eastern Edge robotics

The Power of... Innovation

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

MATE International ROV Competition 2013, Explorer Class

Technical Report

TEAM MEMBERS

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Nick Ash (Pneumatics Designer)
Krista Bennett (Pilot)
Coralie Brown (Chief Marketing & Communications Officer)
Elizabeth Chisholm (CFO)
Kyle Doody (Logistics Manager)
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Riley Edwards (Fabrication Designer)
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Verity Furlong (Safety Officer)
Christina Hamlyn (Marketing Advisor)
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Justin Higdon (CEO)
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Kaitlin Quinlan (Electrical Engineering Designer)
Bethany Randell (Chief Technology Officer, Electrical and Software)
Thomas Seary (Software Developer)
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Adam Wetmore (Research and Development Officer)
Stephen Whiffen (Tool Developer)

MENTORS

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ROCK LOBSTER

ABSTRACT

This technical report describes *ROCK LOBSTER*, the Redesigned Observatory Connecting and Kommissioning Length Obtaining Bio-unfouling Stabilizing Tool Employing ROV. Constructed by Eastern Edge Robotics as a deliverable for the 2013 Marine Advanced Technology Education (MATE) International ROV competition, *ROCK LOBSTER* was designed to perform tasks related to observing the ocean environment and collecting data. Two waterproof, clear acrylic cans containing the ROV's electronics and two Lexan™ plates form the structure of the chassis. The ROV integrates six 28V brushless thrusters and four high resolution, low-light cameras. Also incorporated are six main payload tools to accomplish the challenging mission tasks set forth by the client, the MATE 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 and a third-party controller. A detachable tooling skid houses the payload tools and pneumatics can. During the design and building process, company 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 $45,500 this year, not including the value of donated and reused materials.

Figure 1: Eastern Edge Robotics Team, 2013.

Location: Topsail Beach, Conception Bay South, Newfoundland and Labrador, Canada

Team Members: (Left to right)
Back Row: *Kyle Doody, Thomas Seary, Brian Tiller, Chris Harvey, Justin Higdon, Nick Ash, Tim Oram, Scott Henderson, Josh Penney, Thom Smith*
Middle Row: *Coralie Brown, Bethany Randell, Krista Bennett, Kaitlin Quinlan, Lakshmi Niveditha Viswanathan, Michelle Mifflin*
Front Row: *Calvert Pratt, Christina Hamlyn, Kourtney Duff, Elizabeth Chisholm, Riley Edwards*
(Missing from photograph: Nathan Ash, Jacob Parsons, Petros Mathioudakis, Christopher Finn, Brian Peach, Brandon King, Adam Wetmore, Stephen Jeffers, Verity Furlong, Camille Pagniello, Steven Whiffen)

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1. BUDGET AND FINANCIAL STATEMENT

Item	Donations	Expenditures	Reused	New
Electronics (on ROV)		1725	800	925
Electronics (topsides)		2550	2300	250
Hardware		625		625
Thrusters		10500	10500	
Tether - Leoni Elocab	1800		1800	
Cameras (4 of)		1450	1450	
Analog input board		150	150	
Servo controller board		180	180	
Fiber optic multiplexer - Moog	3500		3500	
Lexan™ & HDPE sheet		1750	360	1390
Miscellaneous electronics parts		850		850
Pneumatics		2368		2368
Pressure sensor - Keller America	575		575	
Digital Compass		140	140	
SubConn connectors	1450		450	1000
Printing		450		450
Group airfare (20 students, 3 mentors)		24700		24700
Van Rental (3 of)		2200		2200
Accommodations		10400		10400
Team shirts		240		240
TOTALS	7325	60278	22205	45398

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

Contributors	
Faculty of Engineering	10000
Faculty of Science	1000
Marine Institute	5000
Government/Industry	20000
Student contributions	10000
New donated materials	1000
TOTAL	47000

Table 2: Contributions to Eastern Edge Robotics.

2. DESIGN RATIONALE

The main objective for *ROCK LOBSTER*'s design is to accommodate the many tools required for the installation and operation of the ocean observation system located near the Juan de Fuca Plate. Eastern Edge Robotics is competing for the contract to service this specific region. This includes the standard requirements for speed, stability, manoeuvrability and vision, while maintaining a compact frame. This contract also entails the challenges of:

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

Consequently, the design features:

- an ROV that is compact and streamlined, with minimal protrusions to snag objects within the working environment
- omni-directional vision in the vertical plane to provide situation awareness and effective viewing while executing the mission tasks
- 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

2.1 ROV Structure

The chassis of *ROCK LOBSTER* was designed and modeled using SolidWorks™ 3D CAD software. It is comprised of two main component groups: the structural plates and electronics canisters. A removable tooling skid incorporates the specific tools required to execute the mission tasks.

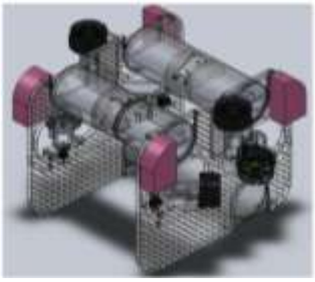


Figure 2: SolidWorks™ Rendering of ROV Structure

The chassis plates are constructed from ½" 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. 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 ½" 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 controllers and electronic components.

The tooling skid provides quick connect/disconnect capabilities for multiple tooling packages to suit a variety of tasks without affecting the main chassis. The tooling skid has been designed to hold a pneumatics control can and to properly attach the leveling device. The addition of a heavy tooling skid at the bottom of the ROV lowers the center of gravity and improves stability in the roll and pitch directions.

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 rotor of the motor. They also provide feedback from the thrusters through the use of embedded sensors. The thrusters are configured to provide the ROV with five degrees of freedom (surge, heave, sway, roll and yaw). Each plate 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° angle 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 colour Charge Coupled Device (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 two auxiliary Inuktun Crystal Cam high resolution (400 TVL), low light (1.0 Lux), 0.64cm colour CCD cameras on the removable tooling skid for enhanced task visibility.

2.4 Pneumatics System Control Can

Figure 5: Pneumatics System Control Can

Several of the tool designs for the vehicle require a linear motion to function properly. As it is an additional task to turn the rotational motion of a normal electric motor into a linear motion, other methods were investigated. Pneumatic power was chosen because it is a simple and effective way to control multiple linear actuators and tools. All of the controls for the pneumatic system are located in their own watertight can in the tool skid, allowing for easy deployment or removal of the system as needed for each mission.

Inside the can are eight solenoid valves used to supply air to eight separate channels. Seven valves can be used on tools and one is used as an emergency dump for the accumulator. The accumulator dump valve is used as a safety precaution and can release all stored pressure in only a few seconds. A 3psi (approximately 21kPa) check valve allows for air trapped inside of the can to be exhausted to the outside. In the event of an air leak inside the can, the check valve will release pressure into the environment, keeping the pressure inside the can from rising more than 3psi above ambient pressure. A custom controller based on a PIC18F1320 microcontroller was designed and constructed to control the valves. The controller accepts a serial input from the ROV and uses that to control eight MOSFETs, each of which controls a single pneumatic valve. Indicator LEDs are placed on the control board to show when a channel is being activated. These LEDs, along with a pressure gauge, are easily visible from a camera so the pneumatics system can be continuously monitored. For a schematic of the Pneumatics system, see Appendix A.

