eastern Edge robotics
The Power of Innovation

Memorial University, St. John's, Newfoundland and Labrador, Canada
MATE International ROV Competition 2014, Explorer Class

# Technical Report

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# KETO

# ABSTRACT

This technical document describes Keto, a Remotely Operated Vehicle (ROV) that has been constructed as a deliverable for the 2014 MATE International ROV competition. Keto was designed and manufactured by Eastern Edge Robotics, an enterprise dedicated to the exploration, restoration, and documentation of aquatic environments. This ROV was designed to address specific needs outlined by the potential client, the Thunder Bay National Marine Sanctuary.

Keto's chassis is comprised of two polycarbonate skids and a single, clear acrylic canister that houses the onboard electronics. The ROV integrates six shrouded 28 V brushless thrusters, three standard definition low light cameras, and one high definition camera. Keto utilizes an interchangeable tooling skid that houses a customizable payload, which is specific to the survey environment. The control system for the vehicle is implemented using Microsoft's .NET Framework and the programming language C#. A custom-built tether connects onboard electronics to the topsides module, a custom-designed computer system controlled via peripheral devices.

Eastern Edge Robotics designed Keto to be a product best suited to carry out precise mission tasks in harsh aquatic environments. Through the development process, company employees have learned essential technical skills and worked diligently to deliver a quality end product. Design, fabrication, and travel costs to compete for this contract are estimated at $43,559.82 CAD.


*Eastern Edge Robotics Company Photograph*
*Memorial University of Newfoundland – Marine Institute*

**Company Roster** (listed from left to right)
Back Row: Doody, Gregory, Oram, Smith, Whalen, Colman, Whalen, Dominie
Center Row: Glatt, Quinlan, Brown, Fudge, Randell, Ryan, Furlong, Ragtah
Front Row: Rodgers, Whitby, Whiffen, Parsons, Pratt, Matthews
Missing From Photograph: Mathioudakis, Hamlyn, Ash, Henderson, Mifflin, Seary

## ACKNOWLEDGEMENTS

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

- Atlantic Canada Opportunities Agency (financial assistance)
- Broadata Communications (financial assistance)
- ExxonMobil (financial assistance)
- Focal™ Technologies (Moog) (donation of multiplexer for fibre-optics – 2006)
- 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 the opportunity to compete)
- Memorial University of Newfoundland (financial assistance and use of facilities)
    - Faculty of Engineering and Applied Science
    - Faculty of Science
    - Marine Institute
- National Science Foundation (MATE supporter)
- O'Donel High School (use of facilities and equipment)
- Province of Newfoundland and Labrador (financial assistance)
- Statoil (financial assistance)
- SubConn® (donation of connectors – 2011 and 2013)
- Subsea 7 (financial assistance)
- Suncor Energy (financial assistance)

Also, a very special thank you to our mentors Clar Button, Dwight Howse, Paul Brett, and Jai Ragunathan for donating so much of their time and energy to this project.

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# 1 BUDGET AND FINACIAL STATEMENT

*Table 1. Revenue*

| Donor | Value | Quantity | Total | Notes |
|---|---|---|---|---|
| Local Industry/Government | | | $20,000.00 | See Acknowledgements for sponsors |
| Broadata Communications | | | $900.00 | Discount on HD-fiber converter |
| MUN – Marine Institute | | | $5,000.00 | Financial assistance |
| MUN – Faculty of Engineering | $1,000.00 | 10 | $10,000.00 | $1000 donation per student |
| MUN – Faculty of Science | $1,000.00 | 1 | $1,000.00 | $1000 donation per student |
| Student Contributions | $800.00 | 16 | $12,800.00 | Contributions from students travelling to competition |
| | | **Total Revenue:** | **$49,700.00** | |

*Table 2. Expenditures*

| Item | Value | Quantity | Total | Notes |
|---|---|---|---|---|
| Materials | $10,389.82 | 1 | $10,089.82 | Cost of materials† |
| Time/Services | $300.00 | 1 | $300.00 | MUN – Technical Services (PCBs)* |
| Flights | $850.00 | 16 | $14,450.00 | 16 round trip flights* |
| Vehicle Rentals | $1,300.00 | 4 | $5,200.00 | $1300.00 per van for 8 days* |
| Accommodations | $120.00 | 96 | $11,520.00 | 12 rooms for 8 nights is 96* |
| Contingency | $2,000.00 | 1 | $2,000.00 | Additional required materials* |
| | **Total Estimate Expenditure:** | | **$43,559.82** | |

* Estimate

† as of May 29, 2014

*Table 3. Balance*

| Item | Value |
|---|---|
| Total Estimate Expenditure | $43,559.82 |
| Total Revenue | $49,700.00 |
| **Revenue over Expenses** | **$6,140.18** |

Note: Balance deferred to 2014/2015 by Eastern Edge Robotics for future projects.

*Table 4. Reused and Donated Materials*

| Category | Item | Donor | Fair Market Value |
|---|---|---|---|
| Reused Total | Miscellaneous | | $7,000.00 |
| Donated | Focal™ Multiplexer | Moog | $3,500.00 |
| Donated | Tether | LEONI Elocab | $1,800.00 |
| Donated | Connectors | SubConn® Connectors | $450.00 |
| Donated | Pressure Transducer | Keller America | $525.00 |
| | | **Total Savings:** | **$13,275.00** |

# 2 TEAM ORGANIZATION

Eastern Edge Robotics is an expanding enterprise employing a multidisciplinary team of twenty-eight people. As the company continues to expand, it becomes crucial to ensure that ideas are properly communicated throughout the organization. This year a new project management structure (Figure 1) was introduced to help ensure all employees understood their responsibilities and that deadlines were met.

The company was split into groups responsible for various aspects of Remotely Operated Vehicle (ROV) design, with senior employees in leadership positions. Each leader managed their portion of the project, delegated tasks, and was responsible for succession planning within their respective group. Each week the senior member reported their group's progress to the team project manager who logged progress on a detailed Gantt chart.

To ensure that the team did not lose track of important deadlines, the project manager held a session at the beginning of every meeting to discuss progress. The project manager's primary role was to highlight the critical path and to determine the best steps forward to ensure that deadlines were met. The entire team was consulted in a forum-style setting to provide new perspectives when groups were unable to meet a target. This became fundamental to how the team approached issues related to project execution.

