



CARIBBEAN ROV

ALEXANDRIA UNIVERSITY

MADE IN ALEX ROBOTICS TEAM

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ABSTRACT

Made in Alex Robotics Company is the first of its kind in Egypt, the company aims to participate in many competitions held worldwide concerning robotic designs and implementation

The Caribbean ROV is our company’s fully functional product after months of dedicated efforts and time, our Remotely Operated underwater Vehicle could operate under high depth with precise and quick motion, its high mobility and features would make it a great support for those who need it in the fields of science and aquatic archaeology



FIGURE 0 - MIA SLOGAN



FIGURE 1 - MIA MEMBERS, SENIORS AND SUPPORTERS

SPECIFICATIONS

ROV name:	CARIBBEAN ROV
Total cost:	1346\$ / 9422LE
Primary material:	cross linked polyethylene
Weight:	almost 30Kg
Dimensions	45x45x45 cm (arm not included)
Max current consumption:	35 ampere

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DESIGN RATIONALE

DESIGN PROCESS

As one of our major concerns to choose the most stable applicable and highly effective body that can matches all our needs starting from material selection down to the smallest electronic boards we wanted to fix in our body

For material selection we stood between two materials: acrylic and cross-linked polyethylene also known as (artylon).

We had a datasheet for both materials and it was settled that artylon fits our concerns and this is due to its Density which is much close to the density of water around 975 kg/m^3 , strength, low cost and easy machining

After choosing our material we used a CAD "Computer Aided Design" SolidWorks 2013 as we managed to find our way to the artylon material providing its properties to SolidWorks and we started immediately designing our body and we used a simulation for our ROV underwater using the SW13

It is a fact that any mechanical design needs a basic structure you can build on. A basic structure gives you both a reference for work and stiffness according to your choice of material

However after a profound search we proposed aluminum as our infrastructure material and it was approved by all experts that aluminum can be used as stakes therefore it is reliable and easily formed, we had a major abstract for using aluminum selection for the proper drilling and cutting tools. However, to have a solidarity body we needed to choose the best fixation materials starting from the smallest bolt to the largest nut, so we came on to use screw bolts and counter nuts to resist vibration produced from our EM54, vibration dampers and brackets were used to fix bilge pumps, EM54 and the pressure hull

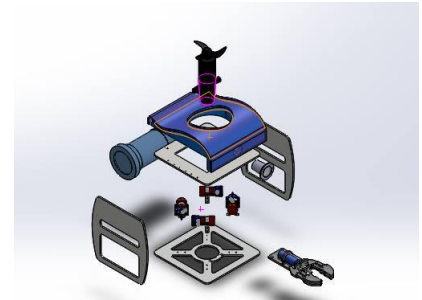


FIGURE 2 – 0% ASSEMBLED

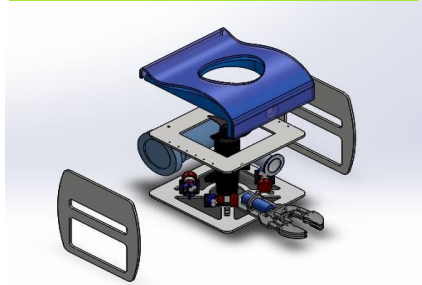


Figure 3 – 50% ASSEMBLED

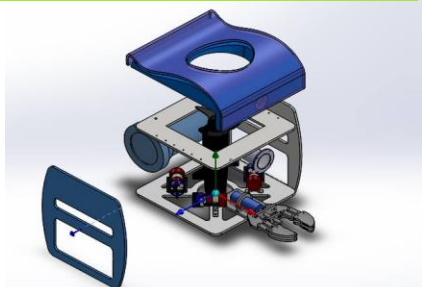


FIGURE 4 – 70% ASSEMBLED

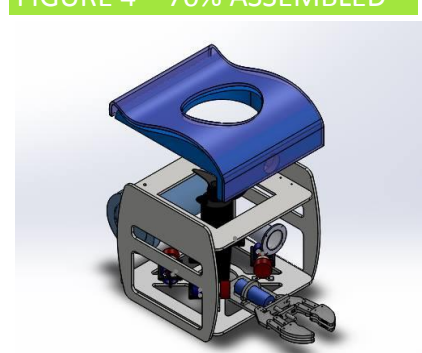


FIGURE 5 – FULL DESIGN

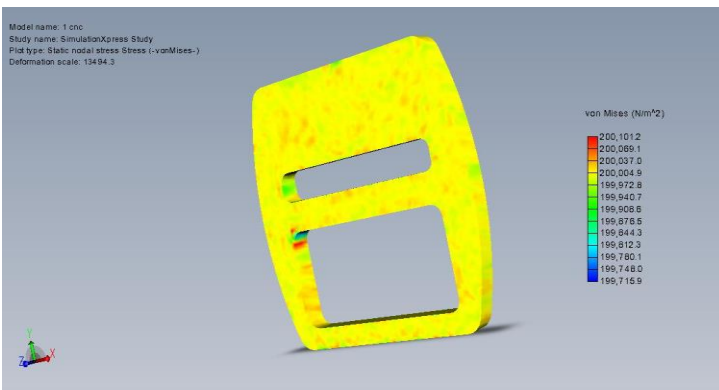


FIGURE 6 – STRESS SIMULATIONS

Stress simulations and force calculations over the main body occurred using ansys simulations so as to check the solidarity of our structure and materials

All components are attached properly to the frame using stainless steel brackets and power screws

DYNAMIC SYSTEM

One of the most critical choices in the design of the ROV is to choose proper thrusters that could afford quite good performance under high pressure, and on the other hand doesn't dissipate much power or goes with the ampere to a risky level. Also arranging the thrusters around the ROV so as to increase its mobility and states of motion is necessary

EM45 trolling motor – for the vertical motion we set to use a single high power thruster trolling motor after huge modifications on it, by removing its manual control device and connecting its terminals to the drivers in the pressure hull, also some mechanical modifications took place to increase its water isolation especially under high pressure