2.5 Safety

Eastern Edge Robotics considers safety a major priority and therefore takes a proactive approach to protecting its members and others in the area. All members received a briefing on workshop safety, operations and procedures from team mentors at the beginning of the project. Specific safety instruction on power tool use was provided as necessary and the team was briefed on safety specific to the pool environment before ROV operations began.

The ROV was designed and developed with safety in mind and has a number of safety features including:

- over-current protection and kill switches in the event an emergency stop is necessary
- temperature and humidity sensors in the electronics cans provide forewarning of overheating or water ingress
- electrical isolation of high power motor components from low voltage electronic components
- completely shrouded thrusters to prevent injury
- rounding and removal of sharp edges

- warning signs to identify moving components and other hazards including electronics and lasers
- laser shields

In addition, Eastern Edge Robotics takes many operational precautions. A detailed safety checklist has been developed for company use (see Appendix B). This checklist emphasizes safe protocols for ROV operations during pre-flight checks, launch and recovery and post flight checks. These checks encompass electronic and water ingress testing, use of safety equipment such as Personal Flotation Devices (PFDs) and eye protection. Eastern Edge Robotics' 3-person launch and recovery method utilizes the ROVs "handles" for safe launch and recovery of the ROV. The post-flight activities include shutdown of all electronics, motors, and re-shielding of lasers.

2.5.1 Pneumatics Safety

Eastern Edge Robotics has taken precautions to ensure safe pneumatic operation. High pressure lines before the regulator are all rated for 300psi (approximately 2068kPa), well above the operating pressure of 120psi (827kPa) supplied by the compressor. Post-regulator, all components are rated for 105psi (724kPa) but are operated at 40 psi (276kPa). At the surface, a supply control box houses a regulator, a supply shutoff valve, and multiple pressure gauges. The regulator is fully enclosed so the dial cannot be knocked out of adjustment, and the supply valve isolates the system from the compressor. The gauges show both supply pressure and the pressure being sent down to the ROV. This allows identification of a leak in the system on the ROV that could lead to a failure. On the exhaust side of the system, there are redundant check valves and a water trap to keep water from entering the can. An extra check valve leads from the inside of the can to the environment in order to exhaust air that would be the result of a pressure buildup in the can.

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 (WCF) 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 facilitates the development of a library of objects that can be used with any ROV built by Eastern Edge Robotics. This allows for easy modification and customization. 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 of 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.

The logic library of the ROV includes an auto depth object. This object samples the current depth from the depth sensor object and a desired depth from the user interface layer then 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.

The auto depth 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 output values are positive, causing the ROV to rise and vice versa. The integration portion of the algorithm eliminates steady state errors. This produces an equilibrium control value that holds the ROV at the desired depth. Using a manual tuning method, the company produced the constant K values used in the PI controller algorithm.

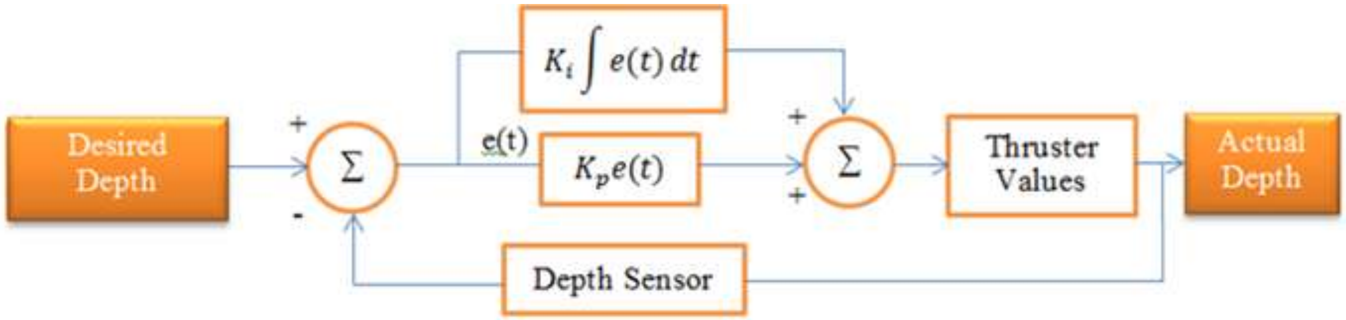


Figure 6: PI Algorithm

3.2 Application Layer

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 (UI), logic connection, device collection]. This allows for greater flexibility. For example, the 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 developers to build a large testing UI, which can be used for various tasks during the development. 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) operate on a remote machine.

3.3 Graphical User Interface

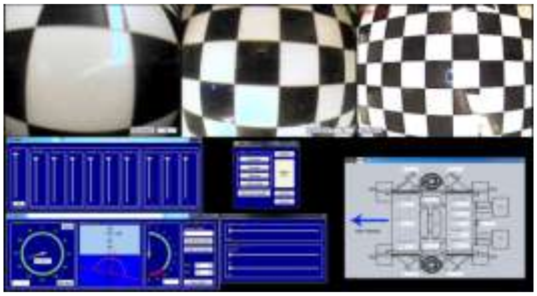


Figure 7: Graphical User Interface

The graphical user interface (GUI) is a multi-windowed display, which allows the pilot and co-pilot to arrange the GUI as manageable windows that can be opened or closed as needed. The GUI has been modified to easily display the graphical presentation of the transmissometer sensor data. The GUI is split into seven windows: main operations, ROV compass and navigation, thruster power control, telemetry, transmissometer graph, 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.

The flowchart shown in figure 8 details program flow for the control system:

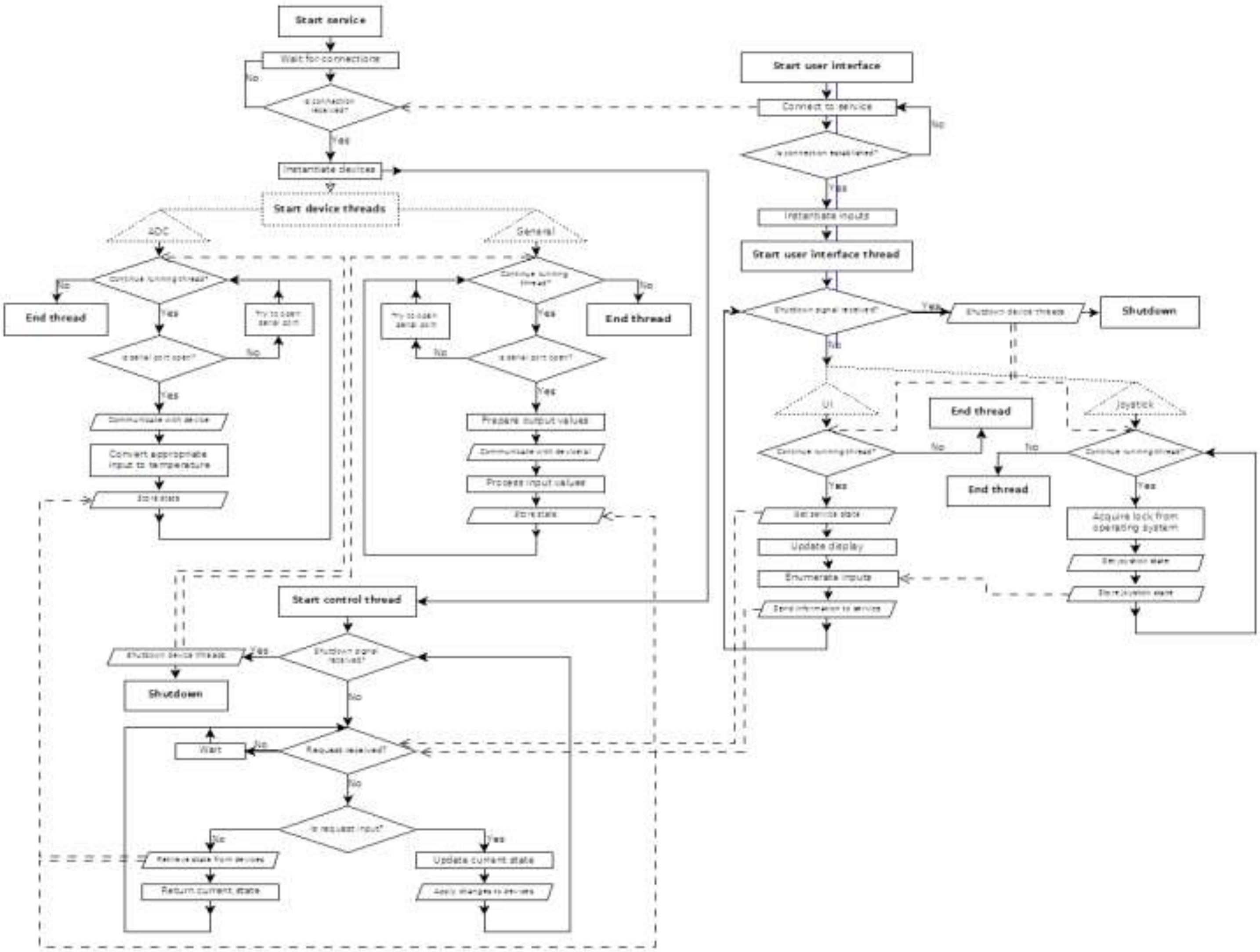


Figure 8: Programming Flowchart

4. Electronics

The electronic system has four key components: the topside control unit (TCU), the tether, the Submarine Vehicle Control Can (SVCC) and the Submarine Payload Control Can (SPCC). The electrical schematic representing power distribution is depicted in figure 9 and the electrical schematic for communications flow is depicted in figure 10.

