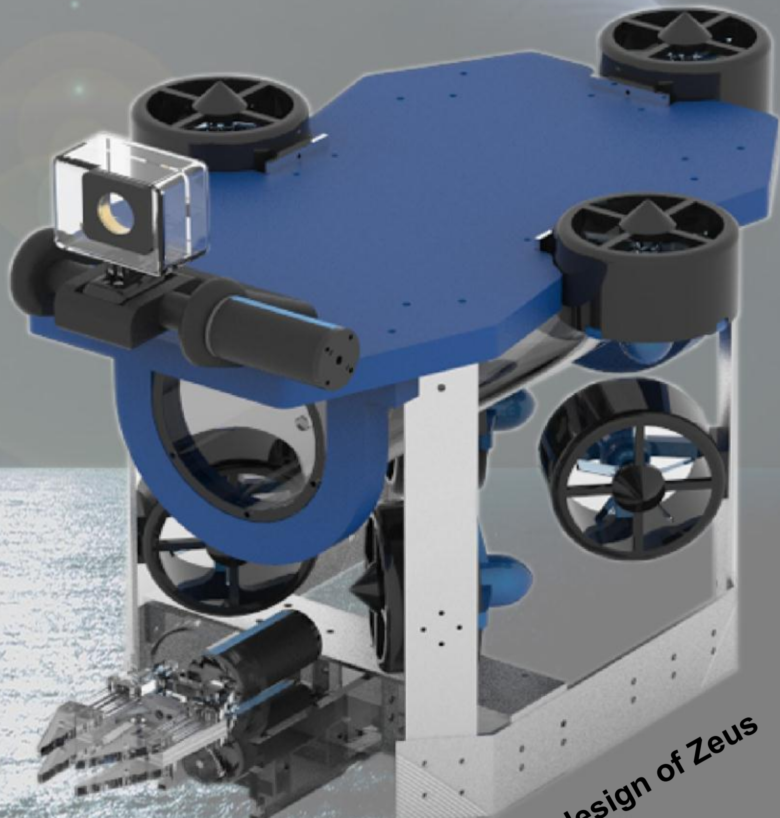
TECXOTIC

MATE 2016
ZEUS

Tecnológico de Monterrey

Instituto Tecnológico y de Estudios Superiores de Monterrey Campus Cuernavaca, Xochitepec, Morelos



CAD design of Zeus

MEMBERS

Enrique Carvajal ‘18	Chief Executive Officer	Raúl Sánchez ‘18	Mechanical Designer
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MENTOR: David García

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I. Abstract

Designed to make a space travel to europa, one of several moons of Jupiter. Zeus is a ROV designed to perform a series of activities proposed by MATE for the 2016 annual ROV competition.

This multidisciplinary project involves engineering developing areas, such as electronic control, mechanical, industrial and software engineering. Other important areas participating in this project are logistics, administration and marketing.

This technical report describes the development process and design of Zeus, which was distributed in four principal areas: Mechanical Design, Control system, Electrical System and Manufacturing. Zeus is the result of months of planning, design, manufacturing and testing. Zeus has an optimal design for a trip to space, as it is a small but awfully robust ROV.

II. Design Rationale

A) Mechanical Design

Our latest ROV, Zeus, was designed and manufactured following the structural and technical product requirements specified in the *MATE ROV Competition 2016 Explorer Manual: from deepwater oil-related operations to the exploration of seas underneath a natural satellite's surface in space*. Due to the restrictions in size and weight of the ROV, volume optimization was the most important aspect considered during the design process.

At the beginning of the process several ideas were evaluated by the whole team. One of our main priorities was that Zeus to be light, because that is an essential characteristic that any robot that travels through the space should have. We also decided the ROV should not have parts that could damage the marine ecosystem of the Gulf of Mexico; that is why all the edges of the structure are rounded and the thrusters are special for underwater activities. Likewise, Zeus' structure had to be robust enough to carry all the weight of its parts and to endure the pressure under twelve meters depth.

Ideas were discarded based on their monetary implication, since we wanted Zeus to be as economic as possible. The aesthetic of the ROV was also taken into account, as well making sure it covered all the safety precautions required by the competition. This is the second time TecXotic will be participating in the competition; therefore, the aspects that needed to be improved from the previous ROV helped us for deciding the best design. A photo of the first design made in Solid Edge is shown in Figure 1.

Figure 1. 1st CAD design of Zeus

B) Frame

For building Zeus, the team decided to use 6mm acrylic for the main plate, the same material used for last year's ROV. This material works perfectly in manufacturing and design processes because of the zero permeability it supplies for underwater purposes. Furthermore, this material has the advantage that it can be cut with a laser machine. This procedure allowed us to cut all the acrylic parts with the exact measures and in a short period of time.

Later on, the team decided to replace the acrylic with 18mm wooden plate. The main reason behind this modification is because the acrylic couldn't resist the pressure created by the load of the ROV and the water under 10 meters. The wood provides more support, and at the same time buoyancy. However, for the wooden plate to be practical, this material must be isolated. A wood sealer was smeared to it in order to make it waterproof plate. After that, a layer of fiberglass was applied in all the wood. The final step for the insolation process was put on a layer of resin to make sure that the water doesn't reach the floating system. The CAD design with this modifications is shown in the cover page.

The rest of the structure is made of aluminum. We decided to use this material instead of acrylic, which we used last year, because it is more resistant to water pressure and more economic. In addition, the aluminum is not prone to oxidation and is easy to handle. The way that it is assembled provides strength and at the same time generates a minimum weight to carry by the main plate.

All of the structure is sustained by joints which are reinforced by rivets. This facilitates the assembling process and the shipping from Mexico City to Houston since all the parts can be carried on the plane. Through this method TecXotic can save the shipping expenses.

C) Propulsion System

For the ROV's horizontal movement 4 Blue Robotics T100 thrusters were used. There thrusters have more strength for moving the ROV than the ones used last year. Each one of them was placed at 45° degrees, this results in a stronger push from the thrusters when all of them are being used. Given that the missions must be completed in a short period of time, a button was configured to turn the motors to high speed. When this button is pressed the greatest push from the thrusters is achieved and Zeus can move faster than normal. One of the thrusters is shown in Figure 2.