Connected by a wide area propeller this motor guarantees high vertical thrust due to its high torque and moderate speed (about 1600 RPM) in air and decreases by 30% in water, also the semi linear change of its produced thrust due to change in the voltage across its terminals gave us some extra good abilities of speed control and thrust variance

Bilge pumps – multidirectional system composed of 4 thrusters perfectly aligned so as to increase the movement options to our pilot was built up using upgraded bilge pumps, by removing the pumping fans and replacing it with high pitch propellers we created these thrusters

Not only known for their high reliability under high pressure but also known for their low need of power and economic price as a product compared to other motors like brushless ones, the bilge pumps seemed to be a great idea to use

Every one of our 4 thrusters is connected to control driver so as to control speed and direction of thrust, giving our pilot multiple levels of operation varies from maximum speed needed to navigate quickly around the field to very low operating speed needed to do some precise work in some small areas



FIGURE 7 – EM 45



FIGURE 8 – WIDE PROPELLER

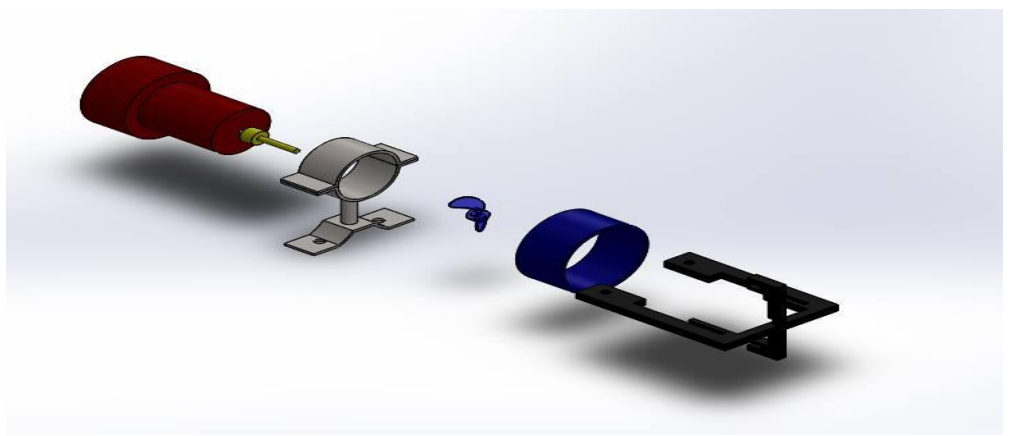


FIGURE 9 – BILGE PUMP FULL PARTS

BUOYANCY

Applying the science of balancing for any immersed or floating body is a major For ROVs, it is considered the most important applied science must be used Targeting the ROV to be suspended makes it more easy to manipulate the ROV for drag up and down and moving in the horizontal level as this makes the ROV weightless Targeting the ROV to be stabilized makes having special drive system to rotate it to its stable position useless.

Synthetic foam – the total weight of the Caribbean ROV is about 30 kg; the floaters we needed had a lot of calculations to be accurate, besides considering the buoyant force of the pressure hull itself the mechanical department members decided to use synthetic blue foam so as to be our floating material in the ROV

The calculations had also some extra considerations, either by attaching the foam at the upper plate of the ROV make the center of buoyancy over the center of gravity and working on the same line of action, and this is handling the stability condition, or by making the shape of the foam varying with distance from the tube due to the variation of mass distribution so that the ROV is always horizontal not just stable

Choosing the primary material to be CLPE offered huge solutions in the issue of stability because it has almost the same specific weight of water so it didn't perform any kind of forces over the body while immersed in water

Fiber glass mold – not only used to give the synthetic foam some resilience and strengthen it, the fiber glass was also used as to make our ROV's shape more beautiful and to give its top side a smooth touch and colorful look

The fabrication of the mold was done on 3 stages; mold formation using other materials to give it the basic shape it should have, hardening and machining to remove extra parts and sharp edges and to form paths for the vertical thruster and light bulb, and finally painting the mold to give it a good looking color and mounting the mold and the foam over the top of the ROV

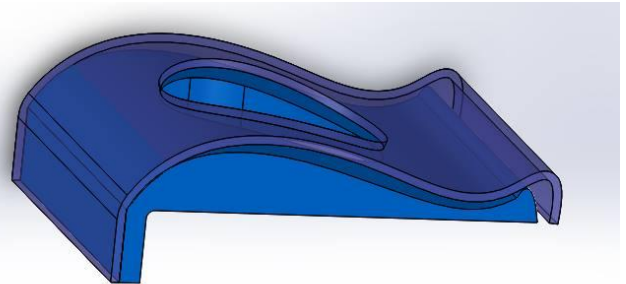


FIGURE 10 – FULLY ASSEMBLED FLOATER

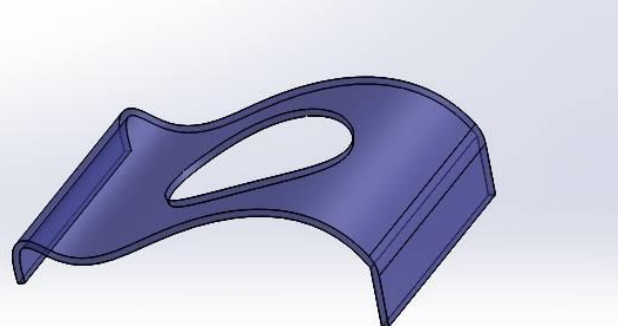


FIGURE 11 – FIBER GLASS MOLD



FIGURE 12 – MACHINING PROCESS

ISOLATION

How good your water isolation technique determines how deep your ROV can dive, depending on those concerns our search began to find out a good isolation for our electronic circuits and control units inside the Caribbean ROV; we began by forming a PVC tube with a movable CLPE cap at one end to store the electronic circuits as a pressure hull, in order to access inside the pressure hull multi terminal cables are used, the cables pass through cable glands which are properly attached to the cap

After this about 1cm of the cap is filled with 3M insulation sealer, this material provides extra safety to our electronic system and extends our allowable depth by few extra meters, the cap is connected to the Tube using 8 long screws, there is a rubber ring between them and the tube formation contained multiple O-rings on the edge to provide maximum isolation

