Eastern Edge Robotics

Memorial University, St. John's, Newfoundland and Labrador, Canada
Technical Report

MATE International ROV Competition 2012, Explorer Class

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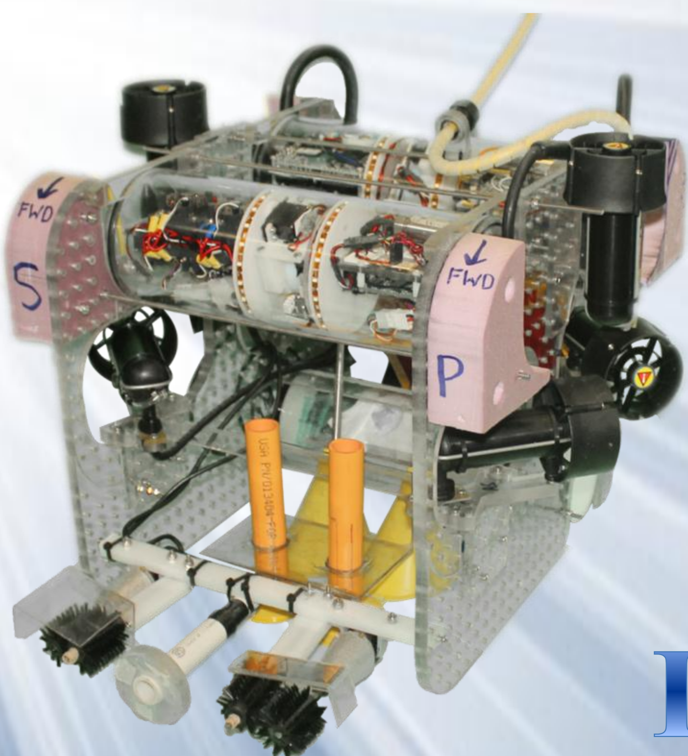

ROCK LOBSTER

ABSTRACT

This technical report describes *ROCK LOBSTER*, otherwise known as the Revolutionary Oil and Coral Kollecting, Length Observing, Bi-directional Spar-Toting Eco ROV. Constructed by Eastern Edge Robotics as a deliverable for the 2012 MATE International ROV competition, *ROCK LOBSTER* was designed to perform tasks relevant to the investigation and retrieval of oil from World War II shipwrecks. Two waterproof, clear acrylic cans containing the ROV's electronics and two Lexan™ skids form the basis of the chassis. The ROV integrates six 28V brushless thrusters and three high resolution, low-light cameras. Also incorporated are six main payload tools to accomplish the challenging mission tasks set forth by the client, the Marine Advanced Technology Education Center. The control system, programmed in C#, is based on a client-server model and implements a proprietary three-tiered architecture. *ROCK LOBSTER* has onboard electronics connected through a custom-built tether to the topsides electronics, which consists of an embedded computer system controlled by a joystick. A major innovation this year was the development of a detachable tooling skid to house the extensive payload tools. During this process, company team members learned essential technical skills and utilized "outside-the-box" brainstorming techniques to ensure a quality end product. The design and fabrication of the ROV and traveling to the MATE Competition cost approximately $35,000 this year, not including the value of donated and reused materials.

Figure 1. Eastern Edge Robotics, 2012.
Photo Location: WWII Gun Battery, Fort Cape Spear, Newfoundland and Labrador, Canada
(The most easterly point in North America)

From left to right: *Kyle Doody, Bethany Randell, Brian Aylward, Petros Mathioudakis, Stephen Jeffers, Adam Wetmore, Chris Finn, Kourtney Duff, Ian Veinott, Jacob Parsons, Mark Flynn, Dan Ryan, Justin Higdon, Jon Watson*
(Missing from photograph: Brian Peach, Kaitlin Quinlan)

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1. BUDGET AND FINANCIAL STATEMENT

(All values are in $CAD)

Items	Donations	Expenditures	Re-Used	Actual
Electronics (on ROV)		1575	550	1025
Electronics (topside)		3120	2100	1020
Hardware		750		750
Thrusters		10500	9000	1500
Tether - Leoni Elocab	1800		1800	0
Cameras (3)		540	540	0
Analog Input Board		150	150	0
Servo Controller Board		180		180
Fiber Optic Multiplexer (Moog)	3500		3500	0
Lexan & HDPE Sheets		1200	250	950
Miscellaneous Electronics Parts		850		850
Pressure Sensor - Keller America	475		575	0
Digital Compass		140		140
SubConn® Connectors	450		450	0
Printing		450		450
Group Airfare (18 * $896)		16128		16128
Van Rentals (3 * $450)		1350		1350
Accomodations		10560		10560
Team Shirts		180		180
Total	**$6,225.00**	**$47,673.00**	**$18,915.00**	**$35,083.00**

Table 1: Total cost of materials and travel to competition.

Contributors	
Faculty of Engineering	8,000
Faculty of Science	1,000
Marine Institute	5,000
Government / Industry	20,000
Student Contributions	4,500
Newly Donated Materials	0
Total	**$38,500.00**

Table 2: Contributions to Eastern Edge Robotics.

2. DESIGN RATIONALE

The central focus for *ROCK LOBSTER's* design was to accommodate the many tools required for mission tasks. This includes the standard requirements for speed, stability, maneuverability and vision, while maintaining a compact frame. This year's mission also entails the challenges of:

- precision movement and holding position
- performance of an assortment of different tasks

Consequently, the design rationale this year focused on:

- an ROV design which was compact and streamlined, with minimal protrusions to catch on objects within the working environment
- complete vision in the vertical plane to permit situational awareness and effective viewing of the mission tasks during performance
- compact, effective and multi-purpose tools to fit in the limited space of the frame
- an effective software implementation to handle the complexity of onboard systems (see flow chat, Appendix B)

2.1 Structural Frame

The chassis of *ROCK LOBSTER* was designed and modeled using SolidWorks™ 3D CAD software to allow the ROV to operate bi-directionally. It is comprised of two main component groups: the structural skids and electronics canisters.

The skids are constructed from 1.27cm Lexan™ polycarbonate and feature a 2cm spaced square grid pattern of holes. This design allows the chassis to be functionally adaptable: it offers flexibility for the attachment and rearrangement of tools and thrusters.

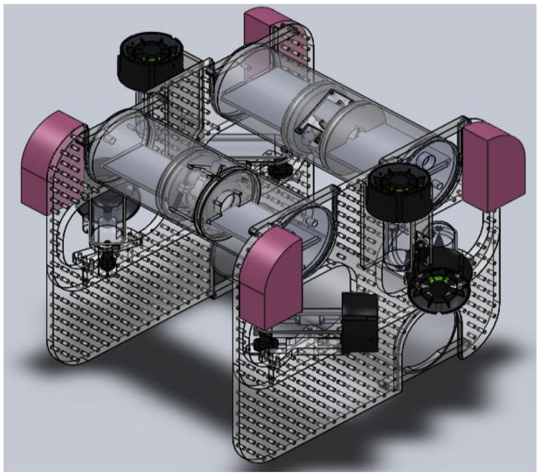

Figure 2. SolidWorks diagram of *ROCK LOBSTER* without payload

In addition, the ROV is equipped with secondary tooling skids attached below the main skids. The tooling skids provide quick connect/disconnect capabilities for multiple tooling packages to suit a variety of tasks without affecting the main chassis. The addition of this new section lowers the ROV's overall center of gravity and provides greater stability in the sway, roll, and pitch directions.

The electronics cans are composed of two optically clear acrylic tubes. Each tube has an outside diameter of 12.7cm and is sealed by O-rings incorporated into 1.27cm Lexan™ end caps. The cans have been successfully pressure tested to 2 atmospheres in the Marine Institute's pressure vessel. They are used to house the motor control and electronic components and distribute power to the tools and thrusters as required. The electronics canisters are mounted in the upper portion of the ROV to provide additional buoyancy and allow the cameras within the cans the maximum field of view.