Figure 2. Blue Robotics T100 thruster

For the vertical control, Zeus used three Blue Robotics T200 thrusters. Two of them are used for the movement in the Y plane. The remaining thruster is used to make the ROV's inclinations. They are mounted with a 45° angle in the corners of Zeus. This thrusters have more strength than the T100, each motor provides 7.5 lbf of thrust. Still, the T200 and the T100 are of the same size. It is important to add that a really economic price was paid for this brand of thrusters in comparison to other brands in the market.

D) Gripper

TecXotic is aware of the essential role the gripper has in the ROV's functioning. In order to make the most of the materials we already had, the claw has been made with acrylic and aluminum. The combination of this materials enables the gripper to be resistant but light at the same time. The design was done on Solid Edge so it could be printed in the school's 3D printer with the exact measurements. This design is shown in Figure 3. Following the overall structure of Zeus, the claw had a proportional (small) size.

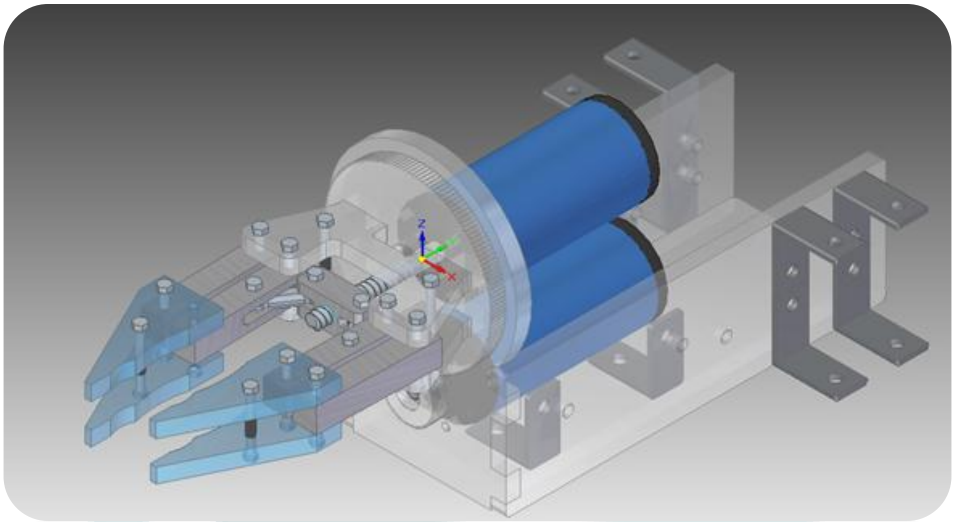

Figure 3. CAD design of the gripper

The gripper has two motors PK22G series of 12V DC to control its movements. One of the motors is strategically placed in the center of the gripper's structure to open and close it by using an infinite screw. The other motor is located below the other one. It is connected to a small gear so it can turn a bigger gear and produce a 360 degree movement. The motor has a 3D printed housing made of ABS plastic to protect it from the water. Likewise, this protection makes it easier to support the motors to the structure of the gripper.

E) Vision System

The vision system was one of the main problems for the company in TecXotic's previous participation. We noticed that a better vision angle and image quality would make a substantial improvement on the navigation, control and accuracy of the ROV. This year, TecXotic is using two cameras in order to fix this issue.

The company has as its main camera a GoPro Hero 4 Silver. This camera has great graphics quality and a wide vision angle. The GoPro is placed inside its GoPro Housing, which has an RCA cable that transmits the image to the computer in standard definition. The camera has one degree of freedom which allows it to have a wider vision of the environment. The camera is fed directly from the power provided by the ROV without the need of having batteries. The GoPro Housing is able to receive 12 volts and convert it to 3.8 volts of operating voltage. The main camera and its cable are shown in Figure 4.

Figure 4. GoPro Hero 4 Silver and an RCA cable.

To complement the vision system, TecXotic is using a generic camera placed above the gripper to supervise its movements. This camera sends the image to the pilot's laptop through an RCA cable as well. Through this camera the team can make sure the gripper is properly grabbing its objective. The pilot would have two screens to see the image from both cameras.

F) Buoyancy

For this ROV, the float system was designed for perform two critical tasks, be the main part of the structure and neutralize the mass of the ROV in the water. The float system is mainly made of pine wood. It was cut with the help of a CNC machine that was guided with a CAD model based on the requirements of the structure.

Since the wood is not a waterproof material, it had to be insulated in order for it to maintain its floating capacity. First of all, the wood had to be covered by a wood seller. After that, two layers of fiberglass were applied to the structure, this in order to add buoyancy and protect the wood from getting wet. Finally, a layer of resin was applied to the fiberglass and painted. For additional buoyancy, polyurethane foam rings were accommodated around the electronic box.

At the beginning, the structure was supposed to be made of 6mm acrylic. However, after some calculus and several experimental tests it was determined that this material was too fragile to support all the pressure experimented under 10m of water and the load created by the ROV's elements.

III. Electrical System

A) System Interconnection Diagram (SID)

The electric current flow is controlled by a circuit breaker connected to a power supply (provided by MATE). The flow can be controlled with both a manual and automatic shutdown in case of emergency. The manual shutdown is simply controlled with a switch. On the other hand, the automatic shutdown is activated by a 40A fuse, the maximum electrical current provided by MATE supply. The SID is shown in Figure 5.

The output from the circuit breaker is plugged to the DC/DC converter, that reduces the voltage from 48V (original supply) to 12V. This would be the voltage with which almost all of the components on the ROV operate with.

As another security measure, a 30A fuse is connected before supplying all the other devices. The optimal size for the fuse is derived from the maximum expected consumption from the ROV, as shown in Figure 6. The Arduino Mega ADK, the thrusters, the gripper motors, and the cameras are directly connected to the 12V output.