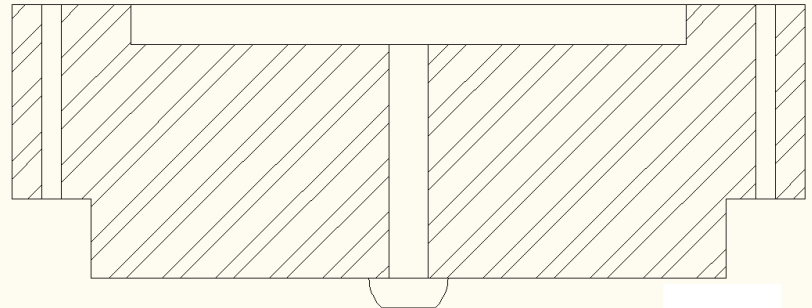


FIGURE 13 – CAP DESIGN

As for the wire connections outside the tube, we found out that we had so many connections and wires that would make it hard to get cable glands with the number of these wires, so we attached our multiple wires to the multi terminal cables and they are isolated inside 2 joints filled with the insulation sealer



FIGURE 14 – INSULATING JOINTS



FIGURE 15 – TURNING PROCESS

ROBOTIC ARM

Sometimes being an observer is not enough in science and since humans can't go deep enough with their hands, they use manipulators connected to the ROV to be able to control objects and grab things from the bottom of the ocean

The Caribbean ROV is provided with a strong, high functionality robotic arm as to use it for manipulating things and grabbing objects

The gripper was designed to be easily assembled in case of modifications and fabrication errors, and to be able to grab objects of different sizes and orientations

The material of the gripper is the same of that of the ROV, CLPE and for the same reasons as well; high durability, easily upgraded and has the same density of water

The actuator of the gripper is an insulated low speed DC motor whose shaft is a power screw to control the level of the gripper either open or closed, the power screw's material is Stainless steel 310/310s to afford high force and the pitch calculations were precise to give a fast motion to the gripper and high resilience to opposing forces

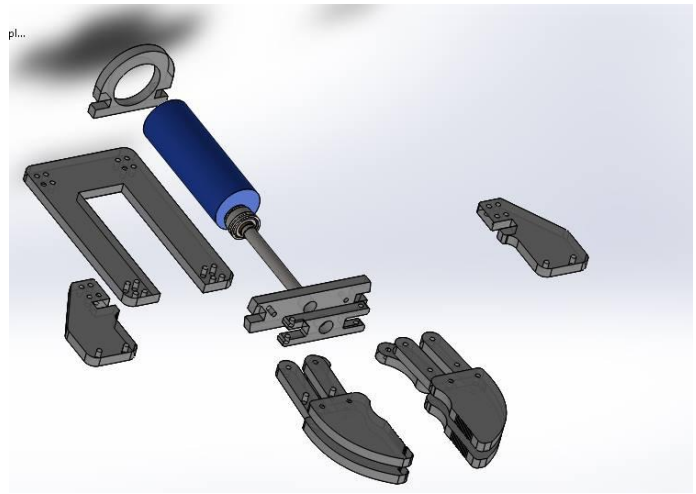


FIGURE 16 – ROBOTIC ARM



FIGURE 17 - ACTUATOR WITH POWER SCREW

TETHER

Choosing a good power rated tether to deliver needed power to the ROV so its operation is done properly, also a cable consists of 10 stranded wires is used to perform the communication medium between the onboard controller and the PC offshore, as well as a transmission medium for the signals of the cameras upwards.

The tether is attached to a foam rod; needed to make the tether critically floating so it doesn't perform drag force or floating force on the ROV

POWER & CONTROL

Power system and control devices are the core of the ROV; depending on them the ROV transforms from a useless prototype to a fully functional machine, that's why our electrical department members dedicated most of their time deciding what to use as a control device and how to analyze power throughout the whole system

DC Converters – SMPS or Switched Mode Power Supply was chosen as our power converter from 48 volts to 12volts and 5 volts with high ampere rating, the 12 volt converters are used to supply the control device, the thrusters, actuators, gripper motors and some payload tools, while the 5 volt is used to supply some of the sensors and the camera's signal selector.



FIGURE 18 - SMPS

Bus-Bar wiring technique – the demands of high stability of the system as well as the accessibility to the power supply was a problem inside the enclosure, until we decided to apply the Bus-Bar technique to deliver power to every electronic device inside the enclosure, this technique didn't only helped in delivering required power to the electronics but it also helped in the wiring by reducing the number of wires and ease the wiring on the implementation engineers

The electronic devices are mounted over several acrylic plates separated by copper spacers, they plates are assembled over each other and they rest over 2 acrylic rods properly attached to the tube so the electronics stay in position well even when the ROV vibrates a lot



FIGURE 19 – BUS BAR AND PLATES

Control Device – choosing a control device with high stability, functionality and reliability, which proceed data with acceptable performance, also easy to detect and troubleshoot errors within the operation, so we chose AT Mega 2560 development kit after long search among the best operating micro controllers

The system operates as a finite state machine FSM depending on the data transferred through the serial port or that from the sensors, safety protocol operates whenever there is a warning signal by any sensor detecting the occurrence of fatal errors; the controller stops operation of horizontal thrusters, operates the vertical thruster and sends a warning message to the PC

Drivers – the high power vertical thruster used in our ROV required a high ampere rated driver, that's why we used a 30 ampere driver. Where the horizontal thrusters required a midrange ampere rated drivers, so we used 10 ampere driver for each

Each driver can operate the thruster in both directions and contains speed control using PWM control pin

The gripper actuator on the other hand didn't require such ability of speed control but continuous full speed operation, so we used relay switch board to control that actuator

Light – we used a water isolated light bulb in order to provide clear vision for the pilot under even when the view is dark, the light bulb operates at 12 volts DC and could vary from 50 to 10 watts depending on the lamp used, and it is controlled for economic usage of power consumption



FIGURE 20 – LIGHT SYSTEM

AUXILIARY ELECTRONICS

Some times in order to reach better functionalities and higher rate of a product by the customer the company has to attach some auxiliaries and accessories to help in the main system operation. In order to do so, our electrical engineers decided to use some sensors to help the operation, also attached some payload tools to help in the mission tasks

Water Sensor – a sensor that detects any leaks in our electronics enclosure and guarantees maximum safety for the whole operation from any short-circuits or defects due to water leakage.

