eastern Edge robotics

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

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Andrew Troake	Chief Operations Officer
Julia Dawe	Safety Officer/Software
David Drover	System Integration
Liam Gregory	System Integration/Pilot
Stephen Snelgrove	System Integration
Zachary Bennett	Electrical
Stefan Boon-Petersen	Electrical
Stephen Fudge	Electrical
Jadzia Penney	Electrical
Shane Tetford	Electrical
Patrick Whelan	Electrical
Bedir Acar	Mechanical
Keagan Brown	Mechanical
Jennifer Clarke	Mechanical
Mark Johnson	Mechanical
Devon Tobin	Mechanical
Tim Squires	Mechanical
Ziad Ayman Abdelrahman	Software
Russell Corbett	Software
Leo Gilbert Software	Software
Alexander Kennedy	Software
Martha Snelgrove	Software

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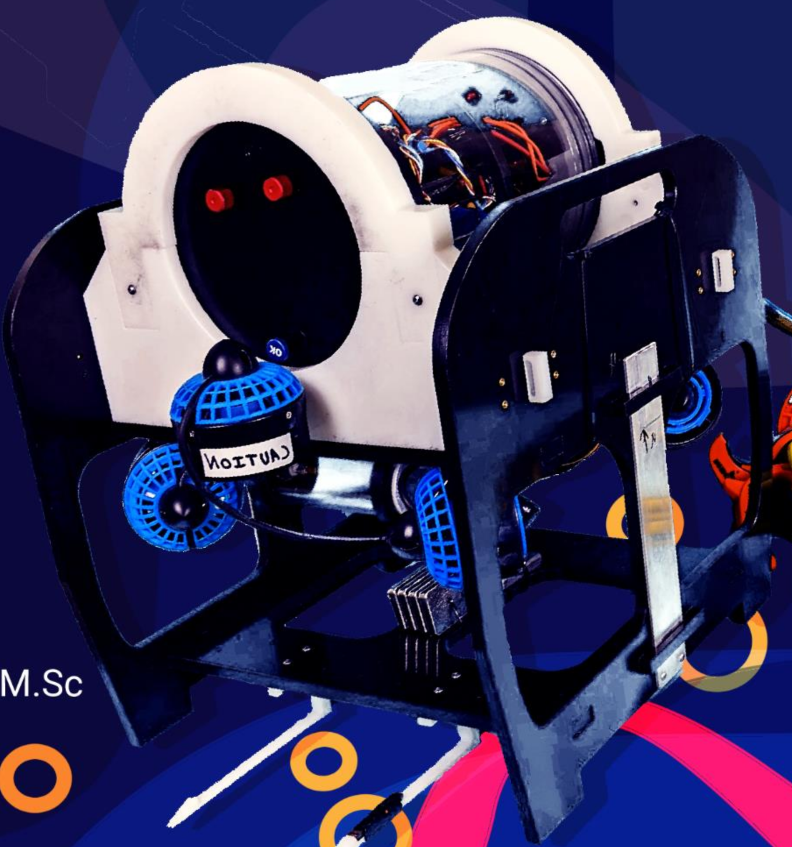

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Technical Documentation

Abstract

Eastern Edge Robotics (Eastern Edge) is a multi-disciplinary Company consisting of twenty-three employees focused on designing, manufacturing, and operating Remotely Operated Vehicles (ROVs). Eastern Edge is based out of the Marine Institute of Memorial University of Newfoundland with twenty years of experience, eighteen request for proposals (RFP), and four previous contracts awarded. Eastern Edge's employees have a diverse set of skills and backgrounds spanning from computer science, ROV technology, engineering, and ocean mapping. This fosters collaboration and creative problem solving, making Eastern Edge a reliable choice for the 2022 contract.

For the 2022 contract, Eastern Edge has developed an ROV, Happy Adventure, from the ground up using lessons learned from previously designed ROVs. Happy Adventure is named after the vessel commanded by the legendary Newfoundland pirate Peter Easton. Known for his time serving as a privateer for the British Empire and later his career in piracy, Peter Easton has a legacy as a force to be reckoned with.