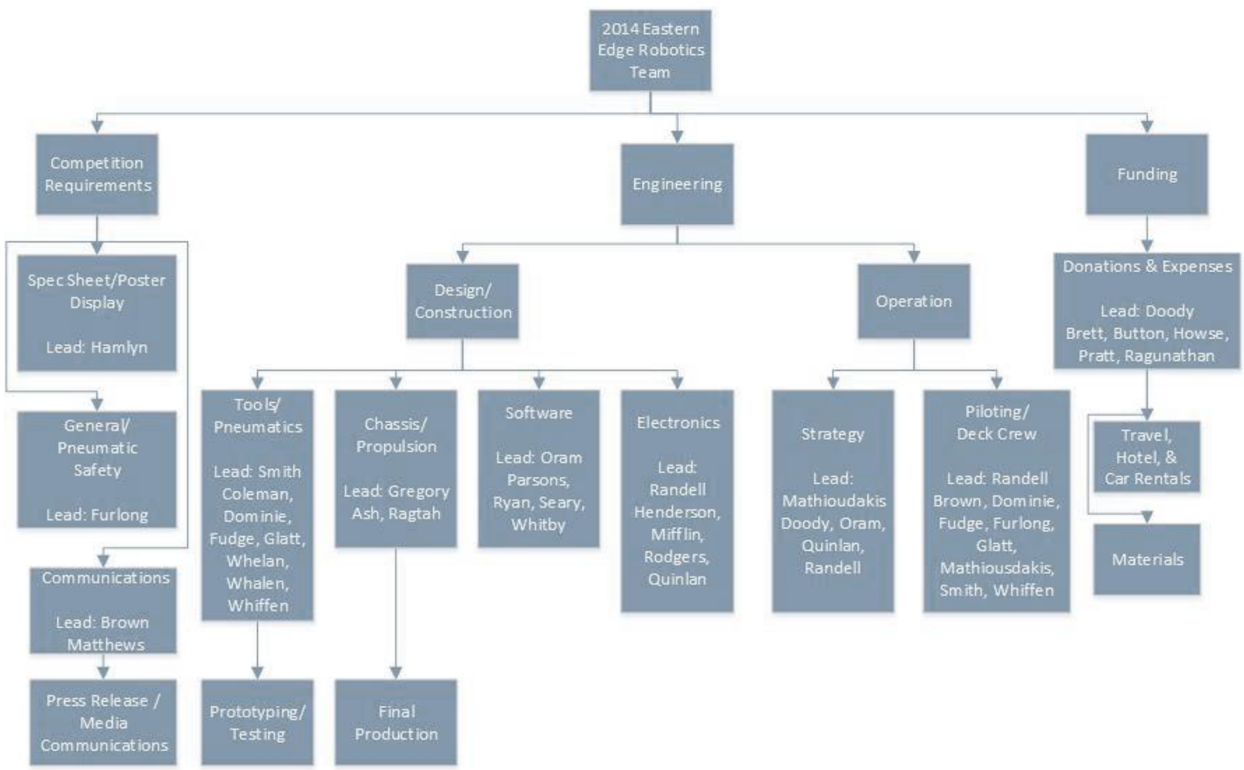



*Figure 1. Team Organizational Structure*

# 3 SAFETY

Eastern Edge Robotics considers safety the number one priority in all aspects of work. The company always takes a proactive approach to ensure members follow safety protocols and they work safely in all environments. All employees are briefed on workshop safety procedures and the location of first aid equipment at the beginning of a contract. Specific safety instruction on the use of power tools is provided as necessary. Furthermore, the team was briefed on safety that is specific to the pool environment before ROV operations began.

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

- over-current protection;
- a kill switch in the event an emergency stop is required;
- temperature and humidity sensors to provide forewarning of overheating or water ingress in the electronics canister;
- electrical isolation of high power from low power components;
- warning labels to identify moving parts;
- completely shrouded thrusters to prevent injury;
- removal of sharp edges.

In addition, Eastern Edge Robotics has developed a safety checklist (see Appendix A) that details protocols for ROV operation during pre-flight, launch, recovery, and post-flight. Pre-flight protocols include electronic and water ingress testing, and post-flight protocols include surface shutdown of all ROV systems. Launch and recovery is accomplished by a two-person team using handles on the ROV for safe entry and removal from the active zone. While the ROV is in operation, members of the deck crew wear closed-toe footwear, personal flotation devices, and safety glasses. By diligently following safety practices, no serious injuries occurred and three minor cuts were treated with Band-Aids®.

Pneumatic safety is a high priority since pneumatics is the primary method for actuation of onboard tooling. All high pressure lines before the regulator are rated for 300 psi (2068 kPa), well above the 120 psi (827 kPa) supply pressure. Post regulator, all components are rated for 105 psi (724 kPa) but are only operated at 40 psi (276 kPa). 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 system is isolated via the supply valve. The gauges show both supply and operating pressure, allowing identification of a leak in the system. On the exhaust side of the system, a check valve leads to the environment to exhaust excess pressure from the pneumatic enclosure.

# 4 DESIGN RATIONALE

A large part of the contract entails surveying unknown shipwrecks, so significant priority was placed on improvement of the ROV's camera system. Keto also requires powerful propulsion with fine control to lift debris from a survey site while maintaining a compact frame. Eastern Edge Robotics attained these characteristics without sacrificing vehicle speed, stability, and maneuverability.

## 4.1 Structural Frame

All components used in the construction of Keto's chassis (Figure 2) were designed and modeled using SolidWorks® 3D CAD software. The chassis was designed to allow for bi-directional operation while maintaining the smallest possible profile in order to maximize the vehicle's maneuverability in confined spaces. It is comprised of three main component groups: the drive skid, the tooling skid, and the Submarine Control Can (SCC). Both the drive and tooling skids were constructed using ½-inch (1.27 cm) Lexan™ polycarbonate, while the support structures use ¼-inch (0.635 cm) Lexan™. Flexibility of tool and thruster placement is achieved using a 2 cm square grid pattern of 0.5 cm holes.

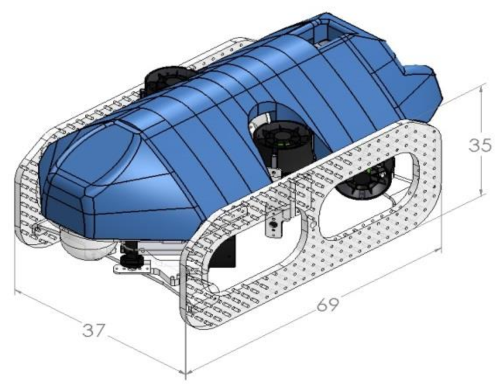


*Figure 2. ROV SolidWorks® Model*

The drive skid is 37 cm by 69 cm by 35 cm. It contains all components essential to piloting the vehicle including the SCC, thrusters, and cameras. Buoyancy is provided by a foam block on top of the drive skid that was cut from layers of polystyrene foam. The buoyancy block is coated in a carbon Kevlar® weave, reducing the chance of a puncture or break in the event of a collision or environmental hazards.

The tooling skid is 37 cm by 55 cm by 12 cm and is attached underneath the drive skid. It provides an interchangeable tool mounting platform that can be outfitted with different tooling packages based on contract requirements. The addition of this section to the chassis lowers the ROV's center of gravity and provides greater stability.

## 4.2 Propulsion

Keto is driven by six 280 W SeaBotix® HPDC1502 brushless thrusters (Figure 3) that are pressure compensated and rated to depths in excess of 1000 m. 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

*Figure 3. SeaBotix® HPDC1502 brushless thruster*

the speed of the motors by varying the rotating magnetic field generated by the armature of the motor. The thrusters are configured to provide the ROV with five degrees of freedom (surge, heave, sway, roll, and yaw). Each side of the chassis drive skid 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. To ensure that the propellers on the thrusters are properly protected, an additional propeller guard was fabricated in shop. These new guards were 3D printed using an acrylic resin, and act as a physical guard against hazards that may be able to pass through the thruster cowling.