The control device algorithm is set to check the signal from the water sensor, if the signal is zero it means that there is water in the enclosure, so a safety procedure starts by preventing any horizontal motion and operating the vertical thruster up, also sending a warning signal to the PC

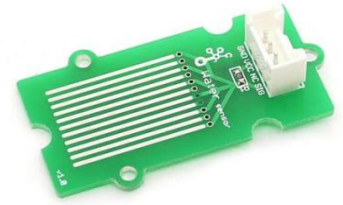


FIGURE 21 - WATER SENSOR

Current Sensor – mainly used to perform dry test, water test and full maneuvering without observing the motors only from the software from the readings being sent to the pilot and to protect the motors from over current by controlling their PWM if the current exceeds a certain limit

The zero current value is set to be 2.5 volts and varies from 0 to 5v depending on the direction of the current in the sensor; sensitivity is 20 mv / ampere



FIGURE 22 - CURRENT SENSOR

Accelerometer/Compass – we use this module to calculate the tilt-compensated headings in degrees relative to a known vector, this reference vector can change to set precision to a certain direction

The module also helps in calculating estimated roll, pitch, and yaw angles from sensor readings that can be visualized with the gyro horizon on the GUI.



FIGURE 23 - COMPASS

Conductivity sensor - It consists of two parallel plates made from aluminium with 1cm spacing between them. One plate is pulled down electrically and it's connected to ADC, the other is connected to VCC, so we can divide the current over the voltage difference and calculate the conductivity of the sink hole.



FIGURE 24 – CONDUCTIVITY SENSOR

VISION SYSTEM

Considered as the eyes of our pilot the vision systems shouldn't only give clear vision from a single point of view, the wide vision and from multiple viewpoints was needed in order to access full control over the ROV and manipulating it perfectly regardless the surroundings

In order to achieve such good parameters Caribbean ROV was provided with multiple wide vision analog cameras, they were placed carefully to have clear vision of the surroundings form different sides and even a vision for the bottom of the ROV

One of the cameras had the gripper in its vision so the pilot could easily use it, while two cameras were pointed forward so as to give a wider angle of vision and a clear 2 sided view of the ROV and finally another camera had the view of the bottom to make sure the ROV doesn't land on any sharp edges or hard places

Another feature of the cameras beside the wide range and good quality is that they are waterproof; this feature saved us time, money and efforts to try to isolate the cameras from water effects

The pilot has a full time vision of one of the front cameras, while he can only access one of the other cameras at a time, this lead us to make a camera selector, so as to choose which camera to operate, we used 4066 analog signal enable to be able to do so, it enables one camera while disabling the other ones

The cameras are connected to the PC using easy-cap device

The cameras operate on a program based on Matlab; we tried to create some features beside the vision on the program so it can capture images and videos also can calculate the any dimensions needed



FIGURE 25 - ANALOG CAM

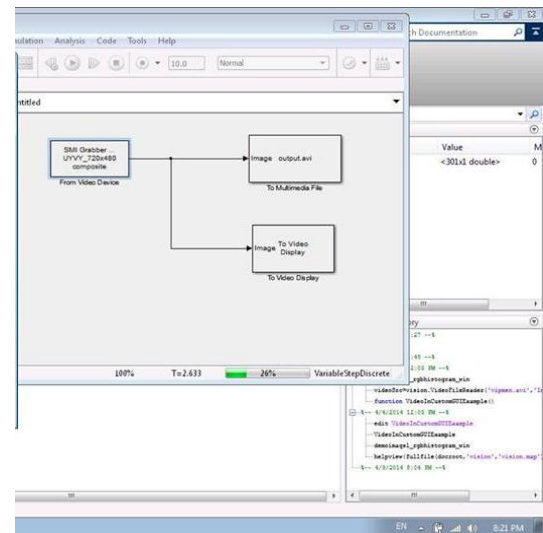


FIGURE 26 - CAMERA CLIENT

USER INTERFACE

The Caribbean ROV was built for everybody. You don't need experience to use it, as it has simple and descriptive “GUI” full of useful signifiers that allow the easy usage of the affordances provided by the ROV, so that everyday person with no experience could get used to it in a couple of hours.

Targeted structure - the user could interact with the ROV using: Keyboard, Joystick, or any USB control device which makes it perfect for all kind of people. The controls are similar to those in any video game; so that people could get used to it quickly, without the need of a manual.

Age of pilot – Any human from 7 to 11 years old could use it based on the GUI controllers; as it's very easy to understand. Any human from 12 to 90 years could use all the capabilities of the ROV including the command line interface. These results were collected in a series of test sessions with kids from schools from Alexandria, Egypt and their parents.

GUI aesthetics – Our software developers have studied computational arts in a MOOC offered by The State University of New York that covered programming in processing and editing digital pictures in Gimp and Photoshop. So we had a solid background on digital art, and that reflected on the GUI design.

GUI design – The code was written in Java, specifically in Processing environment. The used open source code signifies the original writers, as we have used some open source Java classes that made it easier to develop the code. Our main concerns were Simplicity and Power over the ROV.

Features - Speed could be controlled using general sliders for horizontal or vertical speeds or specific speed for each motor; as you can press the specific motor and a pop-up window will appear to adjust the speed, that help us refine the movement of the ROV without the need to bring it up to surface.