2.2 Propulsion

ROCK LOBSTER is driven by six 280 watt SeaBotix™ HPDC1502 brushless thrusters, purchased from the manufacturer. The thrusters are pressure compensated and are rated to depths in excess of 1000m. The SeaBotix™ proprietary 4 pin connectors are accommodated by custom molded wiring harnesses. The thrusters have embedded microcontrollers which communicate using an Inter-Integrated Circuit (I2C) bus. The primary function of the microcontrollers is to control the speed of the motors by varying the rotating magnetic fields surrounding the armature of the motor. They also provide feedback from the thrusters through the use of included sensors. The thrusters are configured to provide the ROV with five degrees of freedom (surge, heave, sway, roll and yaw). Each skid of the chassis supports one vertical thruster that is centrally mounted and two horizontal thrusters that are mounted at a selectable 30°, 45°, or 60° from the longitudinal direction.

Figure 3. *SeaBotix™* thruster

2.3 Cameras

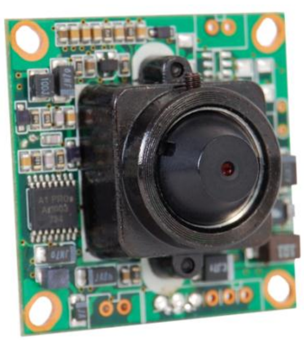

Figure 4. Super Circuits Camera

ROCK LOBSTER is equipped with two Super Circuits PC823UXP high resolution (460 TVL), low light (0.5 Lux) pinhole cameras. Each camera has a 0.85cm color CCD and provides a 90° horizontal field of view in water. One camera is located in the center of each of the electronics cans. The OPTICS (Onboard PlaneTary Illuminated Camera System) uses a set of spur gears, powered by a servo motor, to rotate the cameras and is capable of providing a full 360° field of view in the vertical plane. The ROV is also equipped with an Inuktun Crystal Cam high resolution (400 TVL), low light (1.0 Lux), 0.64cm color CCD camera. It is externally mounted on the chassis, opposite the oil collection tool, which provides an unobstructed view of the tool during mission execution.

2.4 Safety Procedures and Precautions

Safety was a major concern of Eastern Edge Robotics throughout the whole process of design, building, development and testing of the ROV. Team members received training from mentors in workshop safety for shop operations, procedures and power tool use.

The ROV *ROCK LOBSTER* has a number of safety features, including:

- over-current protection and kill switch for emergency stoppage
- completely shrouded thrusters to prevent accidental injury
- rounding and removal of all sharp edges
- temperature and humidity sensors inside the onboard electronics cans to forewarn of overheating or leakages
- electrical isolation of the high power motor components and the low voltage electronic components
- secure tether attachment and strain relief to avoid breakage or damage
- warning signs located near moving components and electrical hazards

Operational precautions include:

- careful stowage, deployment and management of the tether during mission operations to avoid tripping
- a protocol in the pre-dive check operations which requires power off, except when "All-clear" is designated by the deck manager
- life jackets required for all deck crew during testing
- training and practice in safety protocols

3. CONTROL SYSTEMS

Eastern Edge Robotics has developed a proprietary control system for *ROCK LOBSTER*; using Microsoft's .NET framework and the C# object oriented programming language, a client-server interface is setup using the Windows Communication Foundation framework. This framework enforces a strict three-tier object oriented architecture design with the device libraries and application logic acting as the server and user interface becoming the client.

3.1 Libraries

The design of the control system facilitated the development of a library of objects that can be used with any ROV built by Eastern Edge Robotics. This allows for an easily modifiable and customizable system in which library objects are considered immutable. Currently, the architecture has two independent libraries: a device library (sensors, accelerometer, motor controllers, etc.) and a logic library (User Interface and Application level). Any device can be interchanged to give the ROV different functionality based on available hardware. Immutable device objects allow the developer to use the pre-made building blocks (objects), instead of writing and modifying code for each ROV. Coupling this architecture with rigorous unit testing ensures that these elements are bug-free and stable. This reduces debug time by limiting possible problems to a particular new code section.

An important feature of the architecture is that all the device objects are designed to operate with input/output in the range of ±1000. This means that from the developer's perspective, the signal being sent to any device will always produce maximum input/output of +1000, and minimum input/output of -1000. The values get translated onto the range of the given device such that when given a value between ±1000, the value sent to the device is in the true range. This common value set not only makes it easier to pass information around, but it also makes device communication easier. The output of one device can be tied directly to the input of another. A ±1000 resolution significantly exceeds human precision while providing sufficient range to prevent rounding errors when performing floating-point arithmetic. The abstraction of devices as objects makes them universal for implementation on any ROV, thus allowing the software to be easily modified to operate a different vehicle system.

Another crucial addition made to the logic library for this ROV is the auto depth object. The object samples as input the current depth from the depth sensor object and a desired depth from the user interface layer and produces thrust values for the vertical thrusters. Using a proportional integral controller (PI controller), the thruster output values are able to be continuously updated to maintain the desired depth when enabled.

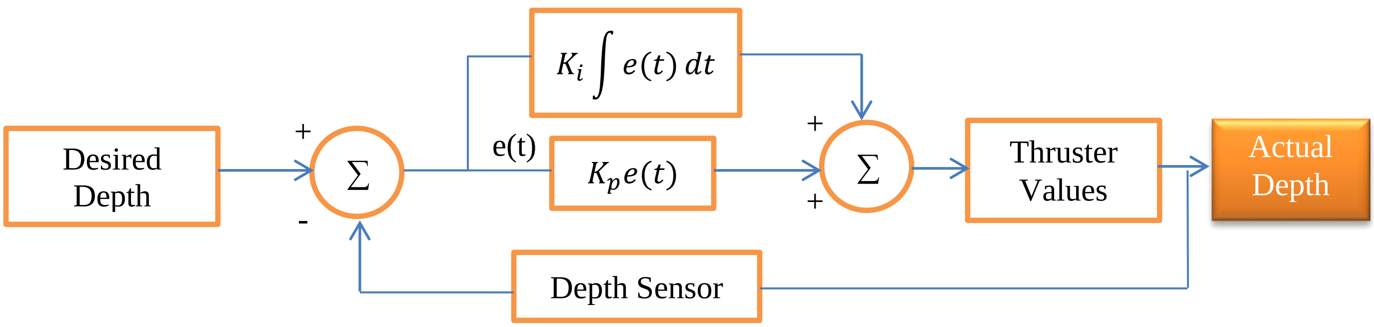

Figure 5. PI Algorithm

The object runs continuously in the main thread since it requires direct interaction with the thrusters. The algorithm works by taking the desired depth and the reading from the depth sensor to produce an error value. The error is then integrated over time and multiplied by the integral K_i value as well as being multiplied by the proportional K_p value. While the ROV is sitting below the desired depth, the values output are positive and cause the ROV to rise and vice versa. The integration portion of the algorithm eliminates steady state errors. The algorithm produces equilibrium control value that holds the ROV at the desired depth. Through manual tuning method, the company produced the constant K values used in the PI controller algorithm.

3.2 Application Layer

An implementation of a particular ROV is accomplished by writing new logical connections between the building blocks. These logical connections operate with a given minimum set of functions, which can be used by any other component (User Interface, Logic Connection, Device collection). This allows for greater flexibility; the user interface (UI) from a previous ROV can be used on the current ROV. The application layer becomes the control software for the ROV, a compilation of the necessary objects from the libraries. Mixing and matching components in the system allows for developers to build a large testing UI, which can be used for various tasks during the development. Windows Communication Foundation (WCF) provides the framework for this communication between the UI and application layer allowing for the control software (application/server layer) to run on a computer connected to the ROV, while having the UI (user interface/client layer) to operate on a remote machine.

3.3 Graphical User Interface

The graphical user interface (GUI) is based on a windowed concept. It allows the pilot and co-pilot to section off the GUI into manageable windows that can be opened or closed as needed. The GUI is split into six windows: main operations, ROV navigation, thruster power control, telemetry, lighting control and video feeds. The GUI communicates with the ROV system through the topsides computer service by sending and receiving a series of serialized objects. This allows the control system and interface to remain separate from each other, which means multiple interfaces could exist based on operating specifications. Building on previous iterations of this interface, the video feeds from the ROV are directly interfaced. The tilt of the cameras is controlled by servos and the video image is automatically flipped and mirrored at predetermined angles, saving the time it would take the pilot to manually reconfigure the image.