## 4.3 Topsides Control Module

The Topsides Control Module (TCM) (Figure 4) consists of a purpose-built computer with peripheral devices (e.g. joystick and keyboard) to control the movement and tooling of the ROV. The computer is based around a micro Advanced Technology eXtended (ATX) form factor motherboard, has 16 GB of RAM, a 3.2 GHz six-core central processing unit, and a 256 GB solid-state drive. These provide the necessary control and video capabilities for the ROV system. The TCM is powered from a standard 120 V ATX power supply and communicates to the ROV through fiber optic connections. This electrically isolates the TCM from the ROV itself, providing additional safety for both the operators and the sensitive electronics in the TCM.

*Figure 4. Topsides Control Module*

Video and serial communication to and from the ROV is provided by a Focal™ Technologies Model 907 multiplexer. Video capture is achieved using Standard Definition (SD) ADLINK PCIe-RTV24 and High Definition (HD) ADLINK PCIe-2602 frame grabbers. Serial communication is provided by a B&B Electronics eight port RS-232/422/485 serial interface.

Power is routed through a 20 A circuit breaker from the main 48 VDC input then through voltage and current meters (built by Eastern Edge Robotics) before reaching the ROV.

## 4.4 Tether

A custom tether was donated to Eastern Edge Robotics by LEONI Elocab Inc. of Kitchener, Ontario, Canada in 2009. It has an outer jacket coating of low-drag polyurethane and is designed to be neutrally buoyant in fresh water. Two 16 AWG copper wires are used to carry DC power while two multimode fiber optic strands are used for control and video signal transmission. The tether is terminated at the TCM inside a protective tube with a Speakon® electrical connector and Straight Tip (ST) optical connectors. A right-angle aluminum penetrator, custom-machined by Eastern Edge Robotics, carries the tether into the SCC, where it is terminated electrically with ring terminals and optically with two ST connectors. The tether incorporates a strain relief on both ends to avoid breakage of the fiber optic strands. To supply the pneumatics system, a flexible ⅛-inch (0.3175 cm) polyurethane airline was attached to the tether using insulating tape. The airline has a slightly positive effect on the buoyancy of the tether, but it is almost negligible due to its low cross sectional area.

### 4.5 Pneumatic Control Can

Keto uses pneumatic power to produce linear actuation for many of its payload tools. Controls for the pneumatic system are located in a 4-inch (10.16 cm) clear-cast, acrylic canister that is 37 cm in length (Figure 5). This watertight canister is mounted on the tool skid to allow for easy deployment or removal as needed. Inside the Pneumatic Control Can (PCC) are eight solenoid valves, each on its own channel, with seven available for tooling. The eighth valve is used as an emergency safety precaution that can release all stored pressure in only a few seconds. In the event of an air leak inside the PCC, a 3 psi (20.68 kPa) check valve will release pressure to the environment, keeping the pressure inside the PCC from rising greater than 3 psi above ambient pressure. To control the valves, a custom controller was made based on a PIC18F1320. The controller accepts a serial input from the ROV and uses that to control eight switches, each one controlling a single valve. Indicator Light Emitting Diodes (LEDs) are placed on the control board to show when a channel is being triggered. These LEDs, along with a pressure gauge, are easily visible from a camera so the pneumatics system can be continuously monitored. As a fail-safe, the board is programmed to shut all valves if the signal is lost for longer than four seconds.

*Figure 5. Pneumatic Control Can*

## 5 CONTROL SYSTEMS

### 5.1 Architecture

The control software for Keto was written by Eastern Edge Robotics using Microsoft's .NET Framework and the C# object oriented programming language. The software uses a multi-tier architecture following the Model-View-Controller (MVC) design pattern. The device tier allows seamless interaction with physical devices, the input control tier accepts input from the pilot, and the display tier provides feedback from Keto. Communication between the tiers is facilitated by the publish-subscribe pattern, which decouples the tiers and decreases the dependencies amongst them.

#### 5.1.1 Device Tier

The device tier consists of a set of classes that mirror the physical devices on Keto. This allows software to be quickly developed without having to consider the hardware level communication. Each device class is developed independently of the control software so it can be tested in isolation. The device classes' inputs and outputs are designed to operate in the range of ±1000 and are then linearly mapped to the range of the device. This allows a developer to interact with a device without knowing its range.

### 5.1.2 Input Tiers

The input control tier consists of input interface classes and facilitates interaction between the user and the control system. Each interface waits for a change in state and publishes an event that can be consumed by the control scheme controllers. The input tier supports Phidget input/output boards, Microsoft® Xbox-compatible controllers, and generic gamepad devices. Control inputs are divided into three primary categories: axes, buttons, and points of view. Axes provide a continuous value range, buttons provide on and off functionality, and points of view provide an angle between 0 and 360 degrees.

### 5.1.3 Display Tier

The display tier is responsible for displaying the video feeds and telemetry data, and allows the pilot to control thruster power, tool power, and to make measurements. It consists of a multi-window environment that can be configured to meet the needs of the pilot and the mission tasks. The video window, along with showing a live video feed, uses a dedicated display to relay important telemetry and mission data. A thruster control window allows the pilot to adjust thruster power levels while a tooling window adjusts tool power levels. A measurement window can be used to grab a frame from a video feed and perform various measurements. Other windows include the input and settings configuration windows.

## 5.2 Mission Specific Software

### 5.2.1 Measurement Task and Zebra Mussel Calculation

The control software uses an image containing the hull and a known length to determine the dimensions of the shipwreck. The software counts the number of pixels in the known length and creates a pixel-to-length ratio that is applied to unknown lengths to calculate the dimensions. As the estimation of zebra mussels is dependent on the dimensions measured, it is critical to ensure the measurements are correct. The accuracy of this measurement depends on the resolution of the image, with more pixels contributing to a more accurate calculation. Significant radial and tangential distortions are introduced when light transitions through a curved surface from the surrounding water to the air in the camera pod. These distortions are counteracted in software using a remapping technique in order for the pixel-to-length calculation to be correct.

### 5.2.2 Photomosaic

A photomosaic of the shipwreck is created using a graphical utility that was developed by Eastern Edge Robotics to stitch five distinct photographs into a single detailed image. To stitch an image with its neighbours the utility allows for each to be individually moved, cropped, resized and skewed.

# 6 ELECTRONICS

## 6.1 Submarine Control Can

The SCC (Figure 6) houses the onboard electronics including components for voltage conversion, communications to the surface, video, thruster control, tooling control, and data acquisition. The SCC is a 36.5 cm long, 5-inch (12.7 cm) clear-cast, acrylic cylinder sealed at both ends with custom-machined Lexan™ end caps. SubConn® low profile multi-pin bulkhead connectors provide electrical connections to the thrusters, the PCC and other external components.

There are four DC-DC voltage converter boards inside the SCC that reduces the 48 V input to:

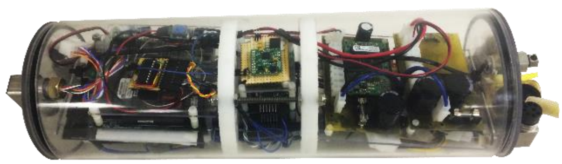


*Figure 6. Submarine Control Can*

- 5 V and 12 V for control circuits;
- 12 V for the tooling supply;
- 28 V to power the thrusters.