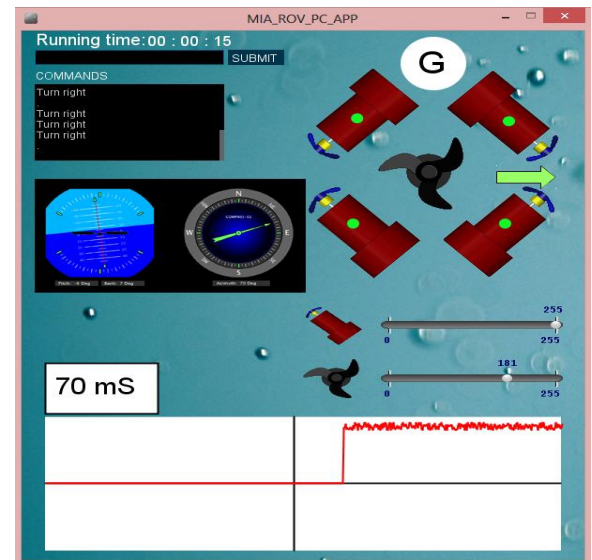


FIGURE 27 – GUI

The GUI contains a command line interface a CLI for complex tasks such as aborting mission, test thrusters, and specifying speed of motors quickly. It uses Linux commands and there is a built in manual just like Linux does. The CLI is for the advanced user so it's not necessary for the usage of the ROV.

Provided with a time varying graph that plots the conductivity values over time, our interface also can save these values in a text time with the associated time for later debugging. Also the current conductivity value is printed above the graph.

There is also a compass and a gyro horizon to help the pilot recognize the heading direction, also informs him of the ROV's orientation and the Pitch, the Bank and the Roll angles

The communication system – is based on UART communication as it provides full duplex data transmission so that we can send and receive data in both directions in 9600 bits/sec baud rate. We found it stable enough to be used in a 25 meters twisted pair cable.

SAFETY MEASURES

SAFETY FEATURES

As always said safety comes first so, MIA Company has considered multiple safety measures and ensured that they are applied to the ROV, not only to ensure the safety usage of the ROV but also to ensure the safety of the ROV itself, those safety measures are divided among mechanical features and electrical features.

Mechanical safety features

- All edges are smoothed
- Wires and connections pass through cable glands, the glands are connected to a cap filled with highly isolating material to ensure maximum isolation under high pressure
- Wire connections outside the pressure hull are contained inside waterproof joints filled with isolating material
- O-rings are attached to the end cap of the pressure hulls
- All cable glands contain O-rings as well on both sides of the cap to ensure maximum water isolation
- Nozzles are attached to the motors for higher protection to bare hands and connecting wires

Electrical safety features

- Main fuse is attached to the off shore end of the power line in the tether
- Circuit breakers are used
- Automatic safety procedures, if an error occurs that might cause fatal harms to the ROV the protocol is to stop any kind of motion, force the ROV to float and reach the side of the pool and sends a warning message to the pilot
- Water detection sensor inside the pressure hull
- Current sensors are used to ensure none of the thrusters exceed a certain amount of power dissipation

COMPANY SAFETY POLICY

Safety comes first is not just a policy for a fully developed product, it is also applied during the whole process until the product is finished, in order to do that safety policy is applied by multiple instruction as follows.

- Safety glasses should be worn all time
- Gloves are on while dealing with machines
- Shields should surround cutting machinery that may throughout small chips
- Before power up the circuit should be checked
- A first aid box should always be available in the workshop
- All components are properly attached and fixed well before operation

CHECK LIST**Pre-Power**

- Safe area
- Motor wire connected to pressure hull
- Thruster propellers clear of any obstacles
- All wire connections are checked
- All electronic circuits are placed well and stable
- Check the circuit fuses

Dry Test

- Dry run
- Check power on system to be 48V
- Test for presence of short circuits
- Thruster test for operation and verify directions
- Video stream on
- Camera has clear vision
- Check video multiplexer performance
- Light system on
- State LEDs verified
- Software test with control
- Sensors test
- Error flags test

In water Test

- Bubble check
- 10 min submerge then leak check
- Check cameras vision under water
- Check light system under water
- All members back
- Start the engine

CONCLUSION

CHALLENGES

Team assemble, leadership and team work have all made challenges upon all team members learning how to organize the work depending on dividing it into small packages and arranging these packages so as to build the whole system in both electrical and mechanical implementation depending on a well known timeline. During the progress the human resources manager was coordinating with the CEO so as to distribute the tasks over the team members so each one grants a task matching his abilities.

Communicating with team members was once a problem, as most members didn't get to know each other well, solving this issue came with either completing tasks in groups or managing to make talks with others during the off-time.

On the other hand technical challenges weren't in any way easier to handle, choosing the main material of the frame of the ROV so that it gives maximum capabilities could be reached of strength, ease upgrading and buoyancy features of the material, other challenges were choosing the best material to make the pressure hull and the best shape of it so as to ensure there will be no leaks in it, thus protecting the electronics inside the ROV.

Other technical difficulties appeared when managing to choose wisely the communication system to be used so as to increase its range and performance and lower the error bit rate, choosing the camera used to increase the performance of the pilot and to finish the missions in a better way, using the stereovision technique to measure the dimensions required a lot of researching and testing, choosing the motors that will operate under water with acceptable performance was also considered.



FIGURE 28 - POWER SCREW FABRICATION

TROUBLESHOOTING TECHNIQUES

The mechanical department dedicated over 2 weeks on searching for the best available material to use as the primary material in the ROV regarding the parameters of strength, density and upgradability. Also choosing other auxiliary materials and certain types of bolts and screws to help in building the frame of the ROV

One of the hardest difficulties was to insulate the gripper actuator; this was a great challenge for the mechanical department members whose searches found that some available easy solutions and Alexfert company's technicians offered help in this process

Choosing thrusters wasn't in any way easier, some mechanical and electrical members started to work together in order to find the best solution and to get the best motor, from the selection of brushless motors, isolated DC motors and upgraded bilge pumps by calculating the parameters of RPM, thrust, consumed ampere and voltage to speed control.

LESSONS LEARNED

Being our first trial in the field of underwater robotics, the MATE competition has led us to discover a lot about this field either mechanical underwater systems or electrical communications with high range and low error rate, the knowledge we gained was extremely helpful when it came to designing the ROV mechanical system and choosing wisely an efficient communication system.

Our team had a great desire of using a system that is built by interfacing raspberry pi with the controller onboard and digital cameras with high quality, this desire led the team members learn more about Linux coding and Ethernet communication, although they weren't used eventually.

Knowledge sharing with other team members, team work and working on a certain policy all were gained after great efforts of each and every one of us.