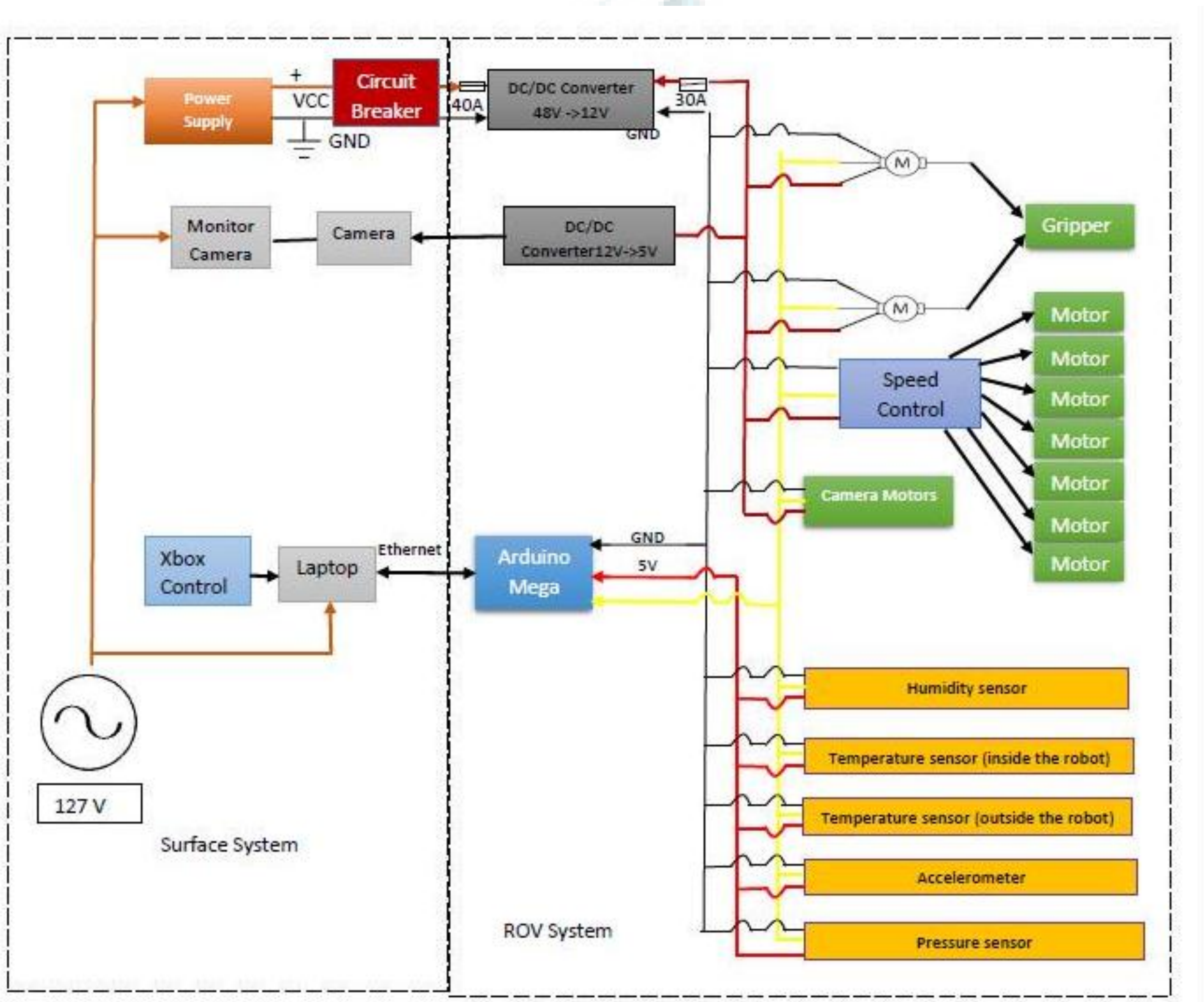

Figure 5. System Interconnection Diagram

Component	Voltage (V)	Maximun electrical current	Maximum power (W)	Quantity
T100 thruster	12	4	72	3
T200 thruster	12	1.8	40.92	4
PK22G2150 Gear Motor	12	0.57	6.84	3
Arduino Mega ADK	12	0.05	0.6	1
Sensors	5	0.02125	0.255	-
Cameras	12	0.3	3.6	3
Full load	-	21.88125	411.855	-
Over current protection	-	32.821875	-	-

Figure 6. Table of ROV's consumption

IV. Electronic System

A) Microcontroller and Shields

The company decided to use the program C# on Unity to control Zeus through the pilot's laptop. The team determined it was the best language because of the wide range of libraries it provides. Unity facilitated the programming of the graphic interfaces since it allowed us to create a platform that will strategically monitor the position, pressure, and temperature of the ROV. Likewise, it enabled us to easily program an Xbox control to guide the ROV's movements via Ethernet. Another advantage of using Unity was that our programmers where already familiar with the program.

For the communication between the laptop and the ROV an Arduino Mega ADK was used. This microcontroller has an Ethernet shield which is placed inside Zeus. The Arduino controls the motor and the sensors with the data it receives from the surface. Programmers assigned an IP to the microcontroller (192.168.1.1) and another one to the laptop (162.168.1.2) using Unity's libraries. In the code an algorithm was created to connect the Arduino with the laptop via Ethernet. A letter was assigned for each operation. Each of them was interpreted by the microcontroller to complete a given command. We decided to use an Xbox control to facilitate the drive of the ROV to the pilots.

B) Sensors

The sensor DTH11 is used to measure the humidity inside de capsule. It detects if water gets in which will allow us to avoid any problems with the electronic components. The data pin of this sensor (the one in the middle) is connected to the port #2 of an Arduino Mega SDK.

The MS5837 sensor (a waterproof sensor) goes outside the electronic capsule. With this sensor it is possible to measure the pressure and how deep the ROV is. The Green cable is connected to the SCL port and the white one to de SDA. They function with 5V.

The last sensor is the DS18B20, with this sensor, temperature of the water is measured. The range of temperature that can be registered is from -55ºC up to +125ºC. (-67ºF - +257ºF) with a 0.5ºC degrees of freedom. Arduino supplies the 5V needed for the sensor to operate. The Figure 7 shows the temperature sensor.

Figure 7. ds18b20 sensor

V. Software Control System

A) Ethernet Communication

The Ethernet communication was made by the Arduino Ethernet Shield, in order to communicate Arduino and C#, because the motors that allow Zeus to move were coded with C#. On the other hand, sensors were coded with the Arduino programming language. An image of the Arduino used is shown in Figure 8.