The converters are rated for an input voltage of up to 75 V and are fused at 5 A or 10 A, as required, for safety. Each of the voltage converters are mounted on Printed Circuit Boards (PCBs) designed and populated by members of the electrical team but manufactured by Technical Services at Memorial University.

The remote unit of the Focal™ Model 907 multiplexer facilitates communication to and from the ROV using one RS-485 channel, four RS-232 channels and three standard definition video signals. Eastern Edge Robotics built a thruster controller using a PIC18F1320 microcontroller. It receives an RS-232 signal and communicates with the thrusters via six I2C lines and a single clock line. Internal sensor communication is provided by a B&B Electronics RS-232 Data Acquisition Module 232SDA12 providing 11 analog inputs with a 0 V to 5 V range.  Tooling is controlled via four Pololu Qik 2S12V10 motor controllers, each with two channels of Pulse Width Modulation (PWM). The Qiks allow flexibility in communication as they are capable of receiving RS-232 or Transistor-Transistor Level (TTL) serial data.

## 6.2 Cameras

Keto uses a variety of cameras to suit the client's needs. Two moving cameras are permanently mounted at the forward and aft of the vehicle while several small stationary cameras can be mounted on the chassis. The forward permanent camera (Figure 7) is an SD pan and tilt camera that is primarily used for general piloting. The camera can pan a full 360° and tilt 90° to give the pilot a view of most components on the ROV. The aft camera is a HD tilting camera used for tasks requiring precise measurements. The HD camera has full 180° movement in the vertical plane allowing the pilot to observe the tether or obtain an overhead view of the seafloor.

The two moving cameras are HD2CP board cameras capable of HD and SD configurations, allowing them to be interchanged. The pan and tilt movement of both cameras is achieved using Hitec servos controlled by a Pololu Micro Maestro servo controller. SD video from the pan-tilt camera, as well as the stationary cameras, is sent to the SCC's multiplexer via coaxial cables. The SD video signals share the same fiber as the vehicle telemetry and control. The HD video is sent to a Broadata Mini-3GHD fiber optic digital video system and sent to the surface using a dedicated fiber.

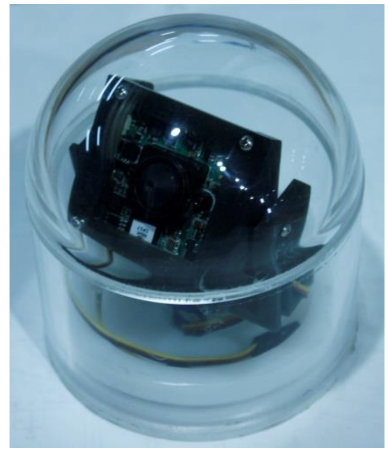


*Figure 7. Keto`s piloting camera*

## 6.3 Sensors

### 6.3.1 Conductivity Sensor

Since salinity in water is inversely proportional to resistance, a conductivity sensor is used to measure the presence of sinkhole groundwater. The sensor is based on a voltage divider circuit in which the load resistor is the groundwater between two copper electrodes. If the load resistance is low then the voltage drop across it will approach zero, and when the resistance is high the voltage drop will be close to the input voltage.

To prevent corrosion of the electrodes, power to the voltage divider circuit is supplied by a ±12 V oscillator circuit that uses an operational amplifier and a MAX232N chip. The output of the voltage divider is fed into an instrumentation amplifier to ensure an output voltage between 0 V and 5 V, the required signal level for the analog to digital converter. The electrodes are contained within a PVC pipe, the circuitry is housed in a watertight container designed and built by Eastern Edge Robotics, and a dedicated tether is used for power and communication.

### 6.3.2 Internal Sensors

Environmental conditions inside the SCC are monitored by three analog sensors that are sampled by the 232SDA12. A Microchip TC1047A sensor, capable of recording temperatures from -40°C to 125°C, monitors the internal temperature. A Honeywell HIH-4030 sensor, capable of recording relative humidity levels from 5% to 95%, monitors humidity to alert the operator in the event of water ingress. A Freescale Semiconductor MPXV5050GP pressure sensor monitors internal pressure, with a rise in pressure indicating a leak. Voltages are monitored, using voltage divider circuits, to ensure that the outputs from the onboard power supplies are within an acceptable range.

### 6.3.3 External Pressure Sensor

A Keller America Preciseline pressure transducer is used to measure depth down to approximately 20 m. It is threaded into the end of the SCC to allow access to the external environment and communicates using RS-485. It has a range of 300 kPa, is referenced to a vacuum, and has an accuracy of ±0.1% due to its floating isolated piezo-resistive sensor.

#### 6.3.4 Navigational Sensors

The SCC contains a CH Robotics UM6-LT orientation sensor that is composed of an accelerometer, a gyroscope, and a compass. An internal microprocessor calculates pitch, roll, and yaw from the sensor values and communicates them to the TCM via RS-232.

# 7 PAYLOAD TOOLS

## 7.1 Agar Collector

The Agar Collector (Figure 8) is a 15 cm long, 2-inch (5.08 cm) Lexan™ tube that is serrated at one end and fitted with a 3D printed end cap at the other. The end cap houses a ¼-inch (0.635 cm) PVC hose, connected to a 12 V bilge pump, and a ⅛-inch (0.3175 cm) quick connect fitting used as an exhaust. To collect agar, the ROV inserts the serrated part of the tube into the sample. The bilge pump provides suction and the ROV applies downwards thrust to core the agar and pull it inside the tube. Velcro® lining inside the tube prevents loss of the sample.

*Figure 8. Agar Collector*

## 7.2 Handy Anchor Grabber

*Figure 9. Handy Anchor Grabber*

The Handy Anchor Grabber (Figure 9) is a tool designed specifically to pick up the Danforth anchor from the seafloor. A hook, fabricated from Lexan™, is attached to a threaded rod such that it is free to rotate forward and backward. A bracket with an embedded rare earth magnet is fixed to the threaded rod. The grabber is shaped such that when Keto touches down, the hook is pushed back and the magnet is used to collect the anchor chain. When Keto rises, the hook rotates to the center of the chassis and the chain falls into the hook, securing the anchor.

## 7.3 Cigar Cutter

The Cigar Cutter (Figure 10) is constructed of Lexan™ and High-Density PolyEthylene (HDPE) plastics and allows the ROV to tightly grasp and manipulate objects. A pneumatic cylinder drives a symmetrical hook that extends a total of 6.35 cm and recesses into a pinch point. This provides a sufficient opening to grasp objects.

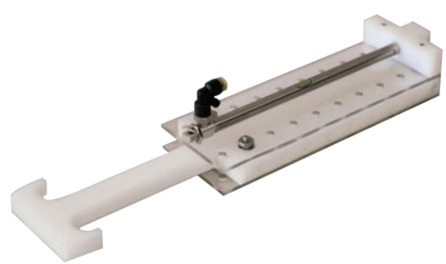


*Figure 10. Cigar Cutter*

### 7.4 Bungee Bucket

*Figure 11. Bungee Bucket*

The Bungee Bucket (Figure 11) is composed of eight elastic chords, spaced 2 cm apart, which span from port to starboard across Keto's tooling skid. This system is designed to deform around the profile of debris, trapping objects within the ROV chassis. This tool has been assembled using repurposed materials from previous contracts.