Happy Adventure is designed to meet and exceed the requirements of the RFP. Happy Adventure has been constructed with revolutionary safety features, a custom printed circuit board based electrical system, and a modular software framework. Happy Adventure is designed for operations in marine renewable energy, offshore aquaculture industries, blue carbon environmental initiatives, and arctic exploration. Happy Adventure and weighs 23.5 kg and has a maximum size of 500 mm L x 420 mm W x 580 mm H. With a fair market value of $5,043.11 USD, Happy Adventure is an effective, low-cost solution built by dedicated employees.

Figure 1: Company Employees, Photo taken at the Marine Institute
(Back Row, L-R): *Bedir Acar, Liam Gregory, Andrew Troake, Charity Talbot, Russell Corbett, David Drover, Alexander Kennedy, Stefan Boon-Petersen, Zachary Bennett*
(Front Row, L-R): *Stephen Fudge, Ziad Ayman, Patrick Whelan, Mark Johnson, Tim Squires, Jadzia Penney, Shane Tetford, Julia Dawe*
Missing: *Stephen Snelgrove, Martha Snelgrove, Keagan Brown, Leo Gilbert, Devon Tobin, Jennifer Clarke*

Table of Contents

Safety

Safety Philosophy and Protocols

At Eastern Edge, the safety of our employees, the public, and the environment is our highest priority. The Company achieves an open safety culture by discussing safe practices during toolbox talks and by completing Job Safety Analysis (JSAs). In addition, an Operational Safety Checklist (OSC) outlined in Appendix A is required to be completed prior to starting any task, thus ensuring all employees have the proper safety mindset and training on all tools and equipment.

The Company's toolbox talks, performed at the beginning of each work day, highlight any necessary safety protocols and best practices relevant to the production stage. Toolbox talks encourage all employees to follow safe practices and identify any concerns before starting any work. All safety documents are reviewed and signed off by the Chief Safety Officer (CSO). JSAs and OSCs are completed for all tasks and are required before vehicle deployment.

All employees at Eastern Edge have a safety passport, indicating that they have completed the required training for the tools and equipment they will use. This ensures that employees understand how the equipment works, understand what personal protective equipment (PPE) is required, and overall best practices. Company mentors or senior employees complete the training for the safety passports. The use of safety passports allows for a record of training, ensures all employees are properly trained, and drastically reduces the probability of safety-related incidents.

Hazardous products that are used by the Company are contained within a dedicated cabinet in the Company storage room. The Company's Safety Data Sheet (SDS) handbook is accessible for all employees before access to hazardous materials.

Vehicle Safety Features

Happy Adventure is outfitted with all safety features outlined in the 2022 contract. Happy Adventure's safety features include, but are not limited to: a 30 Amp fuse within 300 mm of the ROV power supply; thruster guards rated to IP20 standards; smooth and rounded edges on the vehicle and all auxiliary components; warning labels on all moving components and power connections; and strain relief located on both ends on the vehicle's tether. The software of Happy Adventure features a kill switch which shuts down the systems software and an automatic shut down in the case of a loss of communications.

Logistics

Company Organization

For the 2022 contract, Eastern Edge has adopted a new dynamic Company structure to maximize employee contribution and opportunities. The top-level operations, including scheduling, budgeting, Company administration and management are performed by the Chief Executive Officer (CEO) with the assistance of the Chief Operations Officer (COO). The CSO handles safety protocols and training authorization. The Company is subdivided based on sub-systems of Happy Adventure or specifications from the RFP. A division consists of a lead alongside two to four employees. Divisions are created by the CEO and the COO as required throughout the development process. To ensure the smooth integration between the divisions and their respective systems, a separate division titled “Systems Integration” led by the COO consisting of three senior employees. Figure 1 displays the organizational structure of the Company.