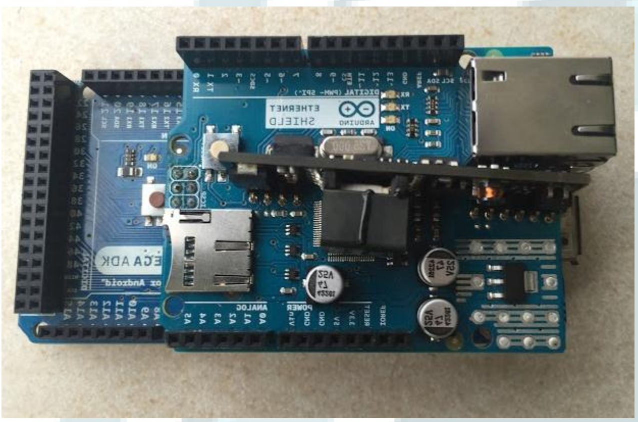

Figure 8. Arduino

A message is sent throughout the TCP protocol, using the port 24, one that personal computers already recognize for such communication. All of which is done from a TCP server to a TCP client. The TCP/IP protocol was originally created for internet communication, nevertheless, that was not an obstacle in order to communicate Arduino boards with our thrusters.

B) Control

The left joystick controls the movement of Zeus in the XZ plane. The Figure 9 explains in which direction the ROV will move depending on which way the joystick is pushed. When the right trigger is pressed and the joystick is moved at the same time the ROV's speed will increase. The right joystick controls de camera movements. The X and Y buttons control in which direction the gripper will turn, while the A and B buttons control when it opens and closes. The R1 and L1 buttons will move Zeus in the vertical plane. The Figure 10 shows the control configuration in detail.

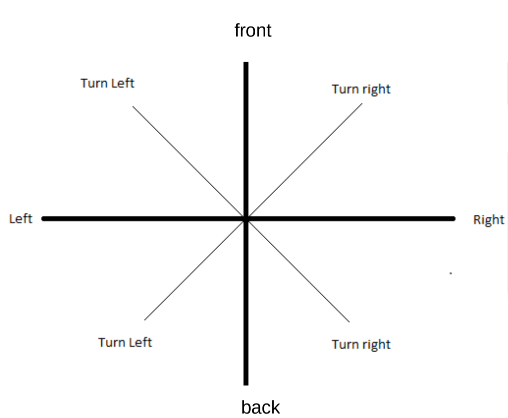

Figure 9. Movements in XZ plane

Figure 10. Xbox control configuration

Given that the pilots can't see Zeus in the water, knowing how it is positioned (level of inclination) is essential for them to effectively guide the ROV. A 3D modelling of Zeus was done in a graphic interface. An accelerometer, a gyroscope and a magnetometer were placed in Zeus detects its level of inclination which is shown in the pilots screen.

C) Software Flow-Chart

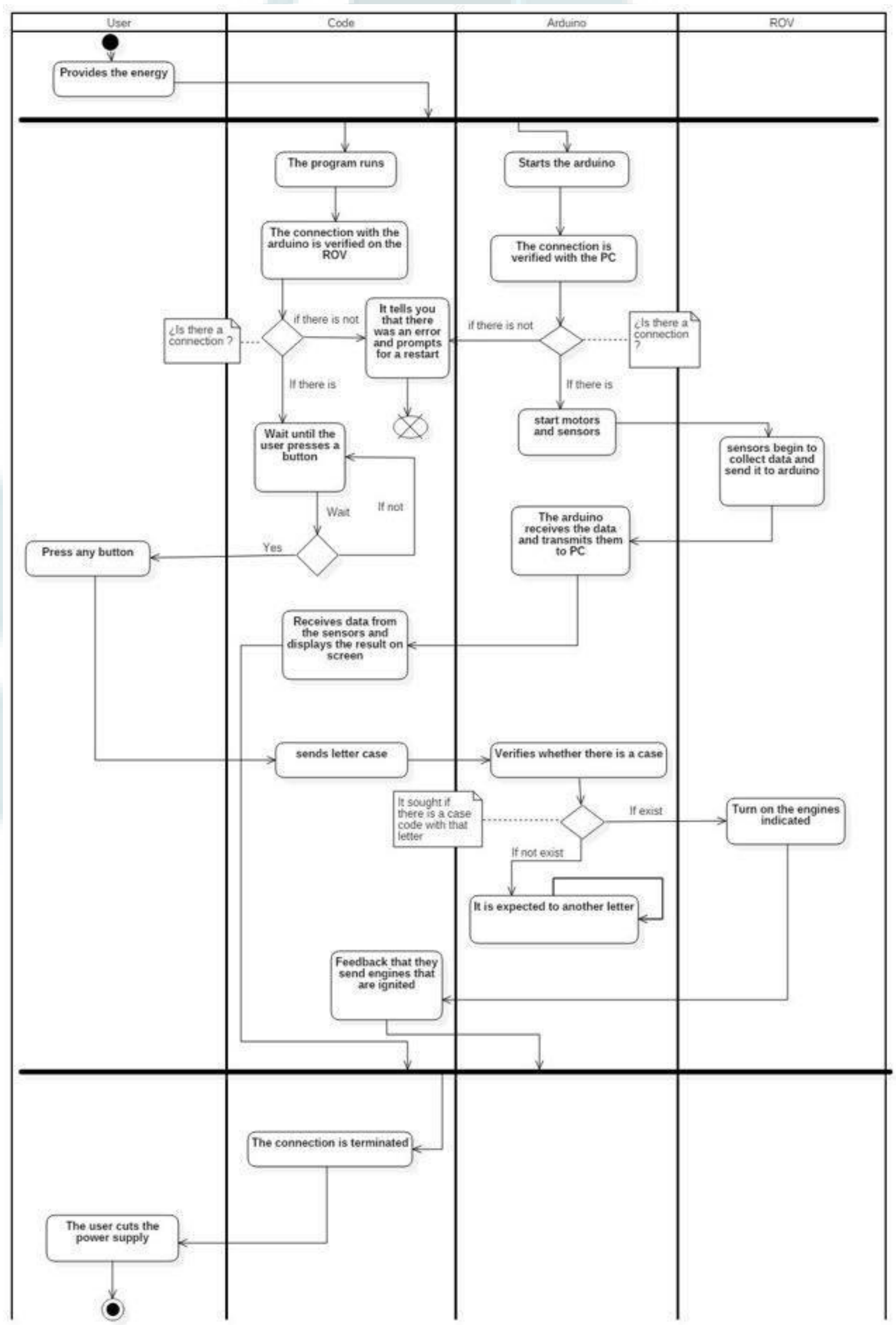

Figure 11. Software Flowchart

VI. Safety

A) Job Safety Analysis Forms

The Figures 12, 13, and 14, show the job safety analysis forms of the experience launching the ROV, laser cutting, and the ROV maintenance respectively.