SINGLE LINE DIAGRAM - POWER

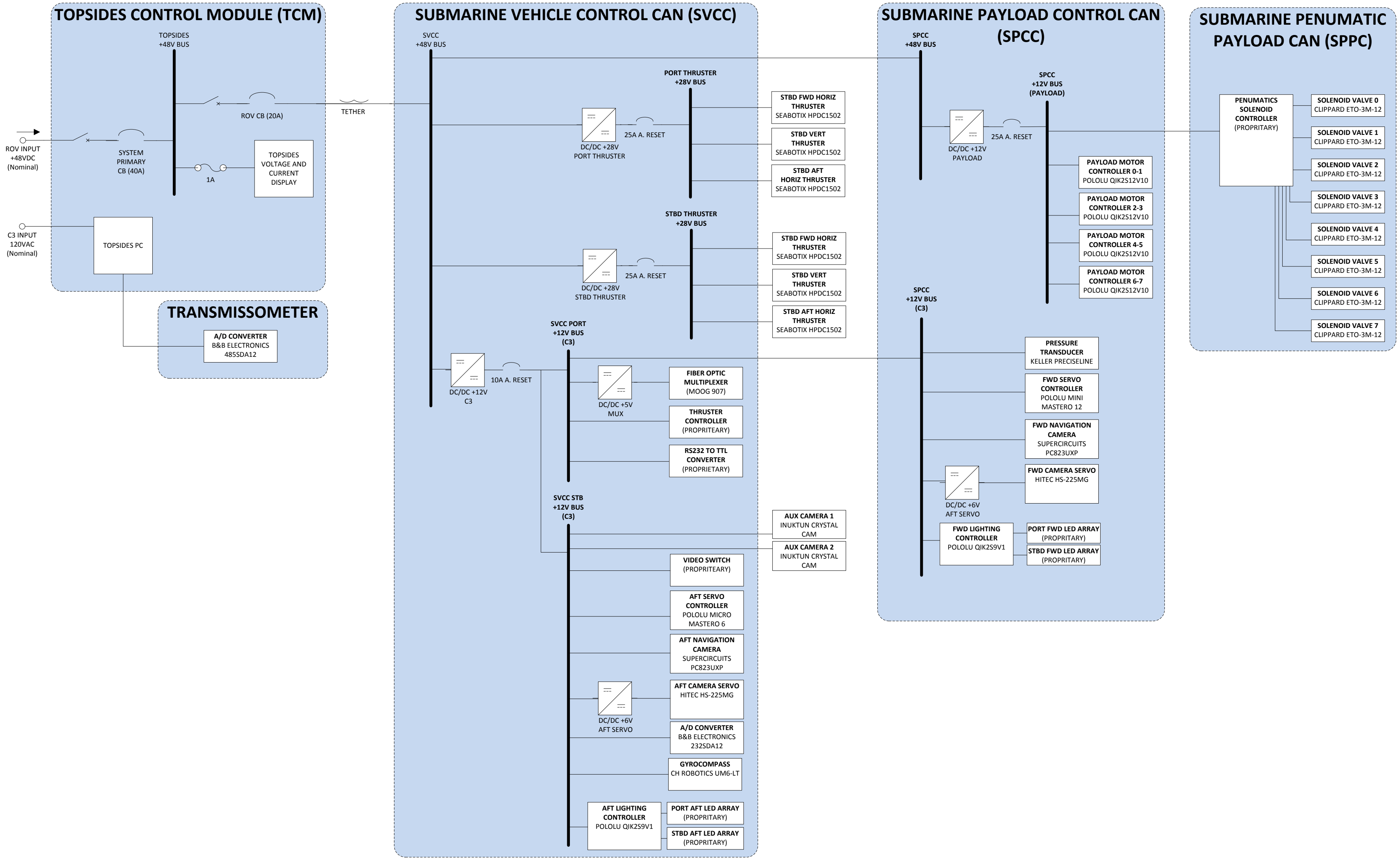


Figure 9: Power Schematic

SINGLE LINE DIAGRAM - COMMUNICATIONS

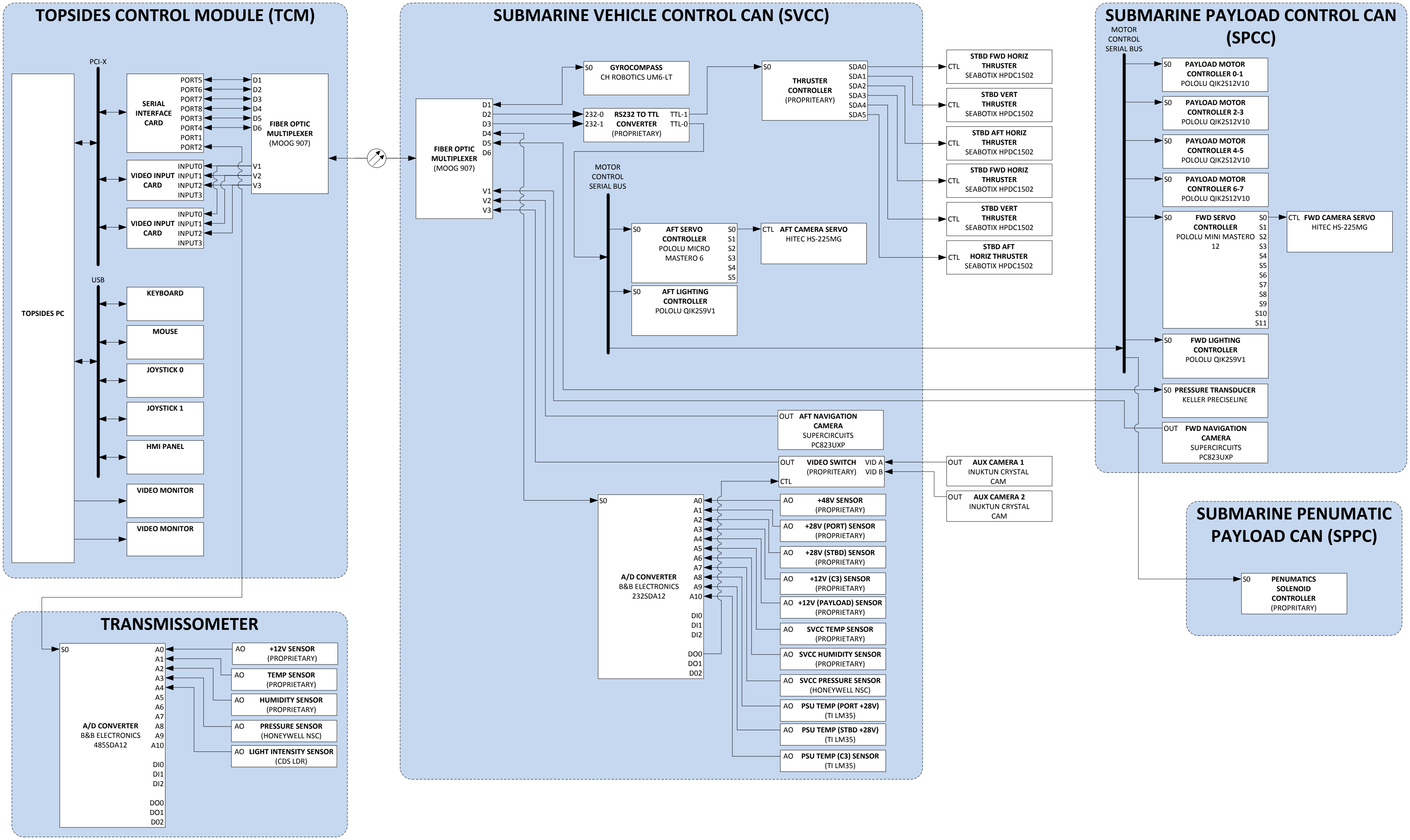


Figure 10: Communications Schematic

4.1 Topside Control Unit

Figure 11: Topside Control Unit

The TCU provides electrical protection and communication to the ROV. From the main 48VDC input, power is routed through a 20A circuit breaker, custom built voltage and current meters, and then to the ROV. The topside controller contains a purpose-built computer based on a µATX form factor motherboard. This computer has 16GB of RAM, a six-core CPU, a 240GB solid-state drive and a 500GB hard disk drive, which provides ample control and video processing capability for the ROV system. Additionally, the computer's DVI output allows for a connection to a high definition monitor (1920 x 1080p), which displays the ROV's GUI and video feeds. The topside Model 907 video/data multiplexer unit from Focal Technologies^{TM}, which provides communication to the ROV over a single fiber, is connected to an Adlink 4-port video input card providing three video channels and to a B&B Electronics 8-port RS-232/422/485 serial interface card providing six serial data channels (2x RS-485, 4x RS-232). The video input card is used to capture the video feeds while the serial interface card is used to communicate data to and from the ROV. The topside computer is powered from a standard 120V ATX power supply and communicates to the ROV through fiber optics. This electrically isolates the TCU from the ROV itself, providing additional safety for both the operators and the sensitive electronics in the topside computer.

4.2 Tether

Figure 12: Tether

A custom tether was donated to Eastern Edge Robotics by Leoni Elocab Inc. of Kitchener, Ontario, Canada in 2009. Designed to be neutrally buoyant in fresh water, the tether has an outer jacket coating of low drag polyurethane. Two 16-gauge copper wires are used to carry DC power while two multimode fiber optic strands are used for control and video signal transmission. The secondary fiber optic strand is reserved for use only in the event of failure or damage to the primary strand. The tether is terminated at the topside end inside a protective tube with a quick disconnect Speakon^{TM} type electrical connector and ST type optical connectors. A right-angle brass penetrator, custom-machined by Eastern Edge Robotics, carries the tether into the communications can on the submarine end. The tether is then terminated inside the SVCC electrically with ring terminals and optically with two ST connectors. To supply the pneumatics system, a flexible 1/8" polyurethane airline is attached to the tether. The airline does not significantly affect the buoyancy of the tether due to its low cross-sectional area.

4.3 Submarine Vehicle Control Can

Figure 13: SVCC

The SVCC is a 36.5cm long clear-cast acrylic cylinder with a diameter of 12.7cm capped with custom-machined polycarbonate at each end. It houses all of the electronics necessary for the operation of the ROV including components for voltage conversion, communications to the surface, video, thruster control and data acquisition. Four Subconn® low-profile multi-pin bulkhead connectors provide electrical connections to the outside and SPCC. Inside the can, two 28V and one 12V output DC-DC converters reduce the 48V main rail input voltage down to 28V for the port and starboard thrusters, and to 12V for the control electronics, cameras and lighting. The converters are rated for an input voltage of up to 75V and for output currents of 10A and 25A, respectively.

Communications to the surface and video are facilitated by the remote unit of the Model 907 multiplexer, which serves as a connection point for one RS-485, four RS-232 buses, and three video feeds on the ROV. The onboard cameras can be tilted by a servo motor controlled by a Pololu Maestro 6-channel servo controller, which receives an RS-232 signal. An RS-232 to I2C bus converter, based on a PIC18F1320 microcontroller and designed by Eastern Edge Robotics, is used to communicate with the embedded microcontrollers of the thrusters. The bus converter connects to the multiplexer via an RS-232 bus and to the six thrusters via six individual I2C bus outputs. Data acquisition is provided by a B&B Electronics 232SDA12 A/D Converter, which communicates via an RS-232 bus and has a 12-bit resolution over a 0 to 5 V range for each of its 11 inputs. Outputs from some sensors are connected to these inputs. In addition, a video switch has been installed to switch quickly between two auxiliary video feeds.

