we were able to integrate our system into a single control board that includes sensors, actuators, the micro-controller, and all its peripherals, eliminating the need to divide the system into several boards of different functions such as before.

3- Electronics Box Components

I- Sensors

To keep the motion of the ROV smooth and stable as much as possible, we used two different types of sensors.

IMU

The MPU6050 IMU (6 Degrees of Freedom) has both a 3-axes accelerometer (which measures acceleration) and 3-axes gyroscope (which measures angular velocity) integrated on a single chip. The previously mentioned data is enough to calculate all 3 angles of rotation, roll, pitch and yaw, so that we can control Polaris‘ orientation and position.

Pressure Sensor

The MS5540C pressure sensor was used to calculate Polaris’ depth underwater. The sensor measures the pressure, then by using the relation, we can calculate the depth of the ROV.

D- Communication

1- Top Side

As for the communication between the TCU and Polaris, Ethernet UDP “User Data gram Protocol” was used. The communication is full duplex; hence Polaris can send and receive data simultaneously. ENC28J60 Ethernet controller was chosen to serve as an ethernet network interface for the used micro controllers since they are equipped with SPI “Serial Peripheral Interface”. On top of that, the “Ethernet” library was used to control.

1- Underwater Side

This year, we decided to use an ESP32 micro controller instead of using three Arduino Nano. This reduced the error due to communication between the three Arduino Nanos. The ESP32 offered several advantages over the Arduino such as its higher processing power, its dual core architecture which allowed us to multitask and its built-in Wi-Fi which allowed us to upload different codes on Polaris’ ESP32 wireless.

E- Vision System

Camera Control

We have used a camera module that is made to operate and receive feeds from the cameras on the ROV. It can capture and process video feeds from various types of cameras. Moreover, it can be configured to work with either an external or local camera, depending on the specific requirements of the task. The module also provides advanced features for managing video streams, such as handling lost connections and automatically reconnecting to the camera when required.

0.2.3 Mission Tools

A- Mechanical Mission Tools

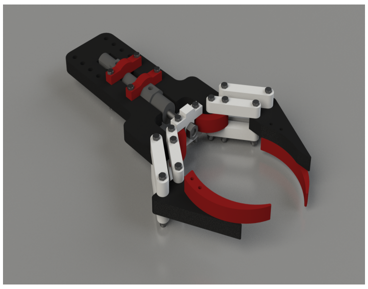

Figure 5: Polaris Manipulator.

I- Multi functional Manipulator

As per the competition's requirements, we built a lightweight manipulator that gives us two degrees of freedom and can execute underwater tasks efficiently. To achieve a high gripping force, it is pneumatically actuated with a 32*25 mm cylindrical piston. We modified its end effector to provide a large contact area, so that it can hold up objects up to 120mm in diameter. Moreover, it was designed to deal with various cross manipulator. sectioned shapes, and rubber was added to provide high friction with objects. The gripper is made of high-density polyethylene (HDPE) due to its high durability and easy mach inability as it was cut on a CNC laser cutting machine.

B- Image Processing Tools

I- Measuring the Length of Fishes

In order to measure the length of fishes model ,our Team create a GUI to make it more easy and professional, in this GUI we can insert the pictures, the model will work and write the length we want to know the category of it, and the model will select all fishes with this length, we can also get the all fishes' length by display all icon in our GUI.

II- Monitor the Lake Against Pollution

To identify shapes (or pollutants) on the ground, we grab a frame of the sheet of paper from our camera feed through our GUI and run multiple image processing operations on this frame. We start by obtaining contours to isolate the black shapes on the paper then in order to differentiate between multiple shapes (squares, crosses, etc.) we used a process that reduces each contour into a collection of corner points. From that we can deduce what shape each contour represents and thus carry out our final calculation.