Job Safety Analysis Form

Safety Information for TecXotic – Monterrey Institute of Technology and Higher Education – Morelos – Mexico

		Task	Launch/Retrieve ROV
Analyzed by:	Tomás Leví Carbellido Guzmán	Department	Safety Office/Pilot Team
Date:	18/5/2016	Information	

Required Personal Protective Equipment:

» Two or more operators.
» Life jacket.
» Non-slip, closed shoes.
» Sun protection (when necessary).

Required/Recommended Trainings:

Experience launching/retrieving the ROV.

Task	Hazards	Controls
Pre-launch	Falling	Wear the required non-slip footwear. Inspect pool area for hazards before launching ROV. One of the operators must always have a hand on the tether.
	Electrocution	1. Verify all power in Control Unit is off 2. Verify electronic box is sealed. 3. Ensure all tools are appropriately guarded and electrical appliances are protected by means 4. Ensureall extension cords are in a safe condition with plugs and connections properly wired.
Launch and Retrieval	Back strain	1. Kneel down. 2. Stay low and close to pool edge. 3. Avoid sharp twistting movements and do not over reach for ROV.
	Finger Damage	Make sure thrusters are disabled and/or power is shut off to the vehicle before putting hands and fingers near thrusters.
	Drowning	Never launch alone. Ensure all personnel wears a life jacket near pool.
	Sunburn	Sunhat / sunglasses / sunscreen / protective clothing
	Electrocution	If a leak is detected, immediately cut power to TCU

Figure 12. JSA of the launch/retrieve of the ROV

Job Safety Analysis

TECXOTIC

Safety Information for TecXotic – Monterrey Institute of Technology and Higher Education – Morelos – Mexico

Task	Operate Wood Laser Cutter
Analyzed by:	Tomás Leví Carbellido Guzmán
Department	Safety Office
Date:	18/5/2016

Required Personal Protective Equipment:	Information
» Protective glasses, ocular protection is mandatory. » Gloves (if available). » Extinguisher.	Laser cutter is used to cut wood items to ease prototyping.

Required/Recommended Trainings:
Tutorial on laser cutting. Tutorial might be imparted by other members and/or experienced operators.

Task	Hazards	Controls
Carrying wood items	Dropping	a) Do not overload b) Carry every wood item one at a time c) Operate with a co-worker
Cutting	Airborne particles	Do not inhale particles generated as a result of laser applications. May cause irritation to the respiratory track.
	Flammability	Operate device ONLY within controlled and supervised environment. Extinguisher must be kept accesible.
	Electrical	1. Verify all electrical components 2. Ensure all tools are appropriately guarded and electrical appliances are protected.
	Beam Emissions	Do not look directly to beam.

Figure 13. JSA for operating the wood laser cutter

Job Safety Analysis

TECXOTIC

Safety Information for TecXotic – Monterrey Institute of Technology and Higher Education – Morelos – Mexico

Task	ROV Maintenance
Analyzed by:	Tomás Leví Carbellido Guzmán
Department	Safety Office
Date:	18/5/2016
Information	

Required Personal Protective Equipment:
» Antistatic wristband.

Required/Recommended Trainings:
Operator must be part of, or be supervised by, a member of the Electronics Department or the Manufacturing Department.

Task	Hazards	Controls
Maintenance	Electrocution	1. Verify all power in Control Unit is off 2. Verify electronic box is dry. If not, proceed to dry it before unsealing it. 3. Ensure all tools are appropriately guarded and electrical appliances are protected. 4. Ensure all extension cords are in a safe condition with plugs and connections properly wired.
	Finger Damage	Make sure thrusters are disabled and/or power is shut off to the vehicle before putting hands and fingers near thrusters Operator must wear protective gloves is thruster testing is needed.

Figure 14. JSA for ROV maintenance

VII. Logistics

A) Project Costing

The 2016 budget was prepared at the beginning of the year based on the expenses from our previous participation. Our university, Tecnológico de Monterrey Campus Cuernavaca, is the main source of income for our ROV's materials, components and manufacturing services. Due to the limited budget available, we as a company had the duty to reduce Zeus's costs as much as possible and to optimize all the available resources.

Each cost made during the year was registered on our project costing sheet the moment the acquisition was made. Since TecXotic is a mexican company, our materials were bought from national suppliers and an important amount from the USA. Unfortunately, some of our costs escalated beyond our control due to the volatility of the dollar/peso exchange rate. The 2016 Project Costing sheet is shown in Figure15 (A&B) with the breakdown of the total ROV cost. Each member attending the international competition is responsible for covering their own travel expenses; the total cost is shown separately in Figure 16.

Project Costing (2016)				
ROV Expenses				
Qty	**Description**	**Type**	**$ USD**	**Total USD**
1	Bar30 High-Resolution 300m Depth/Pressure Sensor	purchased	$ 68.00	$ 68.00
1	UPS delivery	purchased	$ 17.00	$ 17.00
4	T200 Thruster Preinstalled BlueESC	purchased	$ 236.55	$ 946.20
1	UPS delivery	purchased	$ 60.00	$ 60.00
4	T100 Thruster Preinstalled BlueESC	purchased	$ 189.05	$ 756.20
1	UPS delivery	purchased	$ 45.00	$ 45.00
1	Watertight Enclosure for ROV/AUV (4" Series)	purchased	$ 156.00	$ 156.00
1	Cast Acrylic Tube - 11.75", 298mm (4" Series)	purchased	$ 54.00	$ 54.00
2	O-Ring Flange (4" Series)	purchased	$ 29.00	$ 58.00
1	Clear Acrylic End Cap (4" Series)	purchased	$ 16.00	$ 16.00
1	End Cap with 5 Holes (4" Series)	purchased	$ 20.00	$ 20.00
1	Enclosure Vent and Plug	purchased	$ 8.00	$ 8.00
12	Cable Penetrator for 6mm Cable	purchased	$ 3.00	$ 36.00
1	O-Ring Pick	purchased	$ 4.00	$ 4.00
1	UPS delivery	purchased	$ 45.00	$ 45.00
1	MT Hydraulic Pipe 3"	purchased	$ 3.36	$ 3.36
8	Codo rincon hidráulico 19 X 90	purchased	$ 1.21	$ 9.70
2	Hydraulic Cap A 3"	purchased	$ 1.38	$ 2.75
1	MT Hydraulic Pipe 1 1/2"	purchased	$ 1.10	$ 1.10
1	CRUZ 1 1/2" HIDRAULICO	purchased	$ 1.54	$ 1.54
1	Hydraulic Cap 1 1/2"	purchased	$ 0.34	$ 0.34
3	Closed Eyebolt 25 X 130	purchased	$ 0.26	$ 0.77
2	Open Eyebolt 23 X 110	purchased	$ 0.21	$ 0.42
1	MT Hydraulic Pipe 2"	purchased	$ 1.54	$ 1.54
2	Square hinge 3', old, flat	purchased	$ 0.68	$ 1.35
2	CODO 90° X 1/2" HIDRAULICO	purchased	$ 0.13	$ 0.26
3	MT Hydraulic Pipe 1/2"	purchased	$ 0.35	$ 1.05
1	CRUZ 1/2" HIDRAULICO	purchased	$ 0.46	$ 0.46
4	TEE hidráulico 1/2"	purchased	$ 0.16	$ 0.64
4	CODO 90° X 1/2" HIDRAULICO	purchased	$ 0.13	$ 0.52
1	Tangit Glue High Pressure 125 ML	purchased	$ 3.59	$ 3.59
1	Trichlorine powder for pools	purchased	$ 4.57	$ 4.57
1	DC/DC Converter TH QB 12V 500W	purchased	$ 90.75	$ 90.75
1	FEDEX Delivery	purchased	$ 30.00	$ 30.00
2	Ethernet connector - RJ-45	purchased	$ 7.95	$ 15.90
1	IMU Breakout - L3GD20H + LSM303 + BMP180	purchased	$ 29.95	$ 29.95
1	UPS delivery	purchased	$ 25.38	$ 25.38