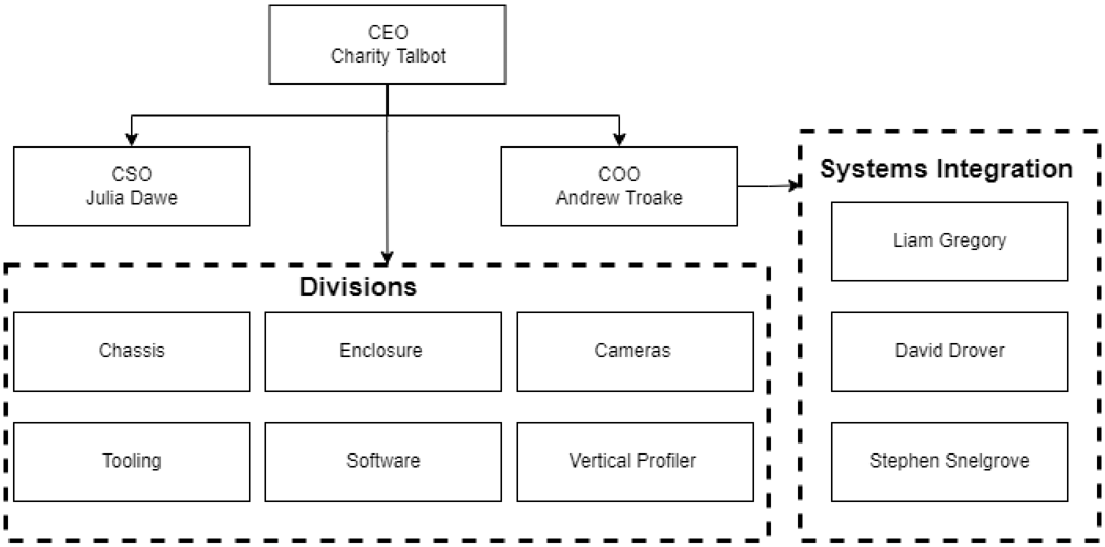

Figure 1: Company Organizational Breakdown Structure. Photo Credit: Charity Talbot

This structure allows for clear and concise communication throughout the development of Happy Adventure and leadership opportunities all employees.

Every two weeks the Company holds a Company-wide meeting called Edge Day. On Edge Day, the leads from all divisions of the Company present the recent designs and works to the CEO, COO and the rest of the Company. This provides an opportunity for design feedback and to re-evaluate deployment of resources as needs change.

Schedule

Eastern Edge began the development of the 2022 RFP in September of 2021. This involved developing a schedule in the form of a Gantt chart using Microsoft Project (Appendix B). The schedule was developed by the CEO and COO in collaboration with the Systems Integration division. The schedule is broken down by division and includes all steps to achieve the completed product.

Also, in September of 2021, the Company held an open house and new member orientation, with the intent of recruiting new employees. The Company held meetings twice a week throughout year with the first four months dedicated to training new employees and reviewing safety protocols. The design of Happy Adventure began in January of 2022, with manufacturing beginning in February of 2022. Once Happy Adventure was fully constructed and operating, the Company began the testing and refinement phase from April 2022 onward.

Budget

After the release of the RFP, the divisions of the Company proposed a preliminary budget to the CEO and COO for the required components and materials for completion of the contract. The preliminary cost proposed for the construction of the ROV was $3,907.24 USD. The cost breakdown can be found in Table 1 on the following page. Included in the budget is the preliminary estimate for travel to and from Long Beach. Initially, the cost of travel and accommodations was $33,193.75 USD. The administrative budget, estimated to be $2,193.55 USD was determined from printing costs, Company uniforms and fees associated with competition registration.

Table 1: Project Budget and Expenditures in USD currency. Credit: Andrew Troake

Eastern Edge Robotics Budget 2022			
Description		**Budgeted USD**	**Expenditure USD**
Vehicle Expenses	Electrical & Software	$885.47	$746.28
	Mechanical & Payload	$3,021.77	$2,564.14
Vehicle Budget Total		**$3,907.24**	**$3,310.42**
General and Administration		**$2,193.55**	**$1,949.81**
Travel Expenses	Flights (15 employees)	$14,062.50	$13,000.00
	Accommodations (11 rooms, 7 nights)	$12,031	$11,000
	Ground Transportation	$2,000.00	$1,890.00
	Misc. Travel Costs	$5,100.00	$4,500.00
Travel Budget Total		**$33,193.75**	**$30,390.00**
Total		**$39,294.54**	**$35,650.24**

Project Costing

After developing the budget for the 2022 RFP, the Company began procurement of all components required for the fabrication of the designed vehicle. The Company decided to manufacture a completely new ROV; however, several components were re-used from stock. This allowed the Company to save money on the fabrication of Happy Adventure. Eastern Edge remained within budget, as indicated in the cost breakdown shown above in Table 1. Appendix C shows the cost of Happy Adventure's purchased components for this RFP totaling $3,310.42 USD. The fair market value, including donations and reused components, of Happy Adventure is $5,043.11 USD.