4.4 Submarine Payload Control Can


Figure 14: SPCC

The submarine payload control electronics are housed in a can with the same design as the SVCC. The SPCC controls the payload tooling onboard the ROV and has been designed to accommodate current and future tooling. Four 2-channel Pololu QIK 2S12V10 motor controllers connected to a serial bus are used to operate the tooling devices. A DC-DC converter is used to reduce the 48V main rail voltage to 12V, and has the ability to provide 25A of current to the onboard tooling. The SPCC is linked to the SVCC using a single 9-pin connector, which supplies both power and communications. One Pololu Maestro 12-channel servo controller, which receives a RS-232 connection from the SVCC, outputs twelve pulse width modulated signals to tilt the onboard camera.

4.5 Lighting

Two 360° white LED arrays in each of the SVCC and SPCC provide illumination to the ROV work area. Each array is individually driven by a Pololu Qik 2s9v1 two-channel motor controller. Connected via an RS-232 bus, this controller allows each light array to be dimmed separately.


Figure 15: LED Arrays

4.6 Sensors & Telemetry

4.6.1 Voltages

Voltages are monitored to ensure that the outputs from the onboard power supplies are within an acceptable range. Voltage dividers measure the 48V main supply, the port and starboard 28V power supplies, the control and communications 12V supply, and the 12V tooling supply. Each is sampled by the A/D converter 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. Three TMP36 sensors monitor the heat sink temperature of the onboard power supplies. The output of these sensors are sampled by the A/D converter and displayed on the GUI. This allows the operator to monitor temperature and in the event that overheating occurs, shut down or reduce demand on the ROV.

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 SVCC. This sensor is supplied by a nominal 5V, draws 200µA, and provides a nearly linear output curve relating voltage to humidity. The output is sampled by the A/D converter and displayed on the GUI to warn the operator of possible condensation build-up.

4.6.4 Internal Pressure Sensor

A Honeywell NSCDANN030PAUNV pressure transducer monitors the internal pressure of the SVCC to detect leaks. The transducer, referenced to a vacuum and configured with a full range of 206kPa, is monitored by the A/D converter and displayed on the GUI. The pressure inside the SVCC should be constant at 1 atmosphere (approximately 100 kPa). If there is a leak, the pressure in the SVCC will rise towards the pressure at the current depth and a threshold alarm will alert the operator of the leak.

4.6.5 External Pressure Sensor

A Preciseline™ pressure transducer from Keller America is used to measure both the water depth (up to 20m) and temperature. In one of the end caps of the SPCC, the pressure transducer is mounted in a ¼” NPT hole. The transducer, referenced to a vacuum and configured with a full range of 300 kPa, communicates using an RS-485 bus. It has a floating isolated piezo-resistive sensor, which gives an accuracy of ± 0.1% and a 16-bit internal digital error correction, to measure the pressure. The software converts this pressure reading into a depth and is displayed on the GUI. The conversion takes into account the configurable water density and the current atmospheric pressure. This depth measurement also acts as feedback for the auto-depth function.

4.6.6 Gyro

The ROV's gyroscope is a UM6 from CH Robotics^{TM}. Located in the SVCC, this instrument is composed of three triple-axis sensors: an accelerometer, a gyroscope and a compass. The combined use of three sensors prevents an anomaly in one sensor from disrupting the outputs. The gyro was tested to ensure that an anomaly, such as the time-varying magnetic fields generated by the thrusters, did not disrupt its function. The outputs are processed by an internal microprocessor to provide pitch, roll and yaw, which are then polled via an RS-232 bus by the control software, and displayed graphically. The instrument can be zeroed through software, providing the ROV is not moving (i.e. resting on the bottom).

4.6.7 Lasers

Figure 16: Lasers

The ROV is equipped with two encapsulated laser diodes. The lasers are class IIIa, 5mW, with a 650nm red wavelength. Each laser has been potted in a brass tube to render it waterproof and mounted to either side of the ROV. The laser assembly is used to provide a reference distance for measurement. This is accomplished by capturing an image containing the target area and the laser points. Using this image and the laser determined pixel-to-length ratio the designated area of the secondary node is identified.

5. PAYLOAD TOOLS

5.1 Transmissometer

The transmissometer is used to measure relative opacity changes using a Light Dependant Resistor (LDR) and an LED. The resistance of the LDR is proportional to the intensity of light shining upon it. The LDR is part of a voltage divider circuit which creates a positive correlation between the light projected across its surface and its voltage. An amplifier is used to scale the voltage to a 0-5V range to create compatibility with the A/D converter. The digital output of the converter is sampled by the computer and used to display the data in a graph.

Figure 17: Transmissometer

The transmissometer circuit is housed in a 14cm x 15cm High Density Polyethylene (HDPE) case with a Lexan^{TM} cover and waterproofed using o-rings. An 18m tether transmits power and signal from the topsides controller to the transmissometer circuit. A four-pin bulkhead connector is used to power the LED from the circuit. The transmissometer delivery device holds the circuit casing and the LED. It is constructed of Lexan™, an HDPE U-bracket and a stainless steel U-Bolt. The Lexan^{TM} is coated in black paint to prevent external light from interfering with the LDR reading. The delivery device is deployed by the vertical manipulator and remains on the seafloor.

5.2 Horizontal Manipulator (M-ROD)

Figure 18: M-ROD

The Magnetic Retrieval, Orientation and Deployment tool (M-ROD) was developed by Eastern Edge Robotics to allow the ROV to complete tasks requiring the ROV to manipulate instruments and connectors. The device is constructed of Lexan^{TM} and utilizes rare earth magnets to pick up these objects. A track orients the payload correctly once retrieved. The M-ROD uses a pneumatic-powered bottom plate to separate the payload from the magnets to allow precise deployment.

5.3 The Leveler

Eastern Edge Robotics’ solution to leveling the secondary node is The Leveler. It consists of four 3” PVC pipes cut to 15cm length tapered on one end and fitted with a 3” diameter polycarbonate cap on the opposite end. Fixed inside the pipes are two 12.5cm x 2cm ABS flaps that orient and engage the T-handles to enable adjustment. This length accommodates the total travel range of the handles. This tool is mounted to the tooling skid using custom-built HDPE mounting brackets. A flexible cable connects a bi-directional motor to each of the PVC pipes.

To complete the task, the ROV rests atop the node with a camera pointed at the bubble level. The pilot can then intuitively move a joystick to control the position of the bubble since the motors will respond to the joystick movement as if the pilot is “driving” the bubble.

Figure 19: The Leveler

5.4 Bio-Unfouler

Figure 20: Bio-Unfouler

A round brush is coupled to the gear-head of an electric screwdriver driven by a bilge pump motor. This is mounted to a piece of HDPE alongside a second idler brush. This tool has proven effective in previous contracts to remove debris from subsea structures and will be reused for this contract.

5.5 Flex Handle

Eastern Edge Robotics developed a simple yet effective tool for opening and closing doors. The main component of the Flex Handle is constructed of flexible plastic tubing with a small piece of rigid rod inserted in the centre. The ends of the tubing pass through a piece of ½“ PVC pipe, shaping the tubing into a triangle. To open a door, the ROV positions the triangular tubing inside the door handle and then moves up or sideways until the door swings open. The flexibility of the tubing allows the tool to easily slip out of the door handle to disengage the ROV.