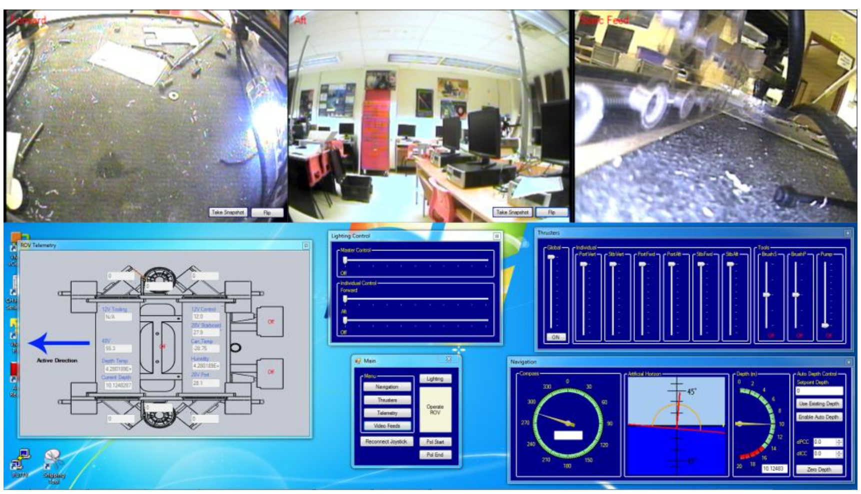

Figure 6. Graphical User Interface

4. ELECTRONICS

The electronics system has four key components: the topside control unit, the tether, the submarine vehicle control can, and the submarine payload control can. See Appendix A for the electrical schematics of these components.

4.1 Topside Control Unit

Figure 7. Topside Control Unit

The topside control unit provides electrical protection as well as communication to the ROV. From the main 48 volt DC input, power is routed through a 20 amp circuit breaker, through custom built voltage and current meters, and then to the ROV. The topsides controller contains a purpose-built computer based on a µATX form factor motherboard. This computer has 16GB of RAM, a six-core CPU, a 32GB solid-state drive (SSD), and a 500GB hard disk drive (HDD). This provides plenty of control and video processing capability for the ROV system. Additionally, the computer's DVI output allows for connection to a high definition monitor (1920x1080P), which displays the ROVs GUI and video feeds. These feeds are captured using an Adlink 4-port video input card. Also, a B&B Electronics 8-port RS-232/422/485 serial interface card is used for data communications to the ROV. Both of these cards are connected to the topsides Model 907 video/data multiplexer unit from Focal Technologies™. This unit provides communication to the ROV over a single fiber strand. The six serial data channels (2x RS-485, 4x RS-232) on the multiplexer are connected to the serial interface card and the three video channels are connected to the video input card. The topside computer is powered from a standard 120 Volt ATX power supply and communicates to the ROV only through fiber optics. This electrically isolates the topsides control unit from the ROV itself, providing additional safety for both the operators and the sensitive electronics in the topsides computer.

4.2 Tether

Figure 8. Custom-designed Tether

A custom tether was donated to Eastern Edge Robotics by Leoni Elocab Inc. of Kitchener, Ontario, Canada. It was designed to be neutrally buoyant in fresh water, with an outer jacket coating of low drag polyurethane. The tether has two 16-gauge copper wires to carry DC power, and two multi-mode fiber optic strands for control and video signal transmission. One of the fiber optic strands is redundant and is reserved for use in the event of failure or damage to the primary strand. The tether is terminated on the topsides end inside a protective tube with a quick disconnect Speakon™ type electrical connector and ST type optical connectors. On the submarine end, the tether is carried into the communications can by a right-angle brass penetrator, custom-machined by Eastern Edge Robotics. It is terminated inside the Submarine Vehicle Control Can electrically with ring terminals, and optically with two ST connectors.

4.3 Submarine Vehicle Control Can (SVCC)

The Submarine Vehicle Control Can (SVCC) houses all electronics necessary to the operation of the ROV platform, providing communications to the surface and control of the thrusters. Four Subconn® low profile multi-pin bulkhead connectors provide electrical connections to the outside as well as the Submarine Payload Control Can (SPCC). Inside the can, multiple devices provide voltage conversion, communications to the surface, thruster control and data acquisition. For voltage conversion, two 28 volt output and one 12 volt output DC-DC converter reduce the 48 volt main rail input voltage down to 28V for the port and starboard thrusters and 12 volts for control electronics, cameras, and lighting. The converters are rated for an input voltage of up to 75 volts, and 25 and 10 amps output current, respectively. Communications and video are facilitated by the remote unit of the Model 907 multiplexer which serves as a connection point for the four RS-232 and one RS-485 bus on the ROV, as well as the three cameras. To communicate with the embedded microcontrollers of the thrusters, an RS-232 to I2C bus converter is used. This was custom designed by the team and is based on a PIC18F1320 microcontroller. It connects to the multiplexer via a RS-232 bus and provides six individual I2C outputs which connect to the six thrusters. A Pololu Maestro 6-channel servo controller, which receives a RS-232 signal, is used to control a servo motor that tilts the onboard camera. Finally, a B&B Electronics 232SDA12 A/D Converter provides data acquisition. It communicates via a RS-232 bus and has 12-bit resolution over a 0 to 5 volt range for each of its 11 inputs. Voltage, pressure, humidity and temperature sensors are connected to these inputs.

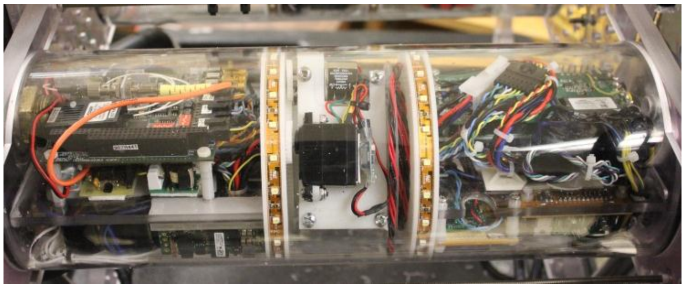

Figure 9. SVCC

4.4 Submarine Payload Control Can (SPCC)

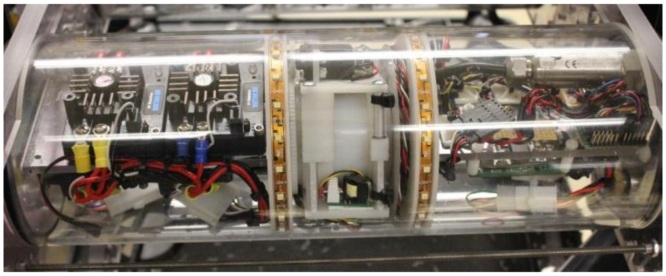

Figure 10. SPCC

The submarine payload control electronics are housed in a can of the same design as the SVCC (Figure 9). It is linked to the SVCC using a single 9-pin connector, which supplies both power and communications. The can controls the entire payload tooling onboard the ROV, and has been designed to accommodate current and future tooling. A DC-DC converter is used to reduce the main rail voltage to 12 volts, with the ability to provide 13 amps of current to the onboard tooling. One Pololu Maestro 12-channel servo controller receives a RS-232 connection from the SVCC which outputs twelve pulse width modulated signals. Four of these signals are fed to IFI Robotics Victor™ HV pulse width modulators (PWMs), which in turn provide bi-directional variable control to 12V tooling motors. Three more of these signals are fed to external servo motors through the external servo connector while another signal is fed to the servo motor that tilts the second onboard camera.

4.5 Lighting

Located in both the SVCC and SPCC, four 360 degree white LED arrays (two in each can) provide illumination of the ROV work area. Both arrays in each can are individually driven by a Pololu Qik 2s9v1 two-channel motor controller. Connected via a RS-232 bus, this controller allows each light array to be dimmed separately.

Figure 11. LED Arrays

4.6 Sensors & Telemetry

4.6.1 Voltages

Voltages are monitored to ensure the output from the onboard power supplies are within an acceptable range. Voltage dividers measure the 48V main supply, both the port and starboard 28V power supplies, the control and communications 12V supply, and the 12V tooling supply. Each is sampled by the 232SDA12 and displayed on the GUI.