Design Rationale

For the 2022 RFP, Eastern Edge used a multi-step design process. This ensured cross-system compatibility throughout the development of Happy Adventure. This process began with brainstorming, initial designs, and prototyping - resulting in a final working product.

During the design and integration process, many factors had to be considered. Creating a stable, easy-to-use vehicle with intuitive piloting controls was the main focus during system design and integration. Every design discussion began with the critical question of whether to build vs. buy new components. Using this methodology, Eastern Edge has produced a vehicle capable of completing all tasks set out in the 2022 contract. A render of Happy Adventure's final design, with a weight of 23.5 kg and a maximum size of 500 mm L x 420 mm W x 580 mm H, can be seen in Figure 2.

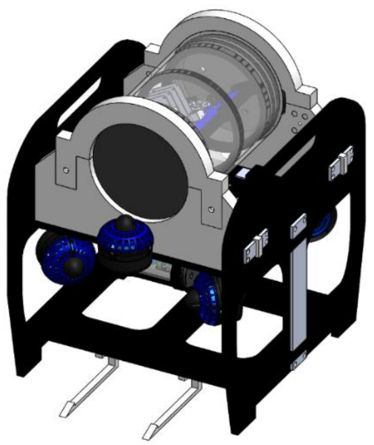

Figure 2: Happy Adventure Render. Photo Credit: Bedir Acar

Chassis

Eastern Edge designed the chassis of Happy Adventure to maximize simplicity and modularity by drawing inspiration from wood joinery techniques [1]. By utilizing the joining techniques of slotting and friction fit, the design shown in Figure 3 limits the use of mounting hardware while distributing all load across the entire chassis. This achieves a rigid and stable structure. This limits possible failure points and simplifies chassis disassembly and customization, allowing for easy modification and improvement.

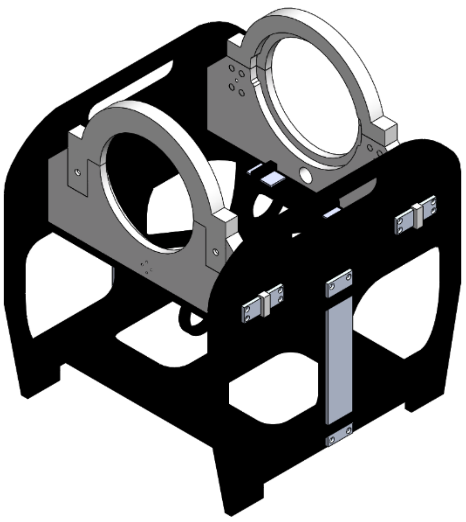

Figure 3: Render of Happy Adventure's Chassis. Photo Credit: Bedir Acar

Happy Adventure consists of five major components: two side panels, a mid-plate, a tooling skid, and an electronics enclosure mount. The mid-plate, tool skid, and enclosure mount fit into slots on both side plates to hold the chassis together. Two aluminum strips are fitted through cut-outs on the mid-plate and tool skid which are screwed into threaded inserts on each side panel. This ensures the chassis is rigidly secured together. The side plates of the chassis have handles integrated into their design to facilitate transport and deployment of the vehicle. The mid-plate and enclosure mount provide space for the six thrusters in the desired configuration. Additionally, the mid-plate fits two camera mounts at the fore and aft ends of the chassis. The tool skid provides several attachment points to outfit Happy Adventure with the tools and payload to complete the contract.

Each chassis component is constructed from high-density polyethylene (HDPE), a marine-grade plastic. The team chose this material for its high strength, similar density to water, and ease of manufacturing. HDPE density is 970 kg/m^3, close to freshwater's 1000kg/m^3 density. The similarity in density means the chassis itself is near neutrally buoyant, so it does not require much buoyancy to compensate for its own weight. The Company has made use of surplus HDPE stock from previous contracts, reducing costs associated with chassis construction. Lastly, HDPE is an accessible material to work with, as it can be easily and quickly machined using the Company’s in-house Computer Numerical Control (CNC) router.