Figure 21: Flex Handle

5.6 Vertical Manipulator

Figure 22: Vertical Manipulator

The ROV uses a vertical manipulator to maneuver the ADCP, SIA, transmissometer, and secondary node, all of which incorporate a U-bolt as an attachment point. A single-acting pneumatic cylinder, with 4 rare-earth magnets secured to its extending rod, is mounted inside a piece of 2” PVC pipe. Magnetic force holds the U-bolt stationary inside the pipe while the rod is extended. Upon retraction of the cylinder rod, the magnetic force is removed thereby releasing the object being transported.

6. CHALLENGES

6.1 Technical Challenge

To determine whether to use a 650nm red laser or a 532nm green laser, Eastern Edge Robotics analyzed the relative attenuation of the two lasers. Specifications limit the power of a red laser to 5mW and the power of a green laser to 1mW.

The approach used was to determine the distance at which the higher attenuation of a red laser outweighs the benefit of the higher power permitted. Analysis proceeded as follows:

The laser absorption coefficient chart was examined to determine the attenuation of red and green light in water.

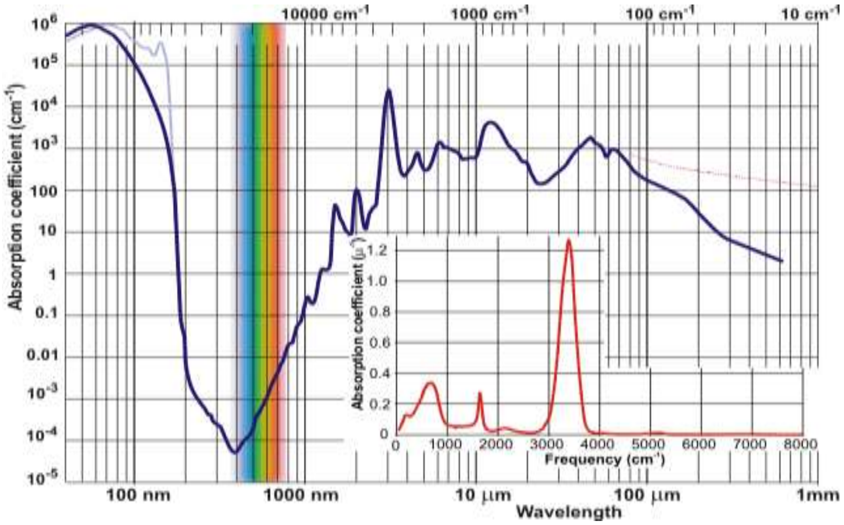


Figure 23: Absorption Coefficient vs Wavelength

Chaplin, M. (n.d.). Water Absorption Spectrum. *Water Structure and Science*. Retrieved March 25, 2013, from http://www.lsbu.ac.uk/water/vibrat.html

Colour	Attenuation
Red (650nm)	0.003dB/cm^{-1} or 0.3dB/m
Green (532nm)	0.0003dB/cm^{-1} or 0.03dB/m

Table 3: Attenuation of laser light in water

$$P_d = P_1 - \alpha d$$

Where: P_d = power level at distance d

P_1 = initial power level

d = distance

For the green laser $P_d = 10*\log_{10}(1mW/1mW) - 0.03d = 0 - 0.03d$

For the red laser $P_d = 10*\log_{10}(5mW/1mW) - 0.003d = 7 - 0.003d$

The power levels will match when $0 - 0.03d = 7 - 0.003d$

Solving for d yields d = 25.9m

Therefore, green lasers with a 1mW rating would be more effective after 25.9m. Until then, the red laser with rated power output of 5mW will be the optimal choice to maximize intensity. Knowing that this contract involves a maximum operating distance of 4m, red lasers were selected.

6.2 Non-Technical Challenge

Retention of corporate knowledge was the greatest non-technical challenge that faced Eastern Edge Robotics this year. Many senior employees left the organization to further their career goals. They took with them a great deal of experience in tool design, computer programming and ROV operations. Since the ROV and its tools are created in-house, these skills are absolutely essential to achieve a fluid transition from year to year. The senior members also have experience in the contract competition setting and the unique challenges presented.

To mitigate these losses the company implemented the following actions:

- previous company members were invited to host workshop seminars relating to their areas of expertise
- newest members shadowed senior members until they were familiar with operations of the company
- tasks were assigned based on interest and experience

7. TROUBLESHOOTING TECHNIQUES

Troubleshooting and testing techniques were used in the development of all aspects of the ROV. During testing of the ROV, a major issue was identified with regard to the leveling of the secondary node. Starting with rough mock ups, the tooling department identified issues such as available space on the ROV, different T-handle sizes and the tool's ability to sit within the frame while landing on the secondary node. Through trial and error, several configurations of the tool skid were designed and tested. Each time, the placement of all tools had to be re-considered and the design was modified accordingly. Testing and subsequent analysis of each iteration revealed issues and improvements for consideration. After changes were made and full system tests were performed, the optimal tool design was implemented on the ROV.

8. FUTURE IMPROVEMENT

An improvement that Eastern Edge Robotics is considering would be a Tether Management System (TMS), with the ability to put the tether on a slip ring reel. This requires hybrid fiber-optic/electrical slip rings. This type of TMS would eliminate tangling on the surface and improve overall storage and transport. Using a commercial off-the-shelf hybrid slip ring, the TMS would be simple to implement. However, this requires a budget commitment that could not be allocated this year due to the travel expenses of the large organization.

9. LESSONS LEARNED

9.1 Technical Lessons Learned

The tooling skid design presented a sizable challenge to Eastern Edge Robotics due in part to the complexity of the leveling task, the large amount of space required by the payload tools, and the addition of the pneumatics can.

The technical lesson learned this year was that the placement of payload tools must be discussed frequently throughout the design process and that it is beneficial to maintain a current electronic drawing of each component and its placement on the ROV. This would have prevented misunderstandings in expected tool placement among design teams, and eliminated the delays in tool skid design.

9.2 Interpersonal Lessons Learned

Eastern Edge Robotics consists of thirty-two members and as such, communication within such a large group is sometimes difficult. Some employees were involved with other projects and could not physically be in attendance at all meetings. This resulted in overlapping ideas and similar tools were developed for certain tasks.

The team turned to online documents and folders to communicate information. This allowed members to keep digital copies of their work to be shared amongst the organization. The online documents were secured and only visible to members who were added to the folders.

A lesson learned was that task managers need to be identified in order to keep track of tools being developed. They must also provide communication between group members. In the future, Eastern Edge Robotics will strive to be more careful in the distribution and organization of tasks to maximize efficiency.

10. Reflections

"This year with Eastern Edge Robotics has taught me an immense amount about ROVs and innovation, as well as about teamwork and creativity. The practical application of the skills I've learned in the classroom has helped in my understanding of many aspects of ROVs. It was wonderful to learn so many skills and apply them with so many intelligent, helpful people. This has been a great experience and I would recommend it to anyone. I look forward to working with Eastern Edge Robotics in the future."

-Elizabeth Chisholm, 1st year ROV Technician, 1st year with Eastern Edge Robotics

Figure 24: Elizabeth working on the Technical Report.

Figure 25: Justin helping new members.

"In my 10 years of involvement with the team, there are few words that can describe the experience as a whole. Always having a passion for electronics and technology, my involvement with the MATE ROV competitions has given me the opportunity to nurture and practice my skills while challenging myself on an international scale. Through Eastern Edge Robotics I have found success on many levels, and upon completion of my bachelor's degree in Electrical Engineering, I feel a sense of fulfillment knowing that I leave university with the most applicable skills for the upcoming challenge."