### 7.5 Pinball Wizard

*Figure 12. Pinball Wizard*

The design of the Pinball Wizard (Figure 12) was inspired by the flippers found in a pinball machine. Two Lexan™ flippers are connected to the tooling skid with hinges and synchronously actuated by two pneumatic cylinders. The cylinders are activated as the ROV approaches the plate, opening the flippers. When in position, the cylinders are deactivated and the flippers snap shut, enclosing the plate within the tooling skid.

### 7.6 Flex Handle

*Figure 13. Flex Handle*

Eastern Edge Robotics has developed and manufactured a simple tool (Figure 13) for opening and closing doors. Clear plastic tubing containing a piece of rod is mounted inside a piece ½-inch (1.27 cm) PVC pipe. The flexibility of the plastic tubing allows the tool to conform to its surroundings.

## 8 CHALLENGES

### 8.1 Technical

Previous ROVs from Eastern Edge Robotics have had electronics split between two canisters. This design was due to brownout problems that occurred when brushless thrusters were initially installed. At the time this was thought to be a power shortage issue, and a second thruster power supply was added. These supplies took up the majority of space inside the canister, requiring a second canister for the remainder of the electronics. It was later discovered that the issue was unrelated to the thrusters and the second power supply was unnecessary. Size restrictions in the latest contract made the dual-canister model impractical and the electrical team integrated the electronics into a single unit.

Several steps were identified to make this process manageable and to ensure the end product functioned correctly. The first of these steps was to identify and create detailed documents of all components and their interconnections. As the canisters were disassembled, photographs were taken of each system and notes were made detailing unintuitive design decisions.

To optimize space, circuits were redesigned to fit on PCBs and small circuits were consolidated into single boards. Power distribution was made simple and easily expandable by creating centralized power buses using the same style of connectors for all components. During redesign, the onboard systems had additional safety features added such as fusing, reverse polarity protection diodes, and indicator LEDs.

The biggest drawback to using a single canister is the limited flat bulkhead space available for external connections, such as power and communication to thrusters, tooling motors, cameras, and the pressure transducer. This, along with designing the PCBs, was a huge challenge for the electronics team.

### 8.2 Non-Technical

This year, Eastern Edge Robotics made the transition to a new location, the Marine Institute, which offered various benefits such as access to new equipment, hardware, and more space. However, the move resulted in various challenges that delayed project progress with regards to the desired timeline.

While the new location provided more space, communication was hindered as teams were physically separated throughout the building. This challenge was overcome through the use of the new project management structure that required the team to regularly report on progress. Through enhanced communication, the team was able to quickly adapt to the transition and complete the project on time.

The new workshop and equipment required the team to learn new safety procedures. The team also had to become acquainted with new fabrication software, presenting an opportunity to expand technical expertise. As the workshop is shared with students of the Marine Institute, Eastern Edge Robotics ensured proper storage of tools and materials such that they were only used by authorized individuals.

## 9 TROUBLESHOOTING TECHNIQUES

Troubleshooting of the control software is facilitated by a system simulator that was written to allow bi-directional communication with a virtual Keto through serial interfaces. To test the control signals sent to the ROV, the simulator reads and displays serial data produced by the control software. Warning indicators and sensor telemetry display is tested by sending simulated data to the control software from the simulator. This allows the testing of the control software without the use of the tether and ROV electronics, eliminating problems that they may introduce. Using the simulator also permits the software team to continue development using laptops without the specialized hardware of the TCM. This allows the control software to remain in a stable state for continuous and full testing of tooling and electronics on the ROV.

# 10 FUTURE IMPROVEMENTS

*Figure 14. Current TCM Setup*

Setup of the TCM has been a longstanding problem for Eastern Edge Robotics as the system is complex with many interconnecting, discrete parts. The number of required power and communication lines that must be connected makes setup time-consuming and prone to error. It is also very heavy and large, covering several square meters, making it difficult to move. In the future, Eastern Edge Robotics would like to improve the system through the design and fabrication of a new, single-unit TCM that will enclose all parts and use lighter materials to reduce the overall weight. The new design would have power supplies, monitors, surge protection and other systems essential to ROV operation pre-connected, greatly reducing setup time and possibility of error. Other features would include wheels to improve mobility and compartments to store peripherals, such as the keyboard, joystick and mouse, which must remain independent.

# 11 LESSONS LEARNED

## 11.1 Technical

During integration and re-design of the electronics, it was determined that PCBs were the best option for consolidating circuits. Each member of the electrical team became familiar with the industry standard CadSoft EAGLE™ PCB Design Software to create the new boards.

When libraries containing the required parts were unavailable, team members built custom components in EAGLE™. The building of components involves creating a symbol with the correct pin-out, a package with precise dimensions, and then connecting the symbol with the package.

After the first iteration of the boards had been printed, the team learned the importance of checking details (like pin diameter and orientation) from component datasheets. Since traces on the PCB are flat and thin, they must be wide enough to allow the passage of several amps and withstand repeated soldering. The entire first iteration, from design to implementation, was a valuable learning experience for the electrical team and has resulted in an improved second iteration of PCBs.

## 11.2 Interpersonal

The implementation of Eastern Edge Robotics' new project management structure resulted in difficulties within the organization. The remodeled structure greatly changed how members participated in the project and how tasks were delegated. It is crucial that all members within an organization work as a single entity to achieve a common goal, so all members had to be in compliance with the implementation for it to be successful. At the beginning of the project, the system was not fully defined which resulted in some confusion within the team. As time progressed, the team learned to appreciate the improved levels of communication. Members became more comfortable with the process and as the project continued the team exhibited greater progress than in previous years.

# 12 REFLECTIONS

## 12.1 Senior – Bethany Randell

I have been a member of Eastern Edge Robotics during my five-year Electrical Engineering Degree from Memorial University of Newfoundland (MUN). Combined with three years of competition at the high school level, I have competed six times internationally. During my final year I had the privilege of being selected the team's CTO – Electrical (Figure 15). Time spent with Eastern Edge Robotics has been the highlight of my time at MUN, and I believe that it has been an integral part of my education. The skills acquired from my time with Eastern Edge Robotics have helped me in the classroom, the lab, and the workplace.

Robotics was the catalyst that made me choose engineering as a career and has kept me interested in the field when the workload of classes seemed overwhelming. Somehow spending sleepless nights working on a robot is more appealing than spending one extra hour in a classroom and the feeling of seeing a robot go through its paces for the first time is better than getting a high grade on an exam.