Propulsion, Ballast, and Buoyancy

Propulsion

Happy Adventure incorporates six Blue Robotics T200 thrusters into its design, chosen for the cost-effective power they provide. Four of these thrusters are used for lateral motion in the surge, sway, and yaw directions. Two thrusters are used for vertical movement in the heave and pitch directions. The thruster configuration can be referenced in Figure 4.

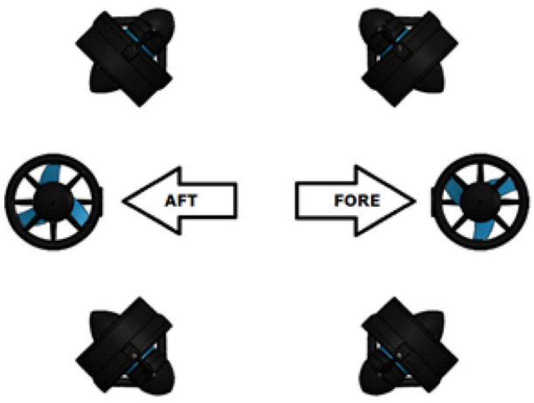

Figure 4: Thruster Configurations. Credit: Tim Squires

For this contract, the active roll motion was ignored because previous experience demonstrated roll motion to be an unnecessary complication. This decision to neglect roll control did limit the number of vertical thrusters and, as such, slightly decreased the maximum vertical thrust of the ROV. The decrease in vertical thrust capacity was determined to be acceptable and would not compromise the performance of Happy Adventure for the RFP.

The four lateral thrusters are vectored at a 45-degree angle relative to the centerline of the ROV to simplify thrust factor calculations. Each of these thrusters is placed in-plane and equidistant from the center of mass of the ROV to achieve the most efficient thrust transfer. The vectoring of the thrusters allows for a theoretical maximum thrust of approximately 100 N in both the surge and sway directions. The two vertical thrusters are placed at the fore and aft sides of the ROV in line with the center of mass, capable of supplying a theoretical maximum vertical thrust of approximately 70 N.

Ballast and Buoyancy

The volume of water displaced by the electronics enclosure provides more than the required buoyancy force to keep the ROV neutrally buoyant. The ROV achieves neutral buoyancy by using ballast weights placed in strategic locations on the chassis. These locations were selected to minimize the ballast impact on the ROV's functions while maximizing impact in lowering the ROV's center of mass. This maintains the position of the center of mass and center of buoyancy.

The center of buoyancy should be as far above the center of mass as possible to achieve maximum stability during operation [2]. Happy Adventure takes this principle into account by having a center of buoyancy at approximately the center of the electronics enclosure and a center of mass approximately 220 mm below, in-plane with the lateral thrusters. This can be seen in Figure 5.

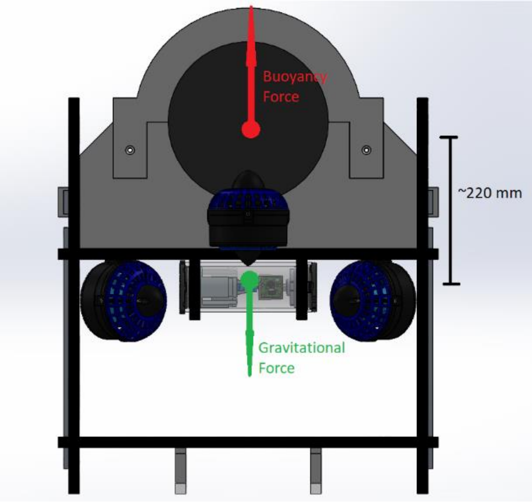

Figure 5: Happy Adventure's center of buoyancy and center of mass (gravity).
Photo Credit: Liam Gregory

Electronics Enclosure

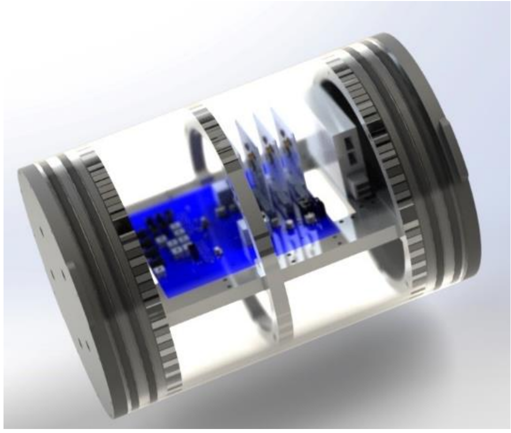

Figure 6: Happy Adventure's Electronics Enclosure.
Photo Credits: Stephen Snelgrove