0.3 Safety Rational

A- Design Safety and Philosophy

Safety is our top priority in Torpedo we aim towards keeping our engineers safe, protected, and satisfied to achieve high-quality work progress. We keep safety aspects for designing, manufacturing, testing, and maintaining our ROV for all tasks. We follow all safety protocol points, and safety checklists and work in a safe work environment so that we keep our members safe.

B- Members' Safety

All members must wear personal protective equipment (PPE) such as gloves, goggles, and face masks while machining or working with epoxy or fibers to prevent the inhalation of dangerous chemicals or particulates. Cords are kept out of aisles and walkways to keep the area neat and prevent tripping. Also, a safety-aid kit is always present in our workshop in case of any accidents.

Table 2: Equipment and Operational Safety

Mechanical	Electrical
Never work alone in the workshop.	All electrical equipment has been enclosed in sealed housing.
Make sure your work piece is fixed securely before work.	All hardware circuits are connected to fuses according to the maximum load.
Do not talk to anyone operating electrical equipment machinery, e.g., Circular saw.	Our TCU is equipped with an emergency switch, in case of any urgent situation.
Inspect equipment before use.	Our tether is covered with a braided sleeve to protect the tether.
Wear gloves and goggles when working with a drill and cutting tools.	Cables and wires must be isolated.
Use cap nuts to cover bolts.	Wear gloves and goggles while dealing with soldering irons.
All sharp edges must be filleted.	

Table 3: Safety Checklist

Offshore Safety	Underwater-Before Mission Safety
The ROV is transported to the competition playground covered in bubble wrap to protect it against impact.	Make sure the electric box is not leaking (no detecting leakage data from leakage sensors, and no bubbles are going up).
Nuts are well-tightened. Thrusters are free from obstructions.	Perform a short wet test to make sure all manipulators and thrusters are fully functional. Test the main gripper to make sure the air compressor is properly connected and functioning.
The tether is well connected to the ROV and the TCU.	Make sure the cameras' signals are not distorted.
Check the strain relief of the tether.	Check the converters' current to ensure your system is working with no danger.
The Area is clear and safe for the tether man motion.	
Dry start-up to make sure of the penetrability of the ROV.	

Table 4: Safety Checklist

Underwater-During Mission Safety	After Mission Safety
Make sure the tether does not surround the ROV so that it would not be damaged and verify the tether is free of kinks. 'Tether man job'.	Lift the ROV out of the water.
The main power is turned off, and the ROV is lifted out of the water in case of leakage.	Turn off the main power supply.
	Turn off the air compressor.
	Cover the ROV in bubble wrap to transport it back to the Torpedo workshop.

0.4 Conclusion

A- Technical Challenges

1- Mechanical Challenges

Our mechanical team faced a lot of challenges this year, including designing the ROV from scratch to be light, have low drag force, and have additional space for mission tools to be mounted to prevent the previous years' problems. When it comes to fabrication, lots of ideas were discussed about the material of each component, including their pros and cons then materials were chosen to provide high efficiency while being cost-effective. However, to ensure the electrical components' safety, a lot of sealing techniques were tested, and we chose the best one of them. Moreover, this year's tasks represented the most difficult challenge for us. We spent a lot of time searching for and designing and developing mission tools to meet the task requirements.

2- Electrical Challenges

This year we faced multiple challenges in our system, one of which was that we wanted to integrate all our system in one board, housing the ESP32 as its micro controller. The ESP32, however, has a limited number of pins which were not enough for the devices in our electrical system. As a solution, we used a shift register as an IO expanded so that the ESP32 can interface with more devices through the same number of pins. Another problem was the lack of resources for the ESP3 platform unlike other alternatives (such as the Arduino). To solve this problem, we had to hack into the available libraries to make them compatible with the ESP32, which was a part of our RnD plan.

B- Non-Technical Challenges

The biggest challenge we faced this season was changing and improving the configuration of the non-technical techniques we used in making our report, and non-technical documents. We were able to handle this problem by including the whole team in the process, where the mechanical and electrical teams worked together to improve our team on all technical and non-technical sides, with the help of the old members, mentors, and seniors which gave us a lot of advantages to organize our schedules.