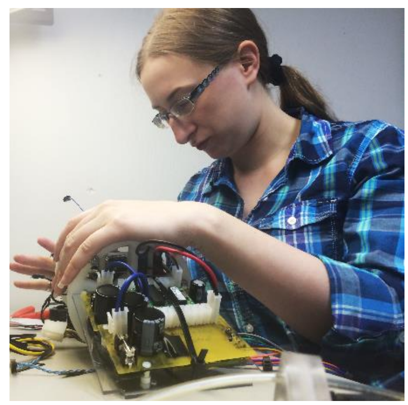


*Figure 15. Bethany Randell*

Through Eastern Edge Robotics and the MATE competition I have been to the top of a volcano, experienced NASA's neutral buoyancy lab, watched a rocket launch, and walked in a red cedar forest. All of these experiences were shared with some of the greatest teammates and friends in the world. For all of the cool things we've seen and done while away, nothing compares to the feeling of the correct feedback from a sensor flash on the computer screen, leaving the judges speechless after a flawless presentation, or the sound of the team cheer after a successful (or unsuccessful) run. The team has gone from despairing moments when components break at the last minute to the height of celebration when we accomplish a task no one else can. My experience has been a roller coaster of success, but being a part of this team is something I will remember for the rest of my life.

## 12.2 Junior – Calvin Gregory

I am a second year mechanical engineering student at MUN and this is my first year with Eastern Edge Robotics. Building an ROV from scratch seemed like the perfect challenge with my particular skill set and interests. I came to the team without any previous experience with ROVs or much relevant experience other than those covered in my first year of engineering courses. I joined expecting to be of limited use, but also expecting to learn.

*Figure 16. Calvin Gregory - CTO Structural*

After some initial exploration and moving amongst the different teams, I settled into the mechanical design team. I quickly accepted responsibility for the ROV chassis design and was eventually put in charge of structural engineering and given the role of CTO – Structural (Figure 16). With no previous experience working on ROVs, I was frequently asking for the opinions of the senior team members on what had worked for them in the past. Everyone I asked was helpful and open to answering even my most basic questions. The team camaraderie was immediately apparent and I was happy to be so easily accepted into the group.

This was my first experience working with a large, inter-disciplinary team. I believe that the experience I've gained working with the team is a far better representation of what I'll eventually find in industry than what the engineering program alone can provide. I've enjoyed applying the concepts and skills I've learned in school, while adding many more to my repertoire. It has been a great experience making friends among the team members and connecting with potential future colleagues. Thus far, I've enjoyed my time with Eastern Edge Robotics and I look forward to returning for next year's competition to share my skills and experiences with future members.

# APPENDIX A – SAFETY CHECKLISTS

**PRE FLIGHT SAFETY CHECKLIST**

- ☐ Electronics pressure release valve is closed
- ☐ Electronics canister is sealed
- ☐ No electronic wires are exposed
- ☐ Underwater connections are seated
- ☐ Tether is untangled and secured
- ☐ Pneumatics canister is sealed
- ☐ Pneumatic lines are secured and connected
- ☐ Pneumatic pressure reading are within safe limits
- ☐ No leaks in pneumatic system
- ☐ Controls in off or neutral position
- ☐ Chassis hardware is tightened
- ☐ Personal are clear from ROV

*POWER ON*

- ☐ All electronics have power
- ☐ Thruster respond to controls
- ☐ Pneumatic channels activate
- ☐ Emergency stop system tested

**LAUNCH AND RECOVERY SAFETY CHECKLIST**

- ☐ Deck crew wearing PFDs
- ☐ Deck crew wearing closed toe shoes
- ☐ Deck crew wearing eye protection when required
- ☐ Two members launch crew ready

*LAUNCH ROV USING HANDLES*

- ☐ Launch team clear from ROV

*PERFORM MISSION TASKS*

- ☐ Deck crew ready to receive ROV
- ☐ ROV controls locked once in recovery area

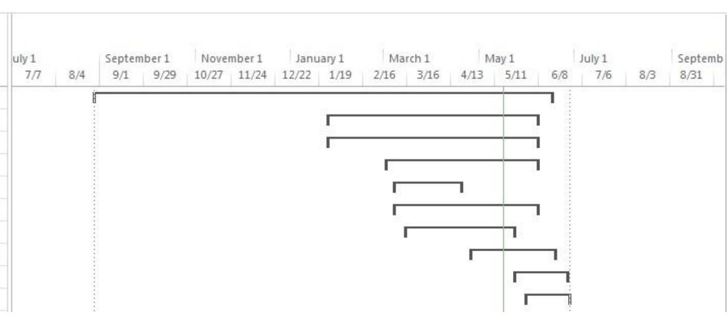
*RECOVER ROV FROM WATER AND PLACE ON DECK*

**POST FLIGHT SAFETY CHECKLIST**

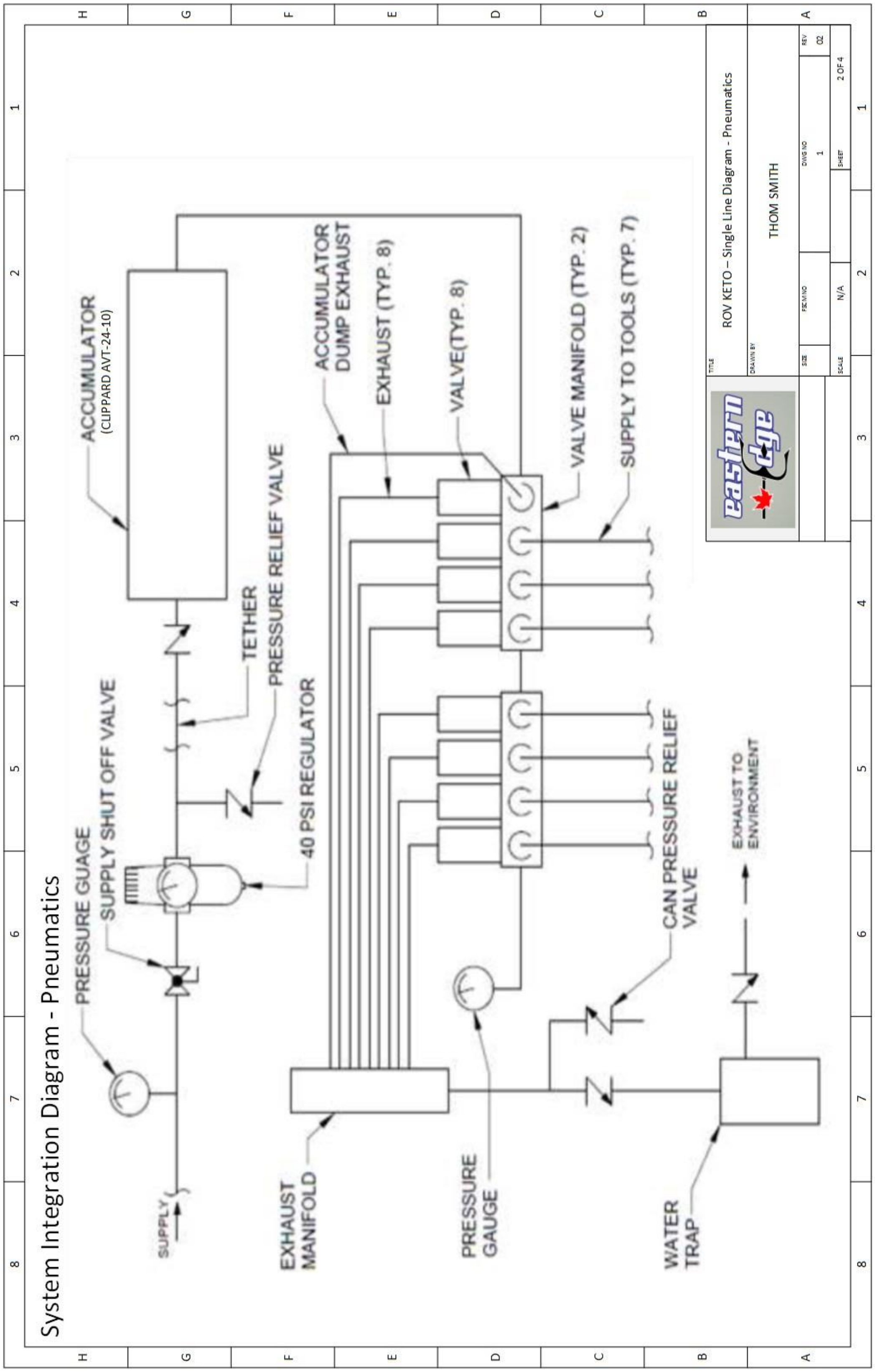
- ☐ ROV is powered off
- ☐ Tether disconnected and bundled