The electronics enclosure for Happy Adventure was designed using a Blue Robotics 200 mm diameter acrylic tube and aluminum Blue Robotics endcaps. An internal HDPE structure is used for the mounting of electronics. The enclosure assembly is shown in Figure 6. The enclosure was chosen to accommodate the mounting of critical heat generating components to the forward end cap for heat dissipation, and to allow space for scalability for future years. The HDPE structure consists of three concentric rings supporting the electronics tray, connected by stainless steel rods. This assembly is then mounted onto the aft endcap providing a stable platform for the electronics. The rings of this structure also allow for easy disassembly and reassembly of the enclosure. In recent years, the Company had been using rectangular prism shaped enclosures but encountered issues with cost, volume, hydrodynamics, and reliability. These problems were solved by using a tube enclosure as it is more cost effective, provides more interior volume, has better hydrodynamic characteristics, and it allows the Company to focus on manufacturing of other important aspects of Happy Adventure.

This enclosure was designed with accessibility in mind. By mounting the electronics in the middle of the tube the Company is given a 360-degree view of the electronics to help diagnose issues as they arise. This mounting method also protects the electronics from water in the enclosure in the case of a slow or moderate leak, giving the Company time to retrieve the ROV before water reaches the electronics. If work is required on the electronics, the enclosure can be opened and the internal structure can continue to support the electronics while work is being done. Modifications and additions to the system are easily integrated to the extensive volume and mounting locations.

Electrical Systems

Overview

The electrical system onboard Happy Adventure incorporates a brand-new architecture for the 2022 contract. This new architecture focuses on ease of repairability, scalability, and space efficiency. With these focuses in mind, it was more effective to design and manufacture our own printed circuit boards (PCBs) rather than buy off-the-shelf components for our desired architecture. The system was split into a high-power conversion and distribution subsystem, and a low-power electronics and communication subsystem. The high-power subsystem is made from one custom-designed PCB, while the low-power subsystem is formed using three custom-designed PCBs in a backplane and card interconnection system. All PCBs were designed collaboratively using the PCB design software, KiCAD, and PCBs were assembled in-house. A full System Integration Diagram (SID) of the electrical system is included in Appendix D.

High-Power Subsystem

The High-Power subsystem for Happy Adventure is designed to minimize space required. This board is mounted to one of the enclosure's metal end caps for optimal heat dissipation. The board is a semi-circle to minimize unused space. To lower the cost of the design, three input 48VDC-to-12VDC Murata DC-DC converters were re-used from previous contracts. Each of the three converters boasts a 95% efficiency and 420 W output power, for a total output power of 1260 W. Another primary design feature of this board is the electrical isolation between the input 48VDC and output 12VDC of the isolated DC-DC converters. The high-power board can be seen in Figure 7.

The distribution of 12VDC power for the system is handled by seven pairs of ring-terminal connectors placed on the outer perimeter of the board. Each power output connector includes current sensors for monitoring power consumption from each of the six T200 thrusters and payload. Additionally, a servo controller is used for the off-the-shelf electronic speed controllers (ESC) from Blue Robotics. These ESCs, mounted on aluminum heat sinks, are encased in epoxy outside the enclosure for improved heat dissipation.

Figure 7: High-Power Board.
Photo Credits: David Drover

Backplane Board

The backplane board is a component of the low-power subsystem which utilizes a PCB quick connect card system. This board allows for the remaining PCB cards in this subsystem to be connected. The backplane Board for Happy Adventure houses Peripheral Component Interconnect Express (PCIe) connectors that each PCB connects to. Each connector contains options for Controller Area Network (CAN) and Inter-Integrated Circuit (I^2C) communications, as well as programming pins for the remote programming of the microcontroller on the cards. This board allows for scalability as peripheral boards can be swapped out or added. Currently, three slots remain to meet future customer requirements. This also aids in the reparability of the subsystem.