Figure 15A. 1st part of the project costing

2	431 Polyurethane Foam VACIADO S.	purchased	$ 10.76	$ 21.51
2	Resin PP-250 -1- 1 KG.	purchased	$ 2.92	$ 5.84
1	Calcite 1 KG.	purchased	$ 0.24	$ 0.24
1	CAB-O-SIL 1/4 KG.	purchased	$ 3.31	$ 3.31
1	Mold Release Wax 700 GRS.	purchased	$ 4.00	$ 4.00
1	Separating Sheet 900 GRS.	purchased	$ 1.50	$ 1.50
1	Fiberglass 1 1/2 1 KG.	purchased	$ 2.65	$ 2.65
1	Modelling Clay Escultor Terracota	purchased	$ 0.79	$ 0.79
1	Brush No. 2 1/2	purchased	$ 0.64	$ 0.64
1	Catalyst K-2000 20 GRS.	purchased	$ 0.64	$ 0.64
1	Catalyst K-2000 1/4 KG.	purchased	$ 2.13	$ 2.13
1	Round Pool INTEX 4.57 x 1.07 m	purchased	$ 314.03	$ 314.03
2	Soleras de alumnio de ½ x 1/8 x 3.66	purchased	$ 14.59	$ 29.19
2	Soleras de aluminio de 2 x 1/8 x 3.66	purchased	$ 16.05	$ 32.11
1	Arduino Ethernet Shield	Reused	$ 43.24	$ 43.24
1	Arduino Mega	Reused	$ 64.86	$ 64.86
1	Tether: Harsh industrial environment Duplex Cable (40 m)	Reused	$ 38.59	$ 38.59
1	Ethernet cable 30 m	Reused	$ 33.08	$ 33.08
1	Power supply	Reused	$ 1,513.51	$ 1,513.51
1	GoPro Hero 4+ Silver	Reused	$ 324.32	$ 324.32
1	Live Video Feed Out Housing Hero3 3+ 4 - 30 m, GoPro housing, Wifi modem + taxes	Reused	$ 480.00	$ 480.00
	Customs tax			$ 233.89
		Total		$ 5,665.40
	Competition Expenses			
1	MATE fees	purchased	$ 250.00	$ 250.00
22	Team's uniform	purchased	$ 10.49	$ 230.70
		Subtotal		$ 6,146.10
		(-) Reused		$ 2,497.62
		Total ROV Cost		3,648.48

Figure 15B. 2nd part of the project costing

	Travel Expenses (not considering mentor)			
10	Airplane Tickets	purchased	$ 218.80	$ 2,188.00
1.00	Transportation (Van)	purchased	$ 540.00	$ 540.00
10	Meals	purchased	$ 100.00	$ 1,000.00
2	Rooms in an hotel (6 days and 5 nights)	purchased	$ 94.50	$ 189.00
		Total		3,917.00
	Income			
	School Funding			3,800.00

Figure 16. Travel expenses and income

B) Resource Administration and Management

In TecXotic we are aware of how important it is to efficiently manage our time and resources. Since the beginning of the project, an organizational structure was made to determine the departments needed for the company to work and for the ROV to be built successfully. A head of department was assigned to each area. Through this method specific goals were given and effectively supervised. Leaders were in charge of organizing their teams and helping them understand their responsibilities, all this in order to prevent any confusions when tasks were assigned. See Figure 17.