- Justin Higdon, B. Eng, 10th year with Eastern Edge Robotics

11 TEAMWORK AND ORGANIZATION

Eastern Edge Robotics utilizes a delegation of authority hierarchy in order to assign specific roles and responsibilities to all of its company members. Although all members contribute to every process, it was necessary to delegate duties to ensure that the project schedule was maintained and completed on time.

In order to easily follow the project schedule, a Gantt chart was created to ensure that the ROV was completed with as much time to practice before the competition as possible (See Appendix C). This also showcased resource allocation and project lags so that tasks that require predecessors were completed with priority.

To aid in this goal, an organization chart, shown in figure 26, was developed to ensure compliancy.

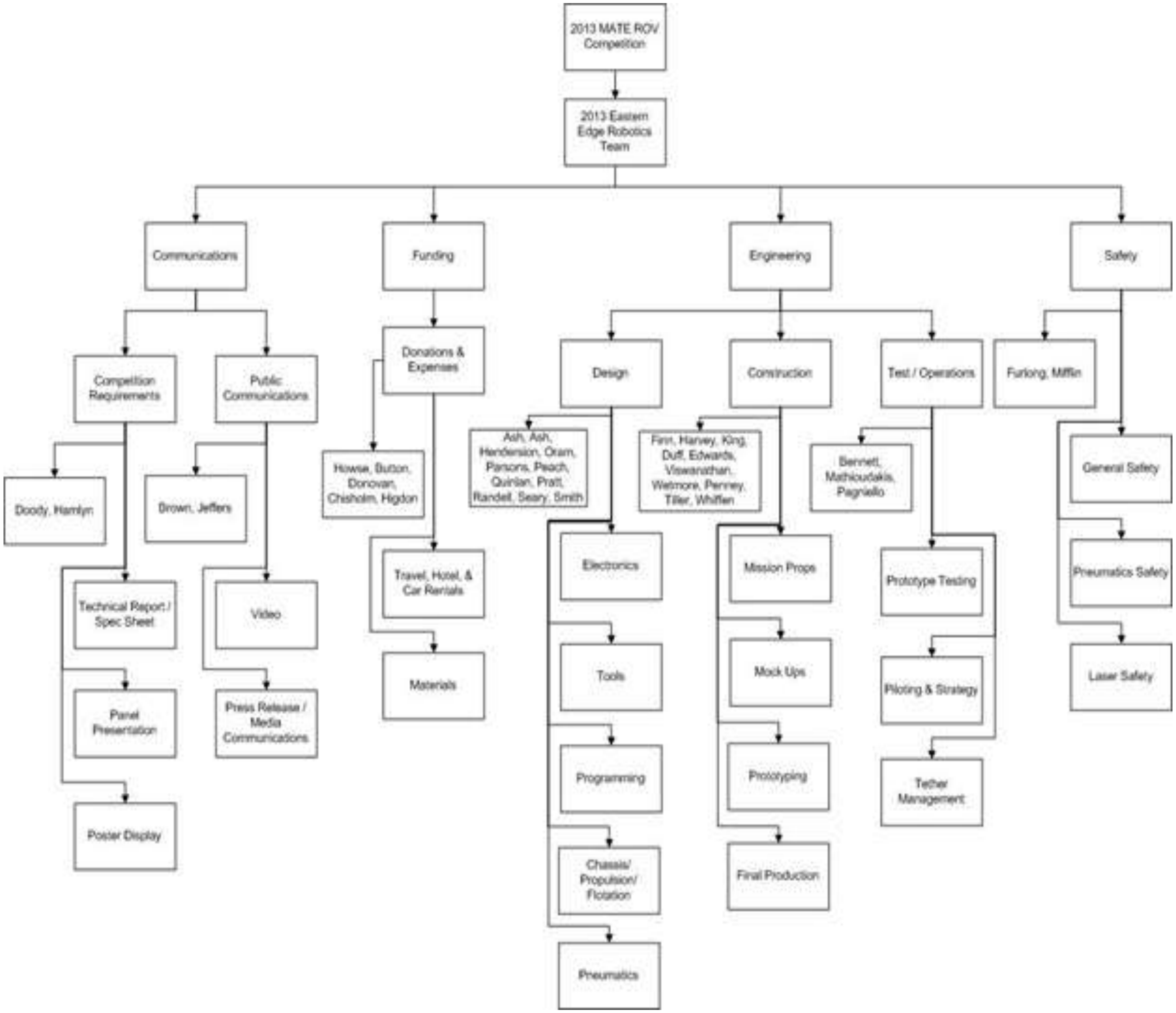


Figure 26: Eastern Edge Robotics Organizational Chart

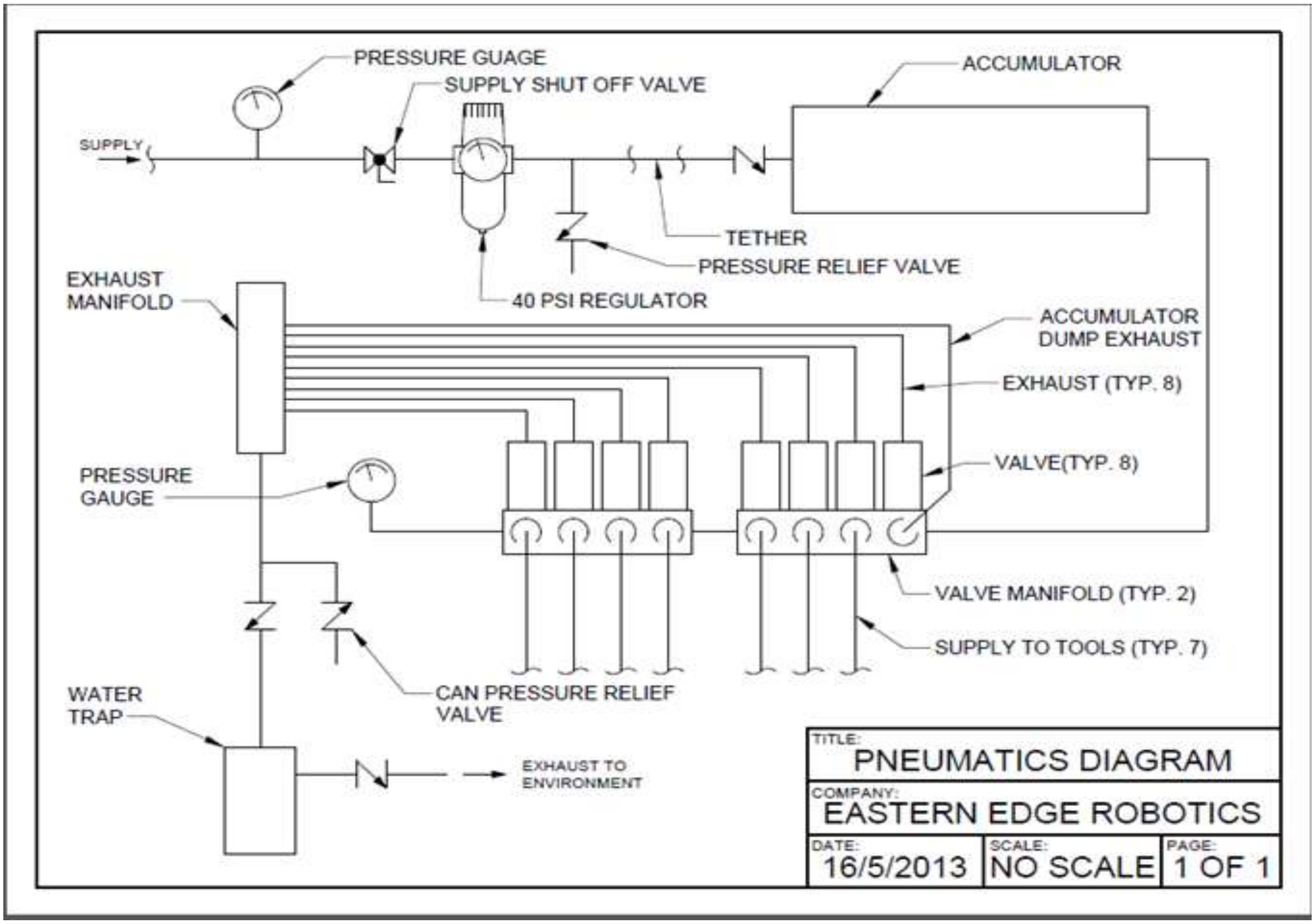
12. ACKNOWLEDGEMENTS

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

- AMEC (financial assistance)
- Atlantic Canada Opportunities Agency (financial assistance)
- Exxon Mobil (financial assistance)
- Focal Technologies (Moog) (donation of multiplexer for fiber-optics – 2006)
- GRI Simulations (financial assistance)
- 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 (MATE supporter)
- O'Donel High School (use of facilities and equipment)
- SubConn (donation of connectors – 2011 and 2013)
- 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 – Pneumatic Schematic



APPENDIX B – Safety Checklist

Pre Flight Safety

__________ Ensure all cans are sealed
  __________ No exposed wires
  __________ Unsealed connections
__________ Check Tooling
  __________ Bolts tightened
  __________ Manipulators moving freely
  __________ Lasers configured correctly & unshielded
__________ Visually inspect tether
  __________ Untangled
  __________ Undamaged
  __________ Vehicle/comp connections secure
__________ Check Pneumatics
  __________ All lines are clear and free of water
  __________ Cans are properly sealed
  __________ All lines are secured and valves are secured
  __________ All pressure readings are within safe limits
  __________No leaks in the system
__________ Test tether telemetry
__________ Check all SubSea assets have power, when given “all clear” is designated by deck manager
__________ Ensure all switches (tooling/thrusters/lasers/pneumatics) and off

Launch and Retrieval System (LARS)

__________ All team members on deck are wearing safety equipment

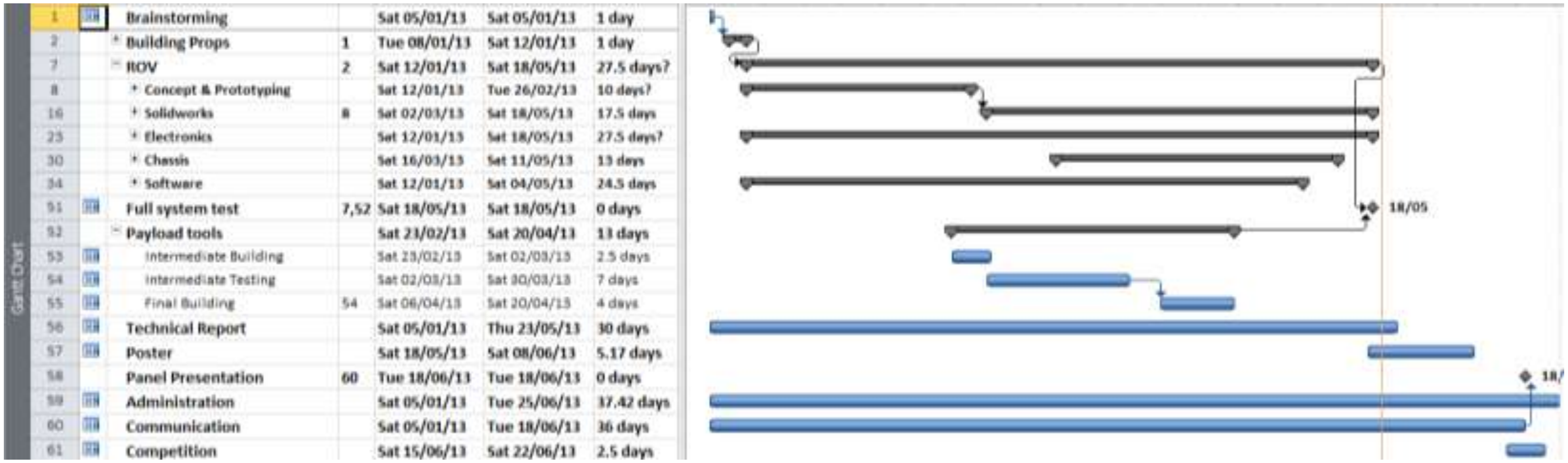
- Closed toe footwear
- Personal Floatation Devices
- Eye protection

__________ ROV launch & recovery completed by experienced two person team, lifted by handles on the ROV frame
__________Remove laser shielding after ensuring all team is wearing eye protection
__________ Ensure LARS team clear before ROV is started

Post Flight

__________ Ensure lasers/electronics/pneumatics/thrusters are off at surface
__________ Ensure laser shields are in place
__________ Two team members remove ROV from pool

Appendix C – Gantt Chart



1	Brainstorming		Sat 05/01/13	Sat 05/01/13	1 day
2	Building Props	1	Tue 08/01/13	Sat 12/01/13	1 day
7	ROV	2	Sat 12/01/13	Sat 18/05/13	27.5 days?
8	Concept & Prototyping		Sat 12/01/13	Tue 26/02/13	10 days?
16	Solidworks	8	Sat 02/03/13	Sat 18/05/13	17.5 days
23	Electronics		Sat 12/01/13	Sat 18/05/13	27.5 days?
30	Chassis		Sat 16/03/13	Sat 11/05/13	13 days
34	Software		Sat 12/01/13	Sat 04/05/13	24.5 days
51	Full system test	7,52	Sat 18/05/13	Sat 18/05/13	0 days
52	Payload tools		Sat 23/02/13	Sat 20/04/13	13 days
53	Intermediate Building		Sat 23/02/13	Sat 02/03/13	2.5 days
54	Intermediate Testing		Sat 02/03/13	Sat 30/03/13	7 days
55	Final Building	54	Sat 06/04/13	Sat 20/04/13	4 days
56	Technical Report		Sat 05/01/13	Thu 23/05/13	30 days
57	Poster		Sat 18/05/13	Sat 08/06/13	5.17 days
58	Panel Presentation	60	Tue 18/06/13	Tue 18/06/13	0 days
59	Administration		Sat 05/01/13	Tue 25/06/13	37.42 days
60	Communication		Sat 05/01/13	Tue 18/06/13	36 days
61	Competition		Sat 15/06/13	Sat 22/06/13	2.5 days