4.6.2 Temperature Sensors

A Microchip™ TC1047A sensor, capable of recording temperatures from -40°C to +125°C, monitors the internal temperature of the SVCC. Additionally, three TMP36 sensors monitor the heat sink temperature of the onboard power supplies. The output of these sensors is sampled by the 232SDA12 and displayed on the GUI. This allows the operator to monitor temperature and shutdown or reduce demand on the ROV in the event that overheating occurs.

4.6.3 Humidity Sensor

A Honeywell HIH-4030 sensor, capable of recording humidity levels from 5% to 95% rH, monitors the relative humidity inside the can in order to inform the operator of the potential for condensation build-up. Its output is sampled by the 232SDA12 and displayed on the GUI. This sensor is supplied by nominal 5V, draws 200 µA, and provides a nearly linear output curve relating voltage to humidity.

4.6.4 Internal Pressure Sensor

In order to detect leaks in the SVCC, a Honeywell NSCDANN030PAUNV pressure transducer monitors the internal pressure. The transducer, referenced to a vacuum and configured with a full range of 206kPa, is monitored by the 232SDA12 and displayed on the GUI. During normal operation, the pressure inside the SVCC is constant at 1 atmosphere (~100 kPa). In the event that there is a leak in the can, the pressure will rise towards the pressure at the current depth. Thus, a threshold alarm is set on the monitored pressure to alert the operator of a leak.

4.6.5 External Pressure Sensor

A Preciseline™ pressure transducer from Keller America is used to measure both water depth and temperature. It communicates using a RS-485 bus and has a measurement opening that is threaded into a hole in one of the end caps of the SPCC. To measure pressure, the transducer has a floating isolated piezo-resistive sensor, which gives ± 0.1% accuracy and 16-bit internal digital error correction. The transducer can measure water depths up to 20m, as it is referenced to a vacuum and configured with a full range of 300kPa. In software, this pressure reading is converted into depth, taking into account the configurable water density and current atmospheric pressure. This measurement acts as feedback to an auto-depth function featured in the control system and is also displayed on the GUI.

4.6.6 Gyro

Located in the SVCC, the ROVs gyroscope is a UM6 from CH Robotics™. This instrument is actually three triple-axis sensors in one: an accelerometer, a gyroscope, and a compass. The outputs from these three sensors are processed by an internal microprocessor to provide pitch, roll and yaw and are polled via a RS-232 bus by the control software. The use of three sensors in one instrument prevents an anomaly in one sensor, such as a time-varying magnetic field generated by the thrusters, from disrupting the entire output. The output is viewed graphically on screen for ease of readability. The gyro was tested to ensure the varying magnetic fields caused by the thrusters did not disrupt its function, providing these fields existed for a short time interval. For this reason, the thrusters only need to stop momentarily to increase the accuracy of the reading required for Task 1.

5. PAYLOAD TOOLS

5.1 <u>Task #1</u>: Survey the wreck site

5.1.1 - Measure the length of the wreck – Measuring Device

Figure 12. Measuring Device

This tool is designed to accurately measure the length of the shipwreck. Composed of a stainless steel measuring tape and a Lexan™ claw, the measuring device operates by hooking the claw to the bow of the shipwreck and having the ROV move towards the stern. This movement pulls out the tape so the precise measurement may be read through one of the onboard cameras. The use of a stainless steel tape prevents the tool from corroding in water.

5.1.2 – Determining the orientation of the ship on the seafloor – Accelerometer

The gyro can determine the orientation of the shipwreck. In order to actualize this, the ROV aligns itself with the shipwreck and receives a heading from the gyro which is displayed on the GUI.

5.1.3 - Determining if debris piles are metal or non-metal – Magnetic Spring Assembly

A magnet is used to determine if the debris piles are metallic or non-metallic. The magnet is held within a small metal cup suspended by four loose springs. The springs are pulled taut and attached to the tooling skid. As the ROV flies over a ferromagnetic debris pile, the cup will become attracted to it and a visible disturbance in the springs will indicate successful observation.

Figure 13. Magnetic Spring Assembly

5.2 <u>Task #2</u>: Removing fuel oil from the shipwreck

5.2.1 - Transporting and attaching a lift bag to a fallen mast / Inflating the lift bag and removing the fallen mast from the worksite – Hook, Line, and Floater System

Figure 14. Hook, Line, and Floater System

The Eastern Edge Robotics' solution to the task of repositioning the fallen mast consists of a system of multiple devices. At the core of the system is a 25 pound capacity inflatable lift bag modified with Velcro™ strips, allowing for the bag to be kept in a folded position when not inflated. Attached to the lift bag is a reel apparatus. Constructed primarily of polycarbonate and HDPE, the reel is designed to spool out high strength fishing line as the ROV descends. When the bag becomes inflated, a cotter pin snaps into place and secures the line such that no more can be paid out. The line is attached to the ROV via a dual purpose release and latch mechanism, which allows the entire system to attach to the mast and be released from the ROV.

The most complicated component to this system is the release and latching tool located onboard the ROV. This portion of this system must perform two tasks, attach itself to the mast and release itself from an extension arm on the tooling skid. The forward portion contains a latching mechanism which tapers into a narrow "U" shape with a toggle bolt affixed to the end to act as a one way gate. This arrangement is used to lock onto the mast's U-bolt. The rear of the latch extends into the coupling portion and locks into place with two toggle bolts snapped into notches in the extension. A sliding trigger is positioned such that the U-bolt entering the latch pushes the slide back. This action locks it into place with a fourth toggle-bolt, pushing and holding the other bolts open, releasing them from the notches. This allows the entire system to disconnect from the ROV.

Figure 15. Release/Latching Tool

The task is completed by suspending the lift bag and reel mechanism 60cm from the surface via a flotation buoy. As the ROV descends towards the wreck, line is paid out and tensioned in a way to only pay out during descent but not with lateral movement. This ensures that the minimum amount of line is used while keeping the entire system positioned directly above the mast. Once the ROV reaches the wreck and position itself in front of the mast, the ROV drives forward, latching itself to the U-bolt. The reverse motion releases the mechanism from the extension arm, detaching the entire system from the ROV. Using a MATE supplied air compressor, the lift bag is inflated, separating the Velcro strips and allowing the bag to unfold. The entire system is then lifted the 60cm distance between the lift bag and flotation buoy thus suspending the mast in the water. The ROV can then push the entire assembly into position, whereupon a tee valve on the air line is opened allowing the lift bag to deflate, lowering the mast into the target area and allowing the ROV to move on to the next task.

5.2.2 - Removing and transplanting endangered encrusting coral from the ship – Coral 'Kollector'

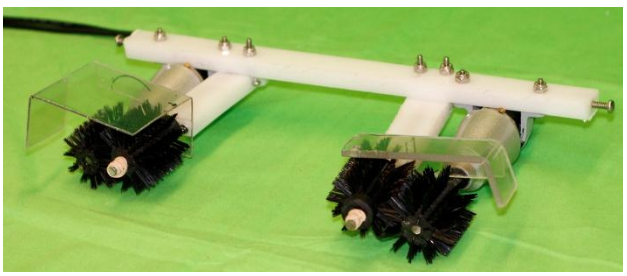

Figure 16. The Coral 'Kollector'

Mounted on a piece of HDPE, two bilge pump motors are attached to the gearheads of two electric screwdrivers. These are connected to half of a standard round hairbrush. One brush is activated using a motor, and the adjacent brush is activated using friction. Both brush devices are operated independently to collect the coral samples one at a time. The direction of the brushes is reversed to deposit the coral in a free grid square.