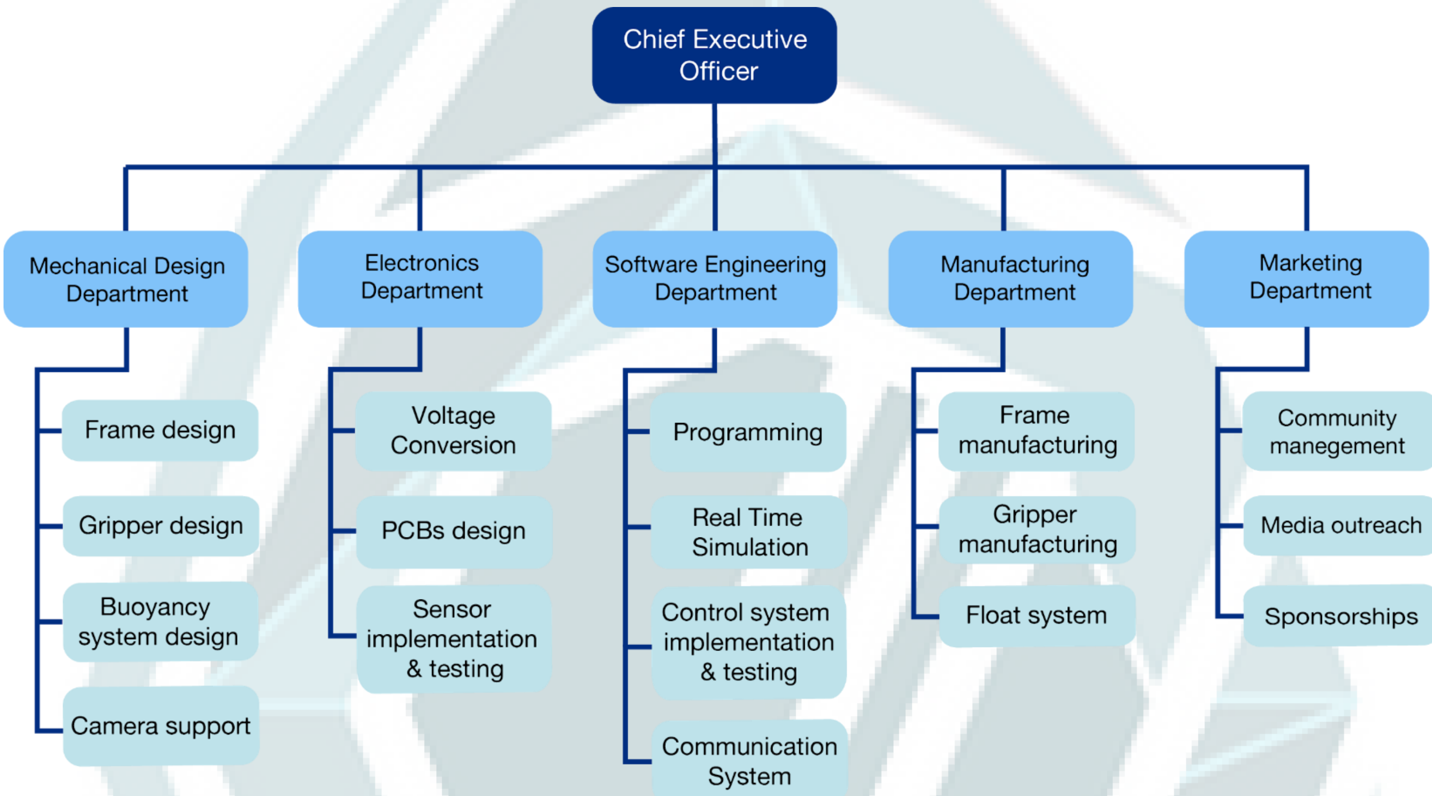

Figure 17. TecXotic's organizational structure

In addition, a survey was made to collect each member's contact info and for them to point out to which department they would belong. A fraction of the survey's results is shown in Figure. 18. Even though leadership roles were given for each department, all member's ideas and opinions were valued at the same degree.

#	Nombre	Apellidos	Matrícula	Teléfono cel...	Dirección de...	Marca el equ...	Carrera y Se...	Comentarios
6	Esteban	Segura Guerrero	A01422353	7772569590	t-bon_960@ho...	Programación	ITC – 4°	
5	Raúl	Sánchez	A01421629	7772196347	demoni_beach@...	Diseño Mecánico	IIS 3°	
4	Erick Alberto	Rodríguez Nandi	A01422229	7441605270	erickalberto199...	Diseño Mecánico	IMT – 4°	
2	Luis Enrique	Carvajal	A01422403	7775651262	carvajalple96@...	Electrónica	IMT – 4°	
1	Tomás Leví	Carbellido Guz...	A01422626		tomas.carbellid...	SET	ITC – 2°	

Figure 18. Part of the survey made for contact info

A Gantt chart was made to keep up with the competition deadlines and deliver the product in time. See Figure 19. Every Friday, leaders got together to discuss their progress. The company CEO would check the goals established in the Gantt chart and update it depending on whether they were accomplished on time or not. If a department wasn't able to finish their week's work on time, the group will discuss ways in which they could help them come back on track. On the last weeks prior to the regional competition, all company members were required to assist to the school's laboratory to integrate their work and finish building Zeus.