INNOVATIONS

The moment you stop developing yourself is the moment you start falling, the research and development department at MIA Company always works as to develop the ROV's performance, the list of future improvements describes our target for next generation of developed ROV's

- Using Ethernet system for higher communication stability, greater data ratio and wider band width
- Using beagle bone black or Raspberry pi in the control system and video streaming with it using digital cameras
- Using thrusters with higher RPM and torque
- Design enhancements, thus reducing the drag forces on the ROV
- Developing the robotic arm for higher functionality
- Developing our GUI system for higher performance and easier usage
- Using HD cameras for maximum quality and apply a night vision system
- Developing our automated protection system
- Installing an offshore system with wheels to drive the ROV outside the water to the edge of the pool
- Improving our pilot system application to simplify the pilot's mission and increase his performance
- Install a GPS module in the ROV
- Applying stereo vision theories to detect objects and colors, also for dimensions calculation
- Improving the performance of our payload tools, sensors and actuators



FIGURE 29 - SIEF AND AHMED FAROUK TROUBLESHOOTING WIRING DEFECTS

REFLECTIONS

Dr. Mohamed EL habrouk:

If we look at those efforts, I would like to thank the robotics competitions they are something that deserve appreciation and respect, we hope to give to the world of engineering more and more as these competitions are always a point of start for successful future engineers

Ahmed farouk (CEO)

While learning to be an electrical engineer in later months managing the team, I learned valuable leadership skills and management techniques. Beyond just the technical, I have gained many cherished memories as a part of this team. I especially want to thank the coaches and each member MIA ROV team they really deserve appreciation.

ACKNOWLEDGMENTS

- **Marine Advanced Technology Education center**, thanks for organizing the great competition with this type of competitions undergraduate engineers will be able to apply theories that are being studied in their universities.
- Special thanks to Arab Academy for Science, Technology and Maritime Transport, ROV Egypt and Hadath company for organizing the regional and local competitions, thanks for giving us a chance to participate in such a great competition
- Alexfert co. thanks for the great help offered, either by offering us great help during the fabrication or by offering us a place at the workshop
- AMOC co. thanks for your great donations to the travel process
- Faculty of engineering Alexandria university for their great donations towards our project and helping us through the competition
- Faculty of engineering Alexandria university students, professors and research assistants for their great support towards us, especially Dr. Mohamed El Habrouk for sharing his experience with the company members
- Mechanism training center for their great donations

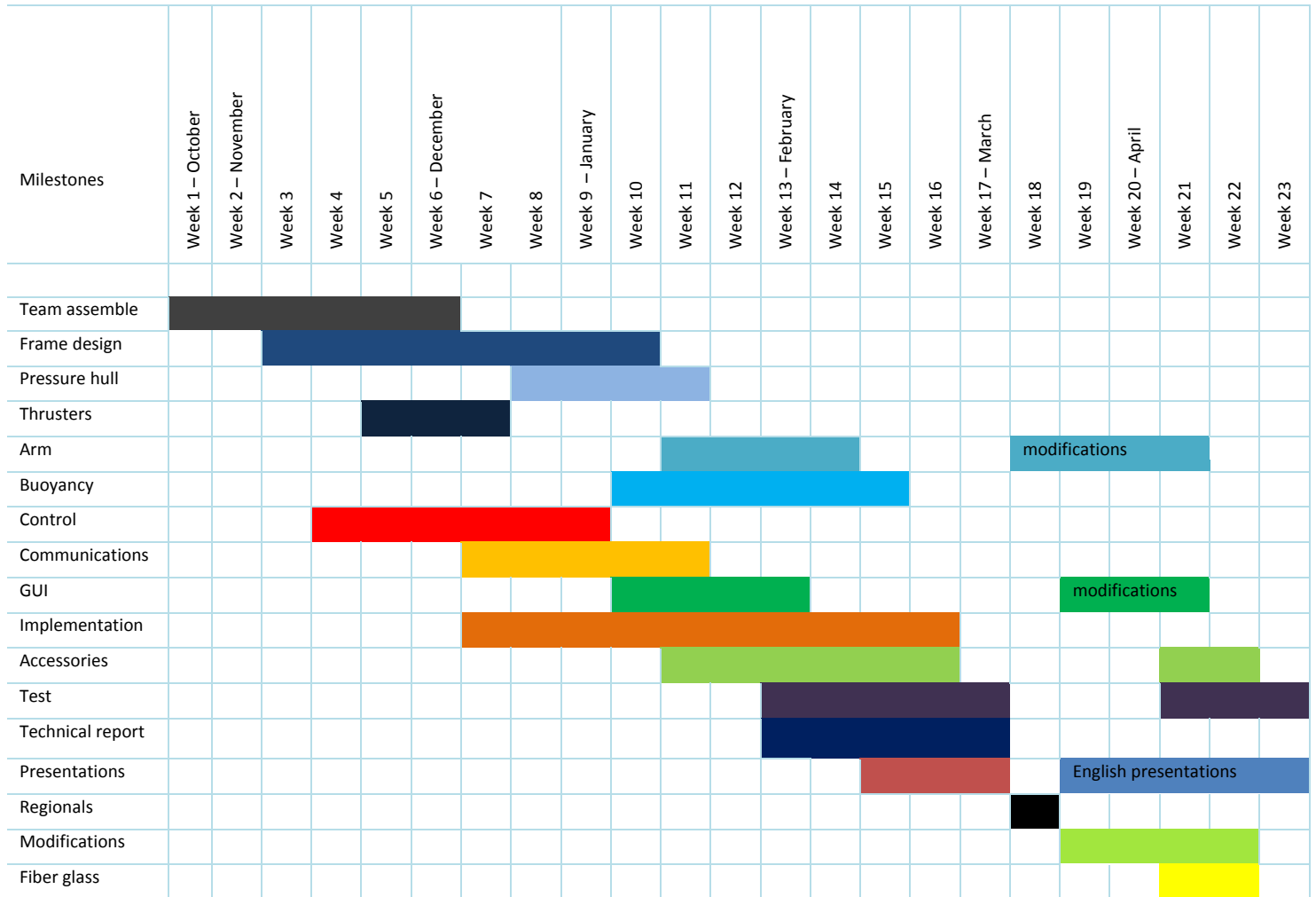


Sponsors:

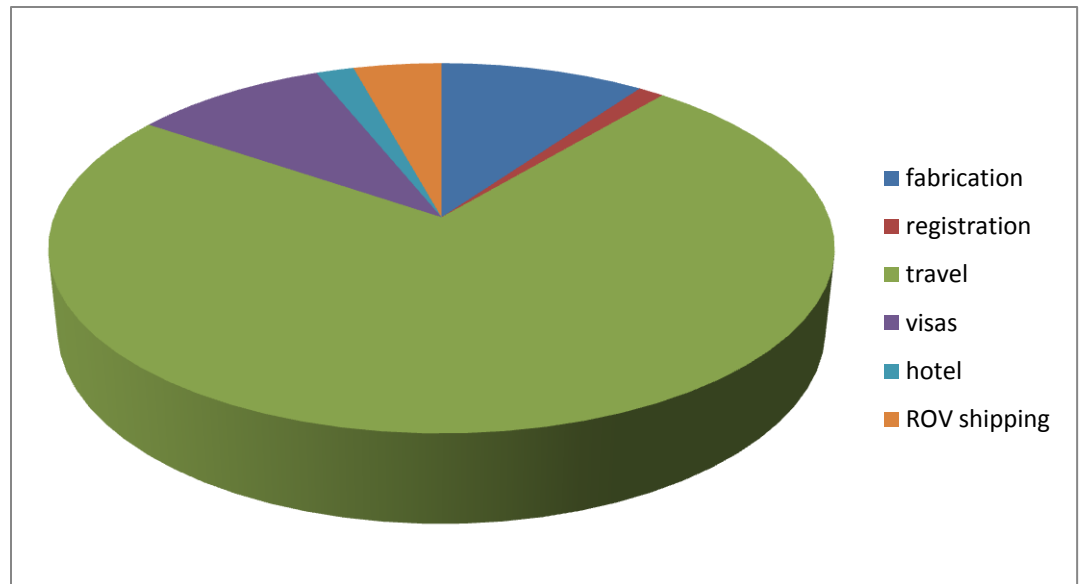
- References**
- processing.org
 - arduino.cc
 - [MATE courses](#)
 - [Introduction to computational arts MOOC](#)
 - [open ROV forums](#)