5.2.3 - Simulating drilling two holes into the hull and underlying fuel tank by penetrating a layer of petroleum jelly / Removing fuel oil from within the tank and replacing it with simulated seawater – Oil Retrieval System

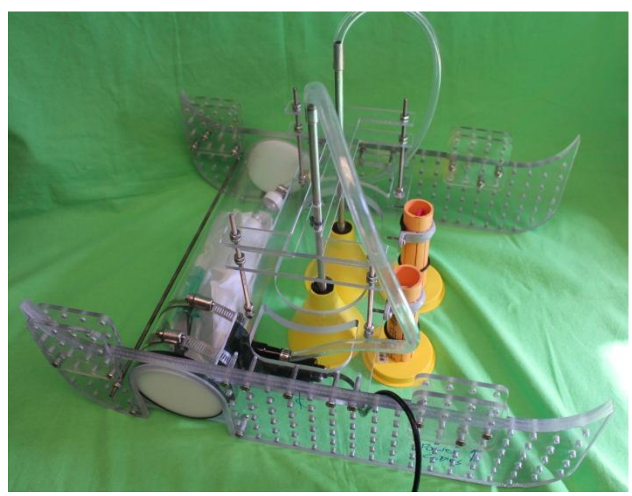

Figure 17. Oil Retrieval System in Tooling Skid

To accomplish the retrieval of oil, a collection bag is located within a cylindrical container placed on the tooling skid, which holds seawater required for the task. Two sets of stainless steel tubing are located within a mounting bracket. These are designed to be telescopic in nature, with a smaller tube located inside an outer sheath tube. The heads of the tubes are encased by funnel-like shells which guide the tubes into the inflow and outflow ports of the oil tank. A tapered spearhead at the end of the tubes is used to penetrate the petroleum jelly. Once the guidance funnels make contact with the tank inlets, petroleum jelly within the shells creates a water-tight seal. The force of the ROV pushes the inner tube through the outer sheath, and into the tank. Access holes are exposed once the jelly has been penetrated. The stainless-steel penetrators run into plastic tubing and then into a bilge pump which uses displacement to pump seawater from the onboard tank while simultaneously forcing oil into a collector bag. This system has the capacity to remove up to 2.5 liters of liquid, which is sufficient for the task.

Once all of the oil is removed and replaced with seawater, the ROV pulls away. The spearhead ends make contact with the outer sheath, closing the access holes, sealing the entire system and thus ensuring no liquid is lost during the extraction process.

5.2.4 - Resealing the drill holes with a simulated magnetic patch – The Capper

The MATE-provided simulated magnetic patches are contained within two 17.5cm long 1" PVC pipes mounted to a Lexan™ L-bracket. These pipes are crafted with 10cm slits at their base, creating 8 chamfered tabs. An O-ring is positioned half-way along the PVC pipe to produce a friction-fit placement for the patches. Once lowered onto the drilled holes, the Velcro patches simulate a magnetic attraction. The upward force of the ROV releases the caps from their holders and securely seals the oil tank openings.

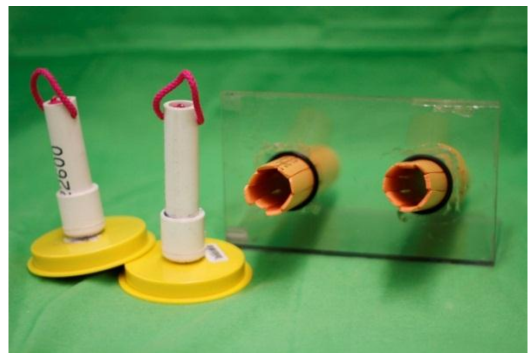

Figure 18. The Capper

6. CHALLENGES

6.1 Technical Challenge

The structural frame of *ROCK LOBSTER* utilizes previous years' chassis, but is modified to accommodate the new mission requirements. In order to create a fully functional ROV capable of precise movement and to house multiple tools to accomplish the tasks provided, placement of components must be considered. After completion of the prototype design for the entire payload, it was determined that the area available on the ROV was inadequate to fit the vast array of tools. In certain instances, spacing also had to be considered to effectively achieve visual clarity and functionality.

Eastern Edge Robotics' method to rectify this issue was to construct a tooling skid: an attached chassis that effectively holds the entire payload while preserving full manoeuvrability. The skid itself was designed in SolidWorks™ along with the already-created ROV chassis model to ensure proper attachment. Tools were then secured on the skid to ensure efficient operation for the mission tasks.

6.2 Non-Technical Challenge

The RFP set forth by the MATE Center required a significant time commitment on the part of all team members of Eastern Edge Robotics. With all of its members already committed to school, work, or volunteering duties, logistics became a challenge for the team on multiple occasions. The original plan called for meetings on Saturdays and one night per week. However, with the increasing demand to complete projects within the given time frame, a system needed to be implemented to organize the office and fabrication area so that project members could streamline efforts. Consequently, these spaces were opened to team members on any given night to coincide with their personal schedules, provided that at least two members could attend. This constraint was implemented for safety reasons.

7. TROUBLESHOOTING TECHNIQUES

Troubleshooting and testing was rigorously performed on every aspect of the ROV. A particular example of this was the new design of the submarine control cans as lighting was required to accomplish the mission objective of illuminating the wreck. Having used Pololu servo controllers elsewhere in the system, the electronics design team decided to utilize Pololu motor controllers to dim the integrated lighting as they communicated using the same serial bus and protocol (Pololu protocol). The motor controllers were purchased, but after testing an issue occurred whereby only one type of controller (either servo or motor) would work at a time on a given serial bus. Upon analysis of the documentation for each device, it was determined that although both command protocols bore the same name, they were in fact different. In particular, the start byte of each command string, used for baud-rate detection, was incompatible. As a result, the electronics team was forced to search for either a new lighting controller or new motor controller. After reviewing products from Pololu a compatible servo controller was found and promptly procured. Upon arrival, the old controllers were replaced with the new ones and a new software module was added to the device library to resolve problem.

8. FUTURE IMPROVEMENT

Future improvements that Eastern Edge Robotics is considering include:

i) A better tether management system, with hybrid fiber-optic slip rings and an improved launch and recovery system. The fiber-optic slip rings allow the tether to be put on a roll, eliminating tangling on the surface.

ii) The implementation of miniature hydraulics to mimic a Shilling™-type robotic arm. This would include a seven-axis manipulator – a versatile tool that could be used for multiple tasks. This would allow the company to remain with industry standards, cutting down on tool design time and increasing mission success rate.

9. LESSONS LEARNED

9.1 Technical Lesson Learned

For the sake of reducing mission time, an idea was presented to utilize a non-mechanical method of measuring the shipwreck and its orientation. Beginning with the use of trigonometry and identities, the concept of employing a mathematical function to determine length was tabled.

By flying over the shipwreck, the idea of using the binocular camera setup and "retinal disparity" to image the ship was the next consideration. After some derivations and research, it was concluded that if the distance to the shipwreck from the ROV was known, an application of stereographic mapping would provide coordinates that could be used to determine the ships length.
The mapping for stereographic projections is shown below:

$$(x, y, z) \rightarrow \left(\frac{2X}{1+X^2+Y^2}, \frac{2Y}{1+X^2+Y^2}, \frac{-1+X^2+Y^2}{1+X^2+Y^2}\right)$$

where x, y, z are the actual coordinates of the ship, while $X, Y$are the coordinates of the pixel location coordinates.

The length measurement formula was adapted from research done by Jernej Mrovlje and Damir Vrančić in their paper *Distance measuring based on stereoscopic pictures*, published for the 9th International PhD Workshop on Systems and Control: Young Generation Viewpoint. Using a flat lens camera arrangement, a formula was derived using trigonometry ratios that would provide distance from an object. Confirming their derivation through mathematical workings, the formula to measure distance is given below:

$$D = \frac{Bx_0}{2tan\left(\frac{\varphi_0}{2}(x_L - x_R)\right)}$$

After rigorous testing, it was determined that the error term was excessive for the estimation. Therefore, a more simplistic approach of using a mechanical measurement tool to determine the length of the shipwreck was adopted. If time had allowed it may have been possible to reduce the error.

9.2 Interpersonal Lesson Learned

One of the major concerns this year stemmed from the realization that senior members would not be around forever. The senior employees of Eastern Edge Robotics naturally have more experience with completing some of the technically complex tasks. They also possess crucial knowledge when it comes to the understanding and operation of tools, computer systems and electronic components. Since almost all parts of the ROV are created in house, these skills are absolutely essential in order to achieve a fluid transition from year to year, ensuring that Eastern Edge Robotics delivers the same quality products the company is known for.

Normal operations dictate that team members focus on tasks that they feel comfortable and familiar with, but certain jobs such as ROV software, electronics, Computer-Numerical-Control machining, and workshop tools require detailed understanding. Therefore, it became evident that senior members would have to pass on their knowledge to other members of the team. Once this was realized, senior staff began to train newer staff in certain tasks and operations, so that the techniques and information could be absorbed and passed on throughout the entire company. This ensured important corporate knowledge would be preserved and would not have to be re-established within the company, taking precious time away from future projects.