C- Technical Lessons Learned

This year, one of our main goals was to avoid the obstacles we had experienced previously, be it the problems in our old vehicles or our way of managing things in general. This made us approach problems differently and find perfect solutions for them. Also, to acquire a more stable system throughout the year, the team had been working with many programming languages such as Python and C++, as well as enhancing our ability to design and simulate stresses and flow using Solid Works®, ANSYS® and Fusion 360®. We have also followed new techniques in making system design for our ROV, and we have dealt with new components with new techniques which helped our team members increase their technical knowledge and go through new experiences.

D- Future Improvements

1- Doing research into new micro controllers and whether they would be better for our use case or not.
2-Improve our communication system and make it more reliable and efficient.
3- Use reliable waterproof plugs for faster maintenance and replacement.
4- Design new modular and adjustable mission tools.
5- Look into new motion and control systems to achieve better maneuverability.

E- Reflections

"Torpedo team had a great impact on my life. This experience taught me a lot in my career. Also, it made me develop a winning mentality and changed my perspective on success. At Torpedo, we believe that our achievements come from the success of each member of our team".
-Yehia Ehab, Electrical Mentor.

"Knowledge is nothing without experience, and this is what I've been building since I joined the Torpedo team. The amazing people I met, the journey I went through, with its ups and downs, and the great things I learned, all of this is what makes joining Torpedo the best decision I have made this year, thanks to all the team".
-Youssef Allam, Electrical Team member.

The journey of being a mechanical member at Torpedo was like being in a family, and it helped me in so many ways, torpedo allowed me to try new ideas and to put my skills to the test, there was no fear of failing because we all knew that from failure comes success".
-Omar Al-lqany, Mechanical Team Head.

F- Interpersonal Skills Gained

Our company relies on university students, throughout the journey of making Polaris they learned how to manage their time between the college track and teamwork, due to the hardships they encounter they managed to adapt to every possible situation and come out with the best results of its which makes them push their potential beyond their limits since the company is divided into two teams. They learned how to communicate with each other in an organized and well-planned method to have the best outcome thus, the communication skills are Improved and developed gradually.