LOGISTICS

GANNT CHART



EXPENDITURE SUMMARY

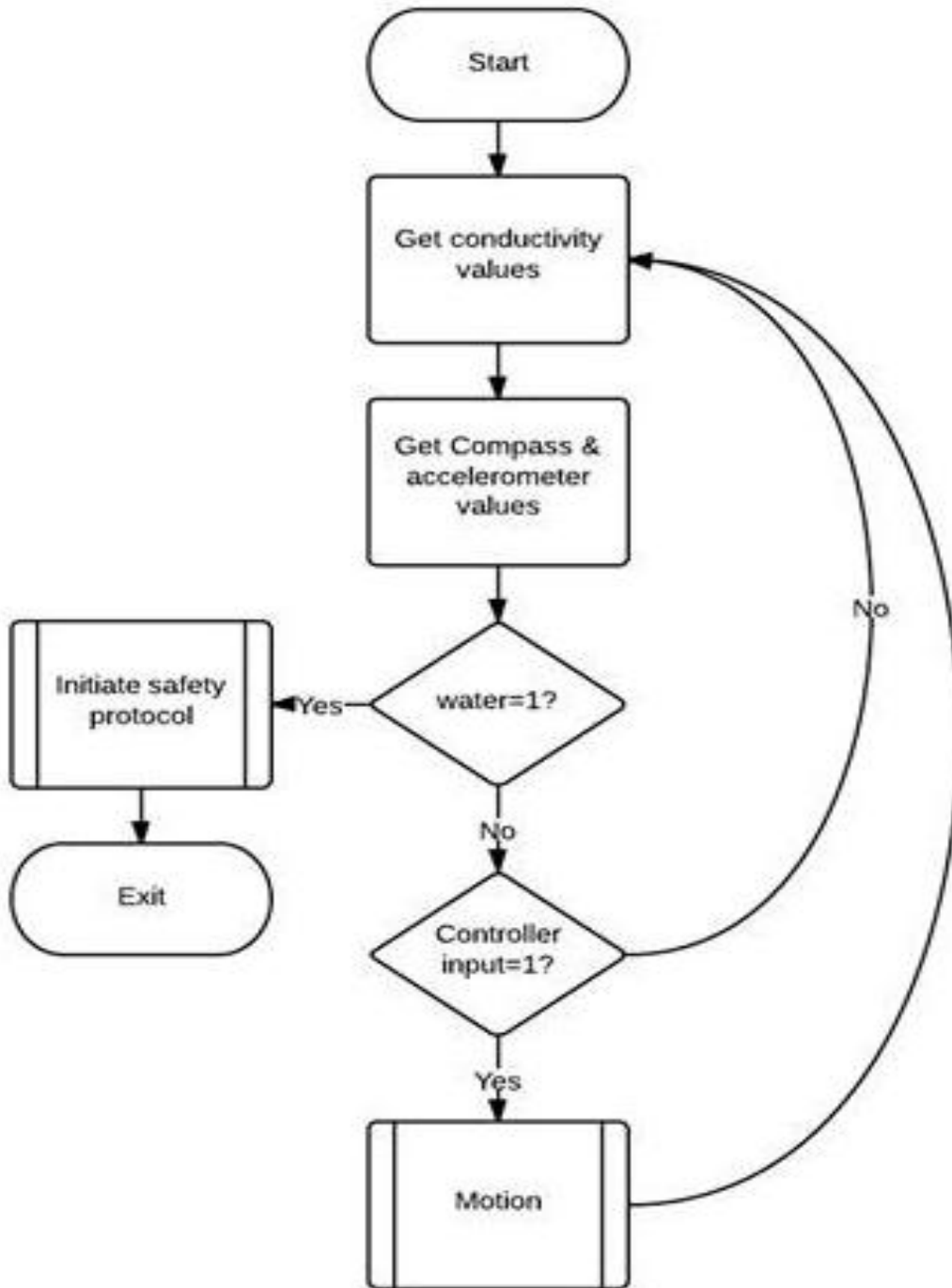


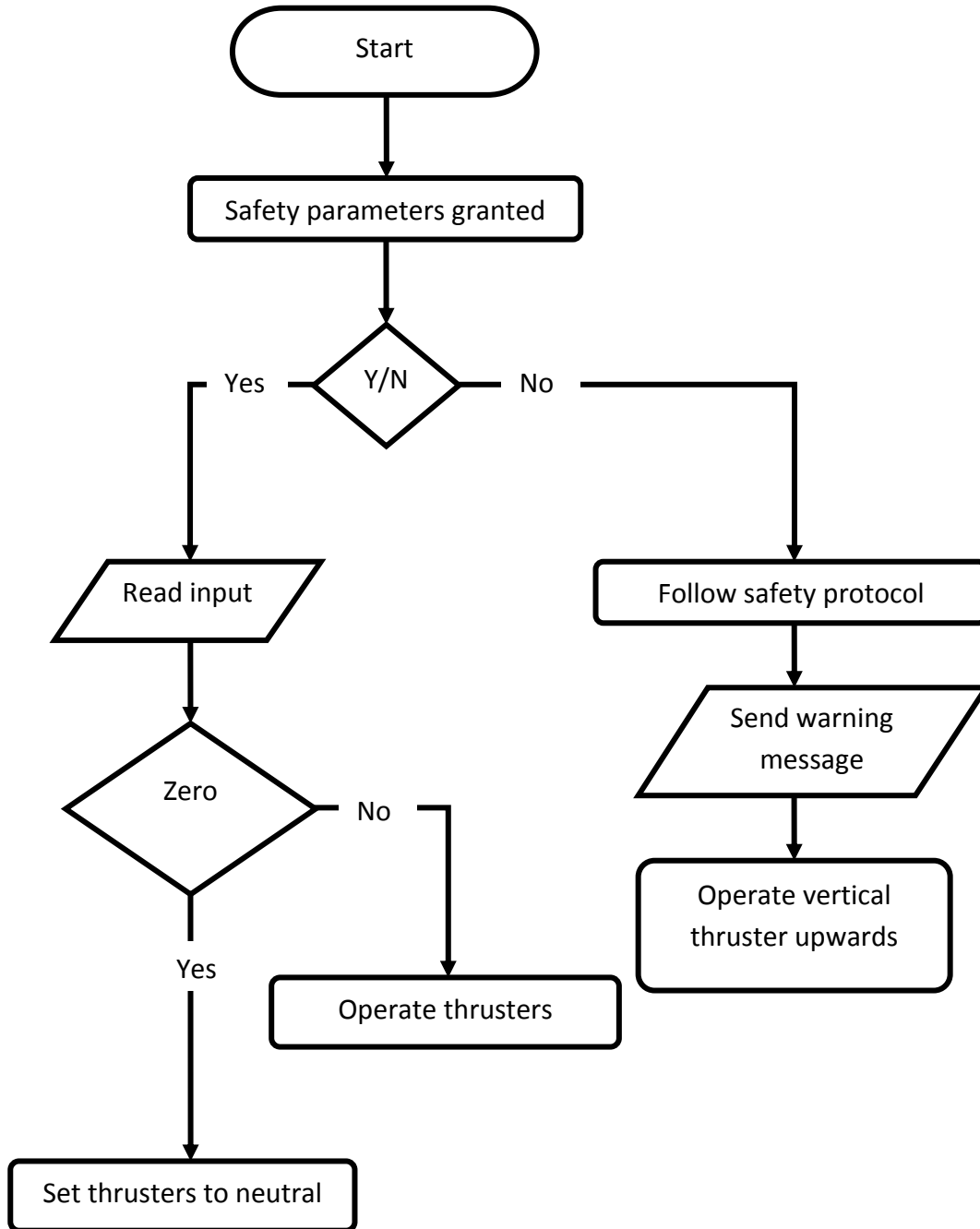
BUDGET

CARIBBEAN ROV component cost				
Category	Component	Price	Quantity	Sponsor
Contest	Registration	170\$		None
Mechanical	EM 54 trolling motor	180\$	1	Mechanism
	Bilge pumps	45\$	4	Alex.univ
	Propellers	1.5\$	4	Mechanism
	CLPE sheet 1x1 m ²	60\$	1	Mechanism
	Fiber glass + machining	20\$	1	Alex.univ
	mechanical extras	35\$	1	Mechanism
	Foam sheet 45x45 cm ²	2\$	1	Mechanism
	CNC cutting	20\$		Mechanism
	Machining	40\$		Alexfert
	Water isolation	30\$		Alexfert
	Aluminum	20\$		Mechanism
	3M joints and material	55\$		Alex.univ
	DC motor + modifications	80\$		Alexfert
	Pressure hull + machining	85\$	1	Alexfert
Electronic	Dc converter 12v/5v	30\$	3	Mechanism
	Isolated light	20\$	1	Alexfert
	Power cable 20m	25\$	1	Alex.univ
	Multi terminal cable 20m	35\$	1	Alex.univ
	Motor driver 10A	7\$	4	Mechanism
	Motor driver 30A	15\$	1	Mechanism
	AT Mega 2560 microcontroller	45\$	1	Mechanism
	Waterproof camera	15\$	6	Alexfert
	Wire connectors and plugs	45\$	1	Alex.univ
	Electronic components and sensors	140\$		Alex.univ
Travel	American visa	160\$	8	Self fund
	Tickets to Detroit	1000\$	10	AMOC
	Reserving hotel rooms	50\$	5	Self fund
	ROV shipping	580\$		Self fund
Total travel budget		12110\$		
Total budget		13626\$		

APPENDICES

APPENDIX A | SOFTWARE FLOW CHART





APPENDIX C | SYSTEM INTERCONNECTION DIAGRAM