10. REFLECTIONS

Figure 19. Adam and Chris working on the Reel mechanism.

"It would be a vast understatement to say that my experience with the Eastern Edge Robotics team has added value to my education. Being my first year with the group, I was amazed by the teams' knowledge and the expanse of their expertise. From engineers to mathematicians, I learned a little something from everyone. Perhaps the biggest educational gain that I will take away is the 'outside the box' approach to problem solving. It is all too easy to say 'that can't be done' but after working with some of the brightest students that Newfoundland and Labrador has to offer, no problem is too great given the proper mind frame. It's been a pleasure working and learning as a team and I look forward to the next challenge that MATE has to offer."

- Adam Wetmore, B.A.
1st Year ROV student and 1st Year member with Eastern Edge Robotics

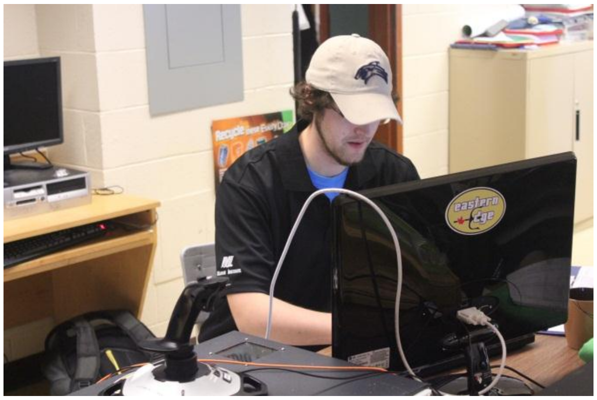

Figure 20. Jon creating the new GUI.

"My involvement in the MATE ROV competition began in 2005 as a member of the O'Donel High School Robotics team, a competitor in Newfoundland's Regional ROV Competition. Through my eight years of involvement, I have experienced the highs of winning and lows of coming home without the gold but perseverance has brought me many life skills and many of my closest friends.

I knew from a very young age that I wanted to be involved in computers and I saw this dream fulfilled this year in completing my Bachelors of

Science, majoring in computer science. I honestly believe that I don't know if I would have completed this degree if I never got involved in the MATE competition. My degree took me down many different avenues in computers including programming.

I've always enjoyed programming but what was lacking in the program was the practical application. Developing software for Eastern Edge Robotics showed me that the software I wrote could actually operate equipment deep underwater. Without this experience, it would have made my university career much more dry and unappealing. In 2008, I joined Eastern Edge Robotics as an apprentice programmer and under the guidance of the senior members, I began my career as a programmer for the team. 2008 was a winning year, taking home the gold was one of the greatest feelings I have ever felt, I was truly part of something. Since then, the company has seen much success, maybe not gold in the competition but in producing many knowledgeable employees. This year marks my final year as an employee and I can honestly say it has been an emotional one, not only because I would like to bring home gold again but because the experience will be greatly missed."

- Jonathan Watson, B. Sc., 8th and final year with Eastern Edge Robotics

11. TEAMWORK AND ORGANIZATION

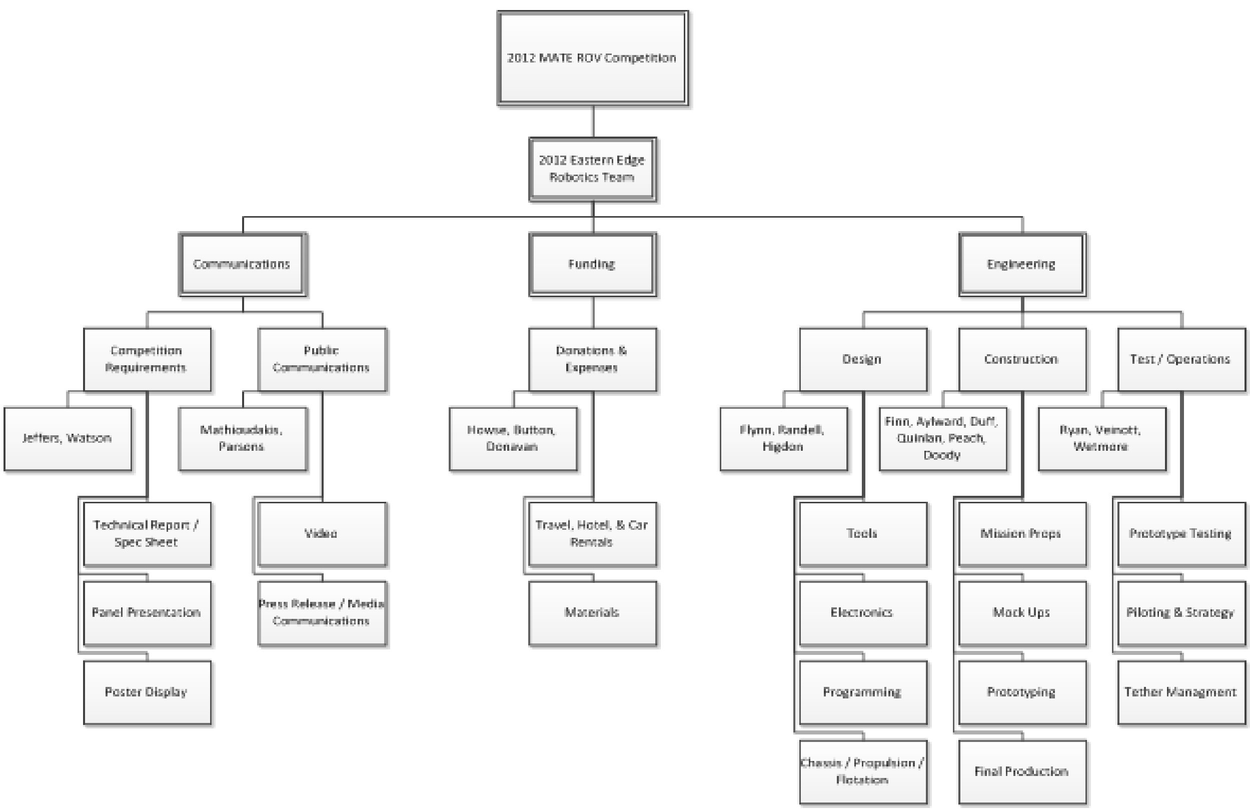

Figure 21. Eastern Edge Robotics Organizational Chart

In order to organize the company and ensure that all components of the MATE Competition were completed on time, each company member was designated to a specific role. While all members were involved in all processes (design, construction, testing, and communications), it was possible to delegate responsibility and ensure that everything would be completed on time. To aid in this goal, a chart noting each member's areas of responsibility was developed.

To aid in the scheduling process a Gantt chart was completed at the beginning of the year (Appendix C). This helped to ensure that the ROV was completed with as much time to practice before the competition as possible.

12. ACKNOWLEDGEMENTS

Eastern Edge Robotics would like to extend sincere gratitude to the following sponsors:

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- Atlantic Canada Opportunities Agency (financial assistance)
- Exxon Mobil (financial assistance)
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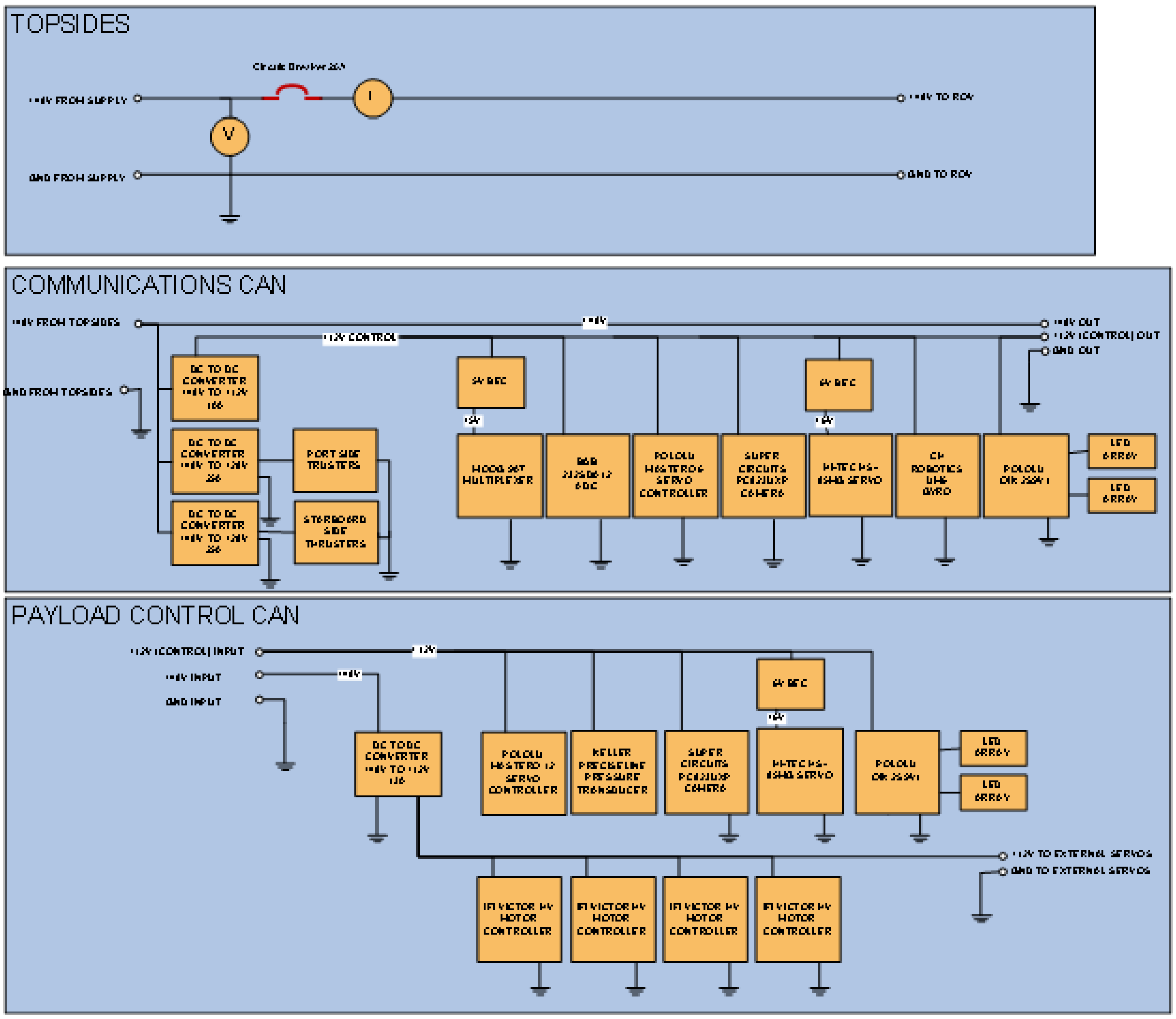
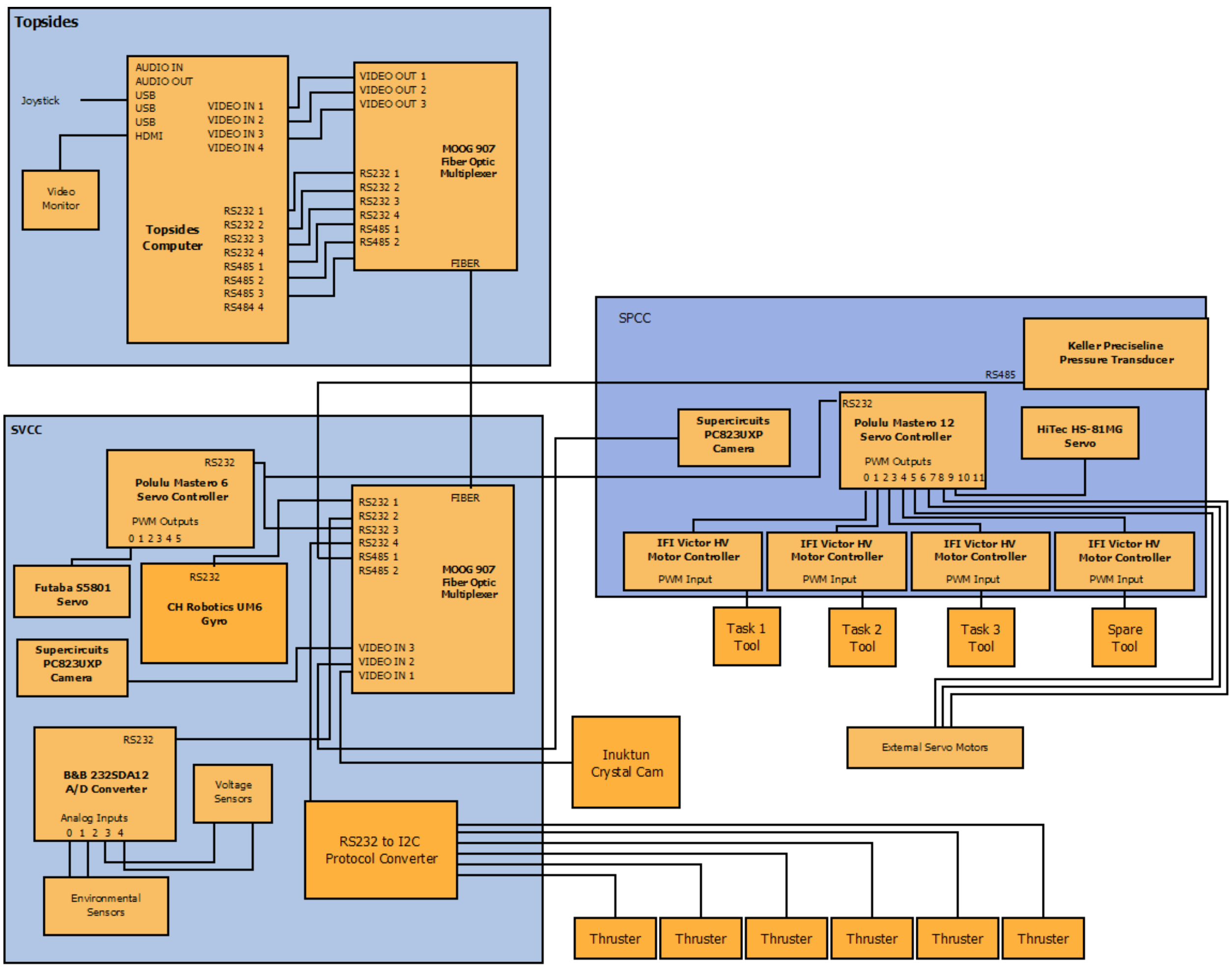
- Hibernia (financial assistance)
- Husky Energy (financial assistance)
- Imprint Specialty Promotions (donation of polo shirts)
- Keller America (donation of pressure transducer – 2005)
- Leoni Elocab (donation of custom-built tether – 2009)
- MATE Center (for providing this opportunity)
- Memorial University Faculty of Engineering, Faculty of Science, Marine Institute (financial assistance)
- National Science Foundation (financial assistance)
- O'Donel High School (use of facilities and equipment)
- Province of Newfoundland and Labrador (financial assistance)
- SubConn (donation of connectors – 2011)
- SubSea 7 (financial assistance)
- Suncor Energy (financial assistance)

Finally, a very special thanks to our mentors Clar Button, Tom Donovan, and Dwight Howse for donating so much of their time and energy to this project.