# APPENDIX B – GANTT CHART

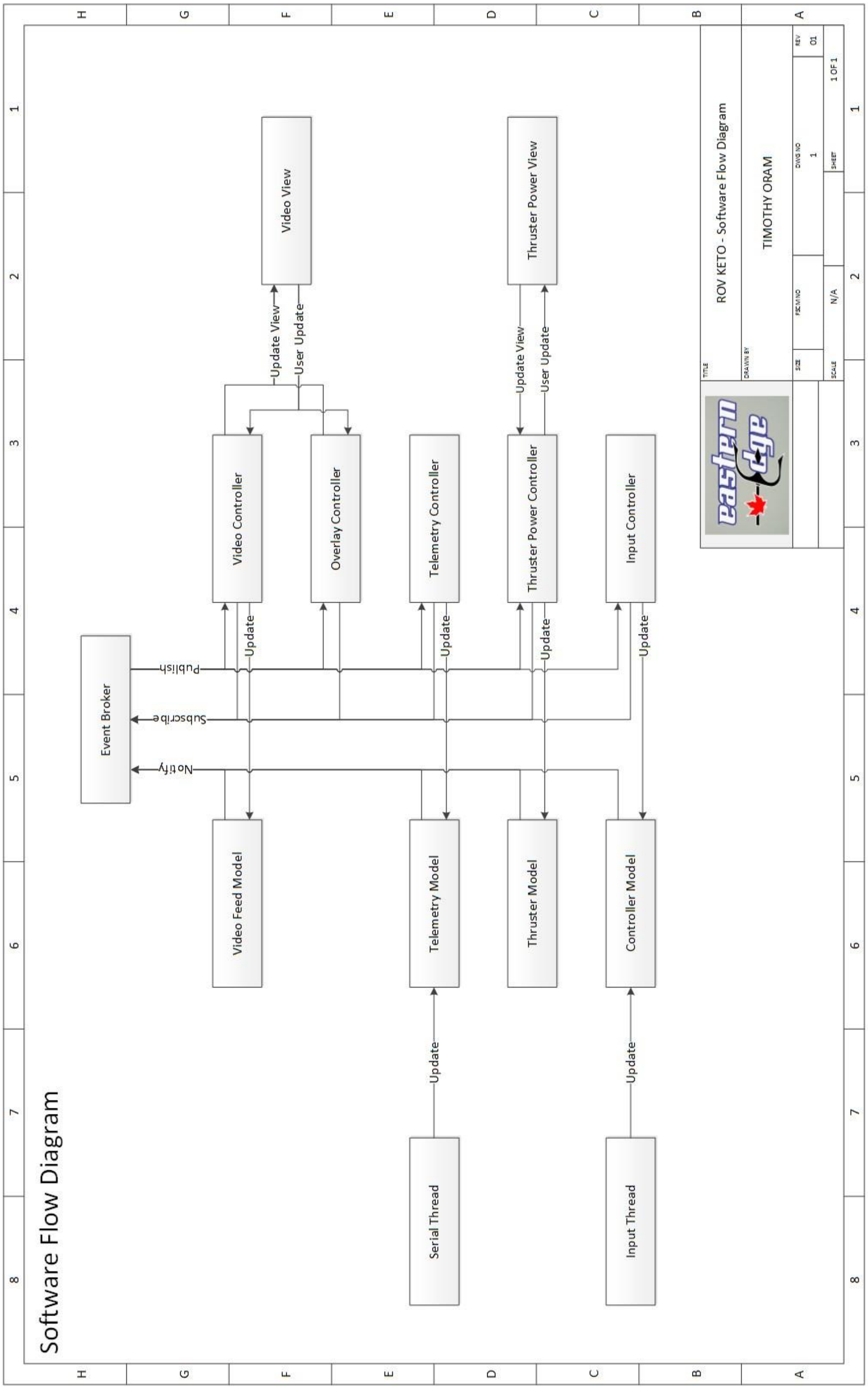
| Task Name | Duration | Start | Finish |
|---|---|---|---|
| MATE Requirments | 230 days | Thu 8/29/13 | Mon 6/16/14 |
| ROV | 113 days | Sat 1/25/14 | Sat 6/7/14 |
| Payload Tools | 113 days | Sat 1/25/14 | Sat 6/7/14 |
| Electronics | 86 days | Mon 3/3/14 | Sat 6/7/14 |
| Chassis Design | 38 days | Sat 3/8/14 | Sat 4/19/14 |
| Software | 81 days | Sat 3/8/14 | Sat 6/7/14 |
| Tech Report | 62 days | Sat 3/15/14 | Fri 5/23/14 |
| Poster | 48 days | Sat 4/26/14 | Wed 6/18/14 |
| Competition & Operation | 29 days | Sat 5/24/14 | Thu 6/26/14 |
| Engineering Panel | 24 days | Sat 5/31/14 | Fri 6/27/14 |