0.5 Appendices

1- Cost Analysis

			Torpedo 2023 Project Costing							
			Type	Classification	Category	Expense	Sources/Notes	Qty	Amount per one	Total
Net Cost Of ROV Vehicle	Product Costs	Electrical System	Re-used	Direct Material	Electronics	Joystick	PC Controller	1	$12.50	$12.50
			Purchased	Direct Material	Electronics	DC-DC Converter	48-12V 30A Output	4	$28.00	$116.00
			Purchased	Direct Material	Electronics	DC-DC Converter	48-12V 20A output	2	$15.00	$30.00
			Purchased	Direct Material	Electronics	DC-DC Converter	48-12V 5A Output	1	$13	$13.00
			Purchased	Direct Material	Electronics	ESP Microcontroller	Microcontroller	1	$10.00	$10.00
			Purchased	Direct Material	Electronics	Camera/ solenoids cables	Cables	1	$4.00	$4.00
			Re-used	Direct Material	Electronics	Motor Driver	Basic ESC	6	$37.50	$225.00
			Re-used	Direct Material	Electronics	Camera	IP	8	$49.00	$392.00
			Purchased	Direct Material	Electronics	Lights	UnderWater Lights	1	$2.00	$2.00
			Purchased	Indirect Material	Electronics	XT-60 Connector	Polarized Power Connector	27	$0.67	$18.00
			Re-used	Direct Material	Electronics	Ethernet Module	Communication Module	2	$10.00	$10.00
			Purchased	Direct Material	Electronics	Ethernet Switch	8 port-switch	1	$22.00	$22.00
			Re-used	Direct Material	Hardware	Tether	Power Cable 13AWG	1	$18.00	$18.00
			Re-used	Direct Material	Hardware	Tether	Ethernet CAT6	1	$18.00	$18.00
			Re-used	Indirect Material	Hardware	Tether Cover	Braided Sleeve	1	$23.00	$23.00
			Purchased	Direct Material	Electronics	IMU Sensor	MPU6050	1	$4.00	$4.00
			Purchased	Direct Material	Electronics	Temprature Humedity Sensor	DHT-11	8	$1.50	$12.00
			Purchased	Direct Material	Electronics	Water Depth Sensor	MS5540C	1	$12.00	$12.00
			Re-used	Direct Material	Electronics	Fuse	Protection (30A)	1	$2.00	$2.00
		Mechanical System	Purchased	Direct Material	Material	Camera Housing	Stainless Steel	8	$3.00	$24.00
			Purchased	Direct Material	Material	Gripper	Artelon	2	$8.00	$16.00
			Purchased	Direct Material	Material	Box	Stainless Steel	1	$80.00	$80.00
			Purchased	Direct Material	Material	Frame	Stainless Steel	1	$20.00	$20.00
			Purchased	Indirect Material	Material	Gasket	Silicon	1	$27.00	$27.00
			Purchased	Indirect Material	Material	Bolts & Nuts	Stainless Steel	92	$0.50	$46.00
			Purchased	Indirect Material	Hardware	Gland	Sealing	28	$1.05	$29.40
			Purchased	Direct Material	Hardware	O-Rings	Sealing	50	$1.00	$50.00
			Re-used	Direct Material	Hardware	T200	Thruster	6	$206.00	$1236.00
			Re-used	Direct Material	Hardware	Tether	PU Hose 6mm	1	$6.00	$6.00
			Purchased	Indirect Material	Hardware	Solenoid Valve	12V	2	$7.00	$14.00
			Re-used	Indirect Material	Hardware	Pneumatic Piston	Double Acting	2	$13.50	$27.00
			Re-used	Indirect Material	Hardware	Compressor	20 Liter	1	$50.00	$50.00
		Services	Purchased	Direct Labors	Fabrication	Welding	-	1	$90.00	$90.00
			Purchased	Direct Labors	Fabrication	Machining	-	1	$60.00	$60.00
			Purchased	Direct Labors	Fabrication	CNC Cutting	-	1	$150.00	$150.00
			Total Product Costs Invested In ROV Vehicle							$2820.90
	Product Costs	Tether Control Unit	Re-used	Direct Material	Hardware	Surface Control Unit	Briefcase	1	$75.00	$75.00
			Re-used	Direct Material	Hardware	Adapters	Powering Arduino, Switch, NVR	3	$2.00	$6.00
			Purchased	Direct Material	Electronics	USB Host Shield	Controller Interfacing	1	$6.50	$6.50
			Re-used	Direct Material	Electronics	Power Supply	48V 31.3A Mean Well	1	$6.50	$6.50
			Re-used	Indirect Material	Electronics	Anderson Connector	Power Connector	1	$40.00	$40.00
			Re-used	Direct Material	Electronics	Ethernet Switch	5 port-switch	1	$6.00	$6.00
			Purchased	Direct Material	Electronics	Power Cable	AC Power	2	$6.00	$12.00
			Purchased	Direct Material	Electronics	NVR	8 Channel	1	$86.00	$86.00
			Re-used	Indirect Material	Electronics	LCD 4x20	Character LCD	1	$7.00	$7.00
			Purchased	Direct Material	Electronics	LCD Screen	17 inch	1	$30.00	$30.00
										$275.00
	Period Costs	Extra	Purchased	-	Other	Competition Registration Fees	-	1	$300.00	$300.00
			Purchased	Rents	Other	Pool Rent	-	1	$200.00	$200.00
			Purchased	Rents	Other	Workplace Rent	-	1	$200.00	$200.00
			Purchased	Other	Other	Printing T-shirts	-	15	$10.00	$150.00
			Total Period Costs Invested							$850.00
			Total Expenses							$3,945.90
			Total Expenses without resused Components							$1,833.00