APPENDIX A – Power Distribution Schematics

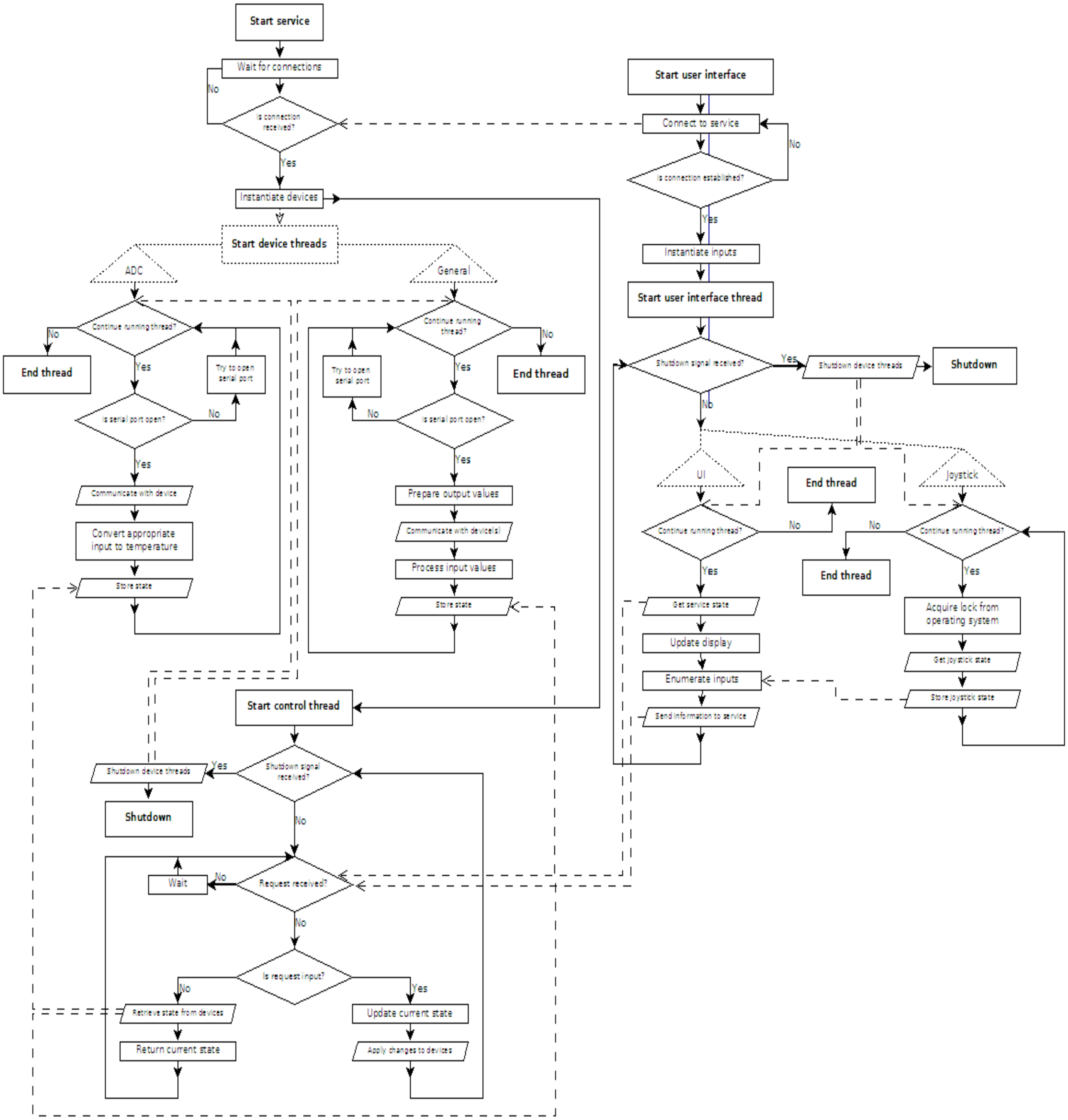


Appendix A Figure 1. Electrical Schematic

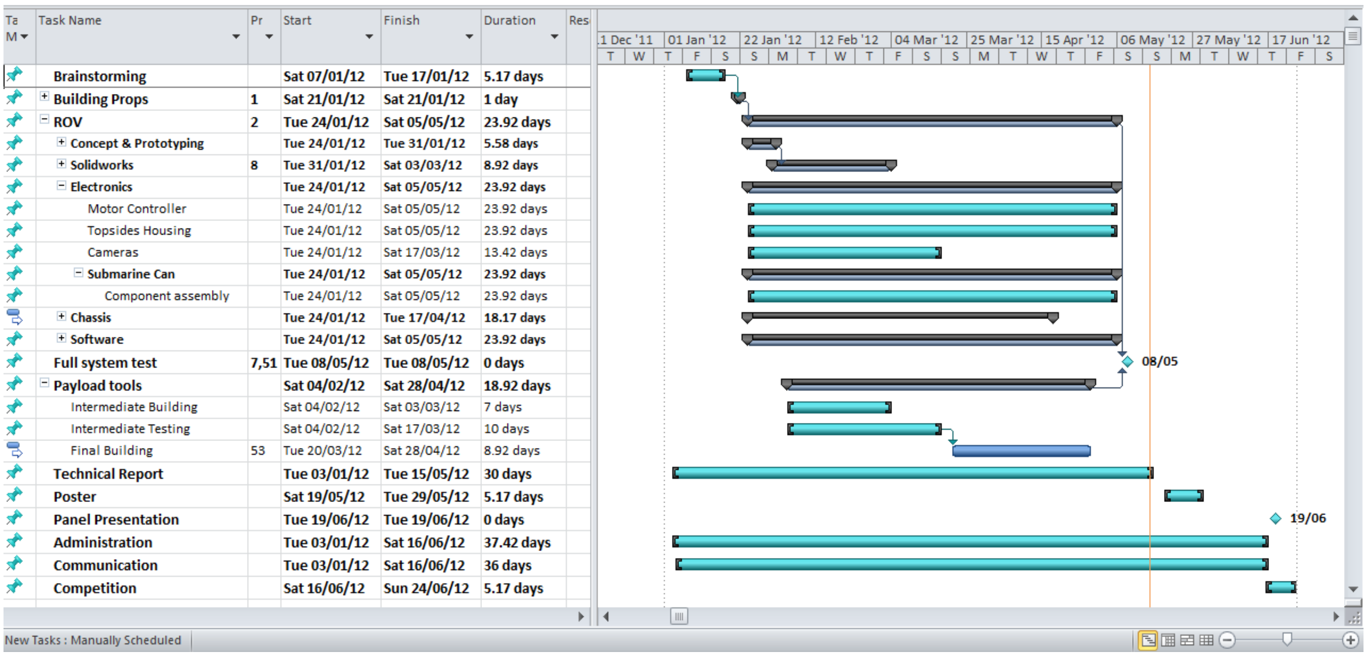


Appendix A Figure 2. Signal Flow Schematic

APPENDIX B – Programming Flowchart



APPENDIX C – Gantt Chart



Task Mode	Task Name	Predecessors	Start	Finish	Duration	Resource
	Brainstorming		Sat 07/01/12	Tue 17/01/12	5.17 days	
	Building Props	1	Sat 21/01/12	Sat 21/01/12	1 day	
	ROV	2	Tue 24/01/12	Sat 05/05/12	23.92 days	
	Concept & Prototyping		Tue 24/01/12	Tue 31/01/12	5.58 days	
	Solidworks	8	Tue 31/01/12	Sat 03/03/12	8.92 days	
	Electronics		Tue 24/01/12	Sat 05/05/12	23.92 days	
	Motor Controller		Tue 24/01/12	Sat 05/05/12	23.92 days	
	Topsides Housing		Tue 24/01/12	Sat 05/05/12	23.92 days	
	Cameras		Tue 24/01/12	Sat 17/03/12	13.42 days	
	Submarine Can		Tue 24/01/12	Sat 05/05/12	23.92 days	
	Component assembly		Tue 24/01/12	Sat 05/05/12	23.92 days	
	Chassis		Tue 24/01/12	Tue 17/04/12	18.17 days	
	Software		Tue 24/01/12	Sat 05/05/12	23.92 days	
	Full system test	7,51	Tue 08/05/12	Tue 08/05/12	0 days	
	Payload tools		Sat 04/02/12	Sat 28/04/12	18.92 days	
	Intermediate Building		Sat 04/02/12	Sat 03/03/12	7 days	
	Intermediate Testing		Sat 04/02/12	Sat 17/03/12	10 days	
	Final Building	53	Tue 20/03/12	Sat 28/04/12	8.92 days	
	Technical Report		Tue 03/01/12	Tue 15/05/12	30 days	
	Poster		Sat 19/05/12	Tue 29/05/12	5.17 days	
	Panel Presentation		Tue 19/06/12	Tue 19/06/12	0 days	
	Administration		Tue 03/01/12	Sat 16/06/12	37.42 days	
	Communication		Tue 03/01/12	Sat 16/06/12	36 days	
	Competition		Sat 16/06/12	Sun 24/06/12	5.17 days	

Figure 22. Gantt chart