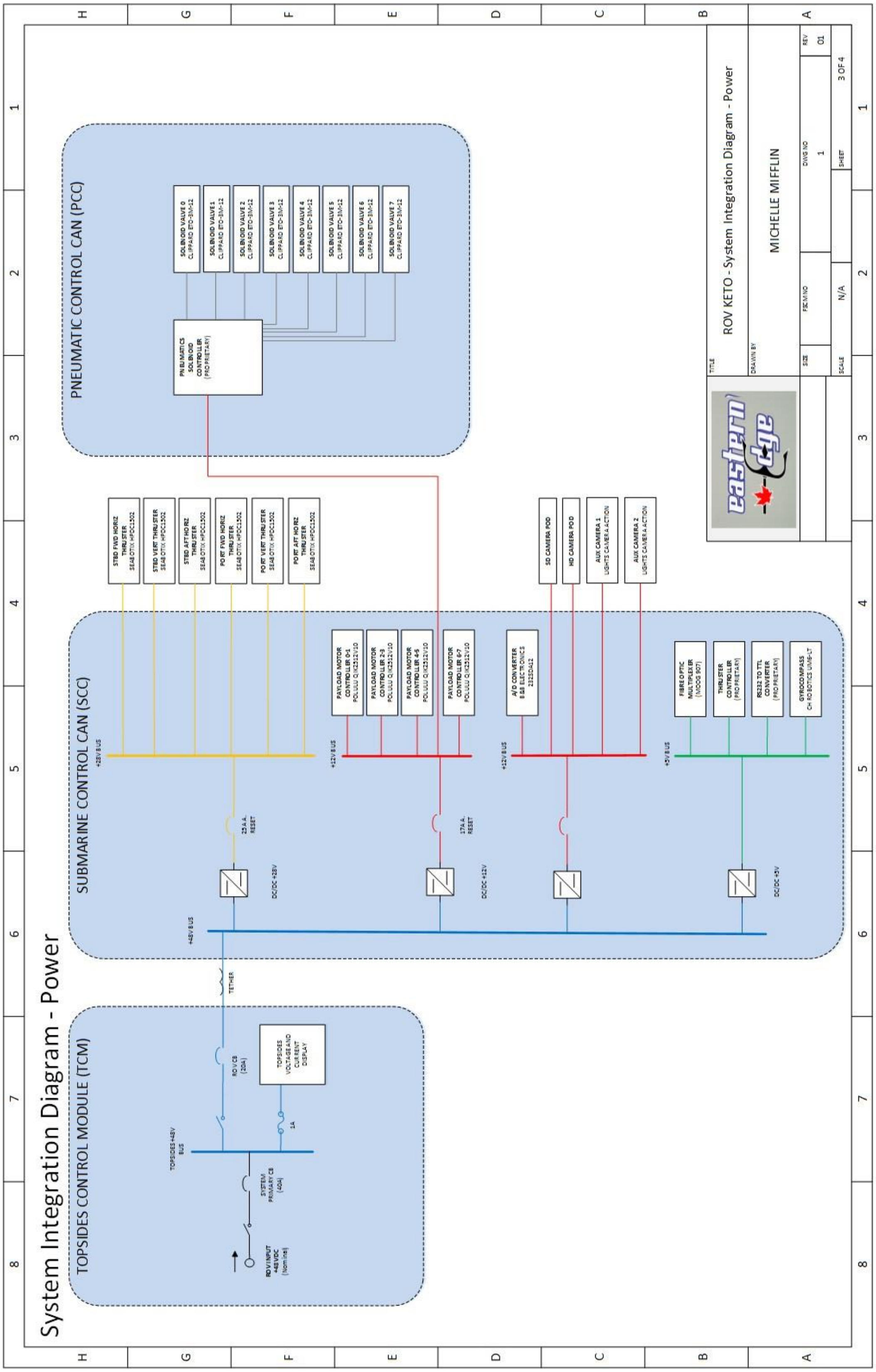
# APPENDIX C – PNEUMATICS SID

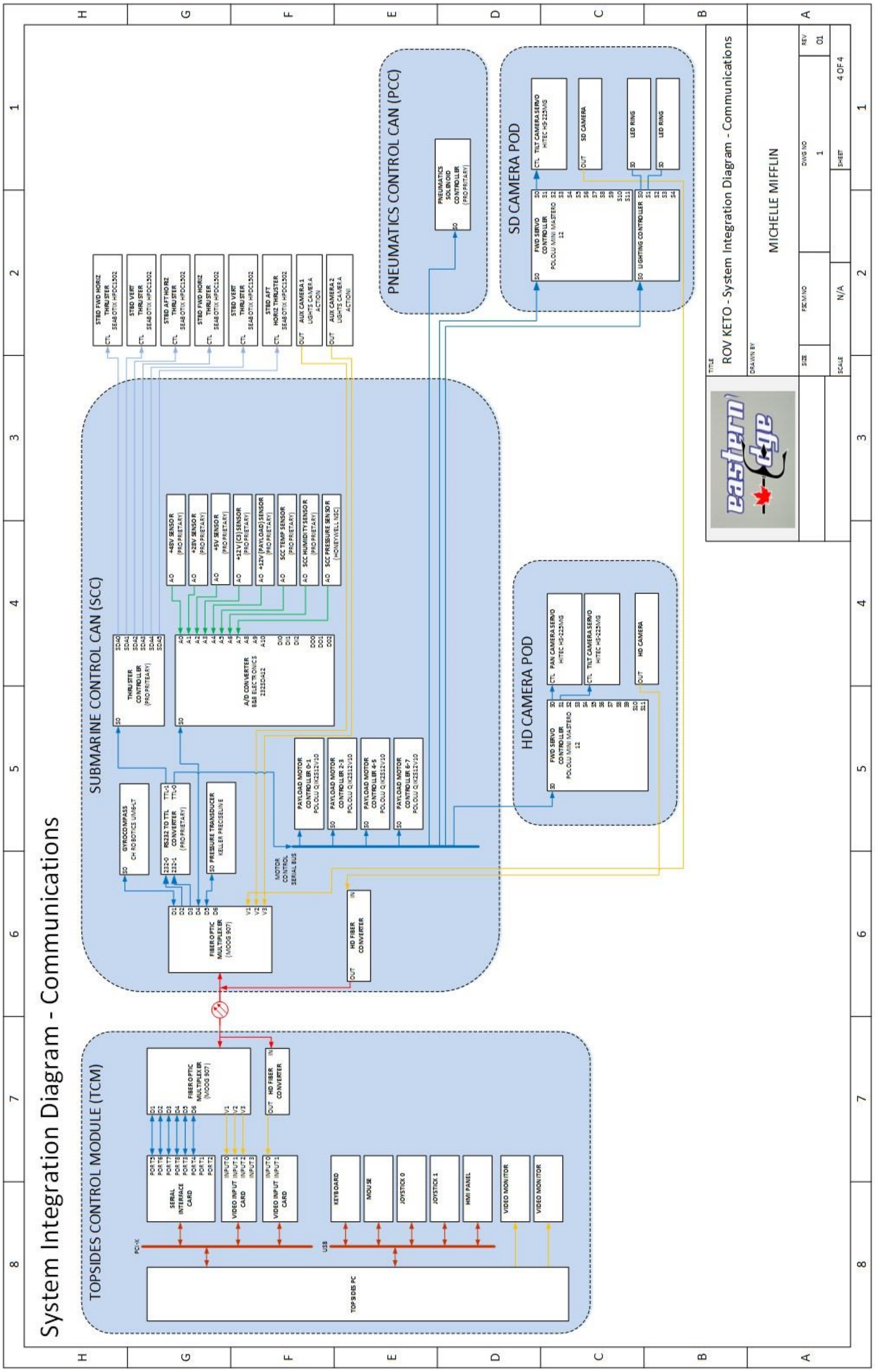


# APPENDIX D – SOFTWARE FLOW DIAGRAM



# APPENDIX E – ELECTRONICS SIDS




System Integration Diagram - Communications
TOPSIDES CONTROL MODULE (TCM)
SUBMARINE CONTROL CAN (SCC)
PNEUMATICS CONTROL CAN (PCC)
SD CAMERA POD
HD CAMERA POD
ROV KETO - System Integration Diagram - Communications
MICHELLE MIFFLIN

# APPENDIX F – SELECTED MECHANICAL DRAWING: TETHER PENETRATOR