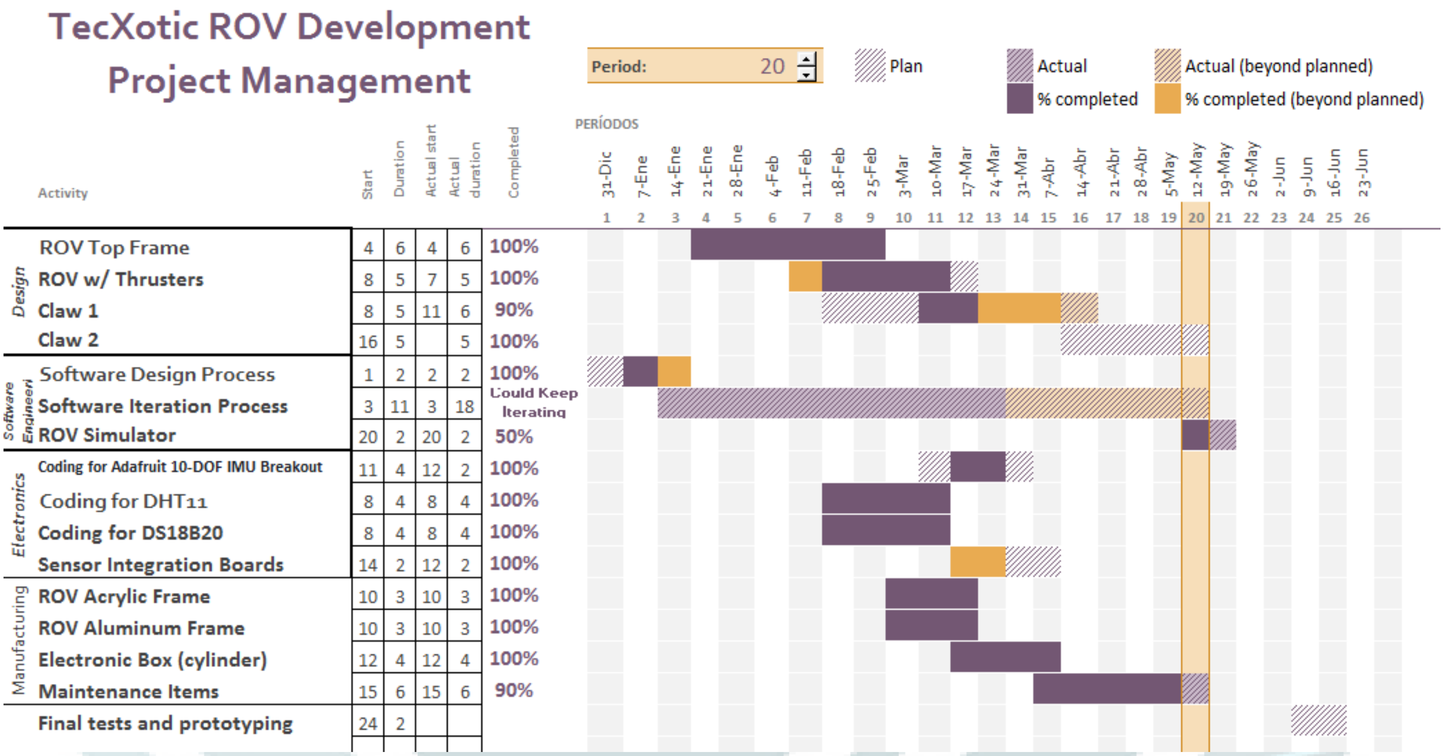

Figure 19. TecXotic's Gantt chart

VIII. Conclusion

A) Challenges

1. **Technical**

Waterproofing proved to be quite a difficult challenge, we could not allow the electronics box to have any water leaks, thus several measures were taken to prevent seepages to damage the electronic devices, such as suspending them in the cylinder, providing the humidity sensor system with enough time to detect such a leak and execute the corresponding security protocols. We were able, however, to diminish this security standards to uncommon contingency measures, given that we managed to seal properly every possible water opening.

2. **Non-technical**

Since the beginning of the project we were aware that the organization of the team was going to be one of our main challenges. Last year, TecXotic was made up by only 10 members. Having less participants meant it was easier to get to an agreement; but it also meant building the ROV would take more time. For that reason TecXotic searched for more participants for the 2016 competition. This year TecXotic has 18 members. Even though it is not a really big quantity of people, organizing them was still a challenge for us. Organizing the whole team was difficult since several members of the team live far away from school and could not always attend the meetings. Despite the fact that a Gantt chart and different departments were created since the start, valuable time was lost trying to synchronize schedules and getting to an agreement. However, this problem got less troublesome as we got closer to the competition date.

Monetary restriction and macroeconomic aspects were challenges for the company as well. TecXotic is dependent of the school funding, which meant the budget available was limited. However, based on the experience from our previous participation, we knew we had to invest in some foreign components in order to optimize our ROV's performance. The company faced the challenge of deciding which components were worth buying from USA and when to buy them. Given the volatile behavior of the dollar to peso exchange rate, TecXotic had to wait for the right moment in which the currency was at its best price. Likewise, the international customs had to be taken into account for the purchase decision.

B) Lessons learned and skills gained

It doesn't matter if you are new or returning to the competition, the whole process of having to build an ROV from scratch will undoubtedly leave lessons to those involved. This year, we particularly learned that planning isn't everything, executing is an essential aspect as well. Given that two of our members had already participated last year and that we had the prior tech report with the aspects to be improved, detailed planning could be done since the beginning. However, it proved to be a hard task to follow the plan to the very detail. We learned not everything could be fun and games, but sometimes strict orders need to be given and executive decisions taken in case things didn't go as planned.

For the majority of the team, this competition was their first approach to underwater robotics. Students did not only join the team because of their interest in the field, but also because they wanted to learn from other students and gain practical skills. To date, we can confirm that goal was accomplished. The competition pushed us to give our best, helping us to improve and develop skills in teamwork, problem solving, work under pressure, creativity, patience, responsibility and so much more.

C) Discussion of future improvements

Building Zeus was definitely not an easy task. We had to make a lot of mistakes in order to make it work. There are some things we would have done differently given more time and resources. The following points explain some of the aspects that could be improved in the ROV in order for it to give a better performance in the future:

- Improving the floating system: We want to make it pneumatic in order to facilitate floating regulation.
- Invest in a better cable that can transmit a better quality image from the camera.

D) Reflections on the experience

It's amazing to see how much TecXotic has grown since the beginning of the project to where it is now. At the start we were just students determined to win the competition but unsure of how. Now with a finished ROV, we understand that although winning would be nice, it is not everything. Whatever the results are, we won't be leaving the competition empty handed. It is a fact that each of us have learned something, gained more experience and definitely had a lot of fun along the way.

Having the honor to participate in the international competition once again is such a big opportunity for us. The chance to meet new cultures, people and places is never taken for granted. We can honestly say this competition has left an important mark in our lives and future careers. Participating in this competition is always a great reminder that when you love what you are doing there is nothing that can stop you from your dreams.

"This is my second year in the Team TecXotic and the only thing that I could say is that it was the greatest experience of my life. Last year competition gave us technical knowledge that was applied in this year development, the experience acquired helped us to realize the requirements of the competition as well as the things we did right last year. But this was not only about technical skills but also about partnership.

When you see the team working and all the nights that we have spent doing the ROV, you can understand why this type of competitions are important for the new generation of scientists and engineers. When you have spent 6 months trying to make things work and you finally see the ROV functioning in the pool you can feel that it was worth it, that moment is priceless. That is why I joined this kind of activities, because I think that creating technology and helping people with our inventions is a way to leave our mark in the world.

This experience opened my perspective about robotics and engineering, now I know that my career will be mostly oriented to science. The competition opened new opportunities in my life. As a team we want to thank MATE for all the support and opportunities during this year. We are looking forward to have a great participation on this year competition, the trip has been difficult but the memories made will not be taken away." – Hilda Rojas

IX. Acknowledgments

TecXotic ROV Team, would like to extend our sincerest gratitude to the following benefactors:

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- Tecnológico de Monterrey Campus Cuernavaca and Director Ph. D. José Carlos Miranda - For being our alma mater, funding the ROV components, materials and all the support given to the team through all these months.
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XI. Apendices

A) Budget 2016

Budget 2016	
Based on 2015 Participation	
Description	**$ USD**
MATE inscription	$ 250.00
Rov Expenses	
Reused Components	$ 2,497.62
New Compontens	$ 2,000.00
Total ROV Expenses	$ 4,747.62
Travel Expenses	
Airplane Tickets	$ 3,000.00
Transportation	$ 500.00
Meals	$ 1,000.00
Hotel	$ 200.00
Total Expenses	$ 9,447.62
Income	
School Funding	$ 4,000.00
Deficit	$ 747.62