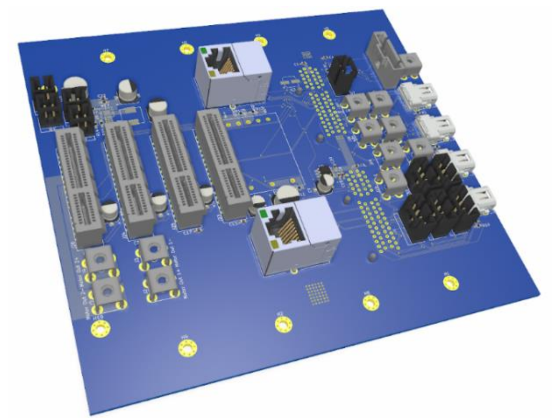

Figure 8: Backplane Board.
Photo Credit: David Drover

The backplane is equipped with two ethernet connectors, four DisplayPort Mini connectors, three I^2C connectors and two CAN connectors. Ethernet connectors are used to communicate from the topsides to each Compute Module card. The DisplayPort mini connectors are used for the cameras. One of the I^2C connectors is reserved for a pressure sensor. The remaining two I^2C connectors and the CAN connectors are used to connect future devices and facilitate debugging communications.

The backplane board is used to distribute 5V12DC, 1.8VDC, 3.3VDC, and 12VDC to the rest of the electronics system. The 48VDC is input to the backplane board from the topsides via the tether. The 48VDC-to-5VDC DC-DC converter can output 5VDC at 10 A. The backplane board can be seen in Figure 8.

Tooling Card

The tooling card for Happy Adventure features a leak detection sensor, a dual DC motor driver, four N-channel Mosfets and an Inertial Measurement Unit (IMU). The Tooling Card is a peripheral card of the backplane board, which connects to rest of the electrical system through the use of a PCIe connector and communicates with the rest of the system through CAN. The dual DC motor driver allows for any payload motors to draw up to 4 A. This allows for the ability to add future upgrades to active tools. The N-channel Mosfets are used as LED drivers and configurable outputs on the ROV. To ensure that the IMU is in the correct position in the electronics enclosure it has been placed on its own separate, smaller board, that is attached to the Tooling Card using a 90° connector. The mosfets and motor drivers are controlled by an onboard STM32 microcontroller. The tooling card can be seen in Figure 9.

Figure 9: Tooling Card.
Photo Credit: David Drover

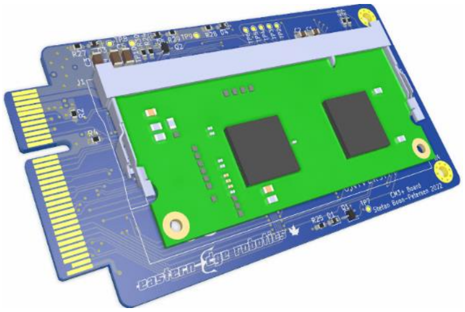

Figure 10: Compute Module Adapter Boards with the Compute Modules
Photo Credit: David Drover

Compute Module Adapter Card

Happy Adventure uses two Raspberry Pi Compute Module 3+ (CM3+) as the onboard computers to handle communications with the surface and to control the other aspects of the electrical system. Two CM3+ are used to provide four camera feeds and to distribute computing load. The CM3+ provides similar functionality to that of a Raspberry Pi 3B+ while using a much smaller form factor. Due to this form factor, the CM3+ is able to be seamlessly integrated into the rest of the electrical system. The two adapter cards, shown in Figure 10, provide an interface between each CM3+ and the rest of the electrical system. The compute module cards are capable of achieving gigabit ethernet speeds. These fast ethernet speeds allow for low-latency communication with the surface via fibre. The CM3+ also provides 400 Kbps I^2C communication and 500 Kbps CAN communication (via the MCP2515 CAN controller). Using these communication protocols, both CM3+'s is able to communicate with the other peripherals in the electrical system. The compute module adapter cards are also capable of programming all other onboard microcontrollers via Universal Asynchronous Receiver/Transmitter (UART), allowing them to be programmed without removing them from the enclosure.

Cameras

Happy Adventure's camera system for the 2022 contract incorporates three Internet Protocol (IP) Raspberry Pi V2 cameras, with the ability to expand to a fourth. These cameras stream 720p HD, 60 FPS video to Happy Adventure's topsides control system, with a latency of only 80ms. Each camera is connected to one of two onboard CM3+ modules, utilizing dedicated encoding hardware of the compute modules, reducing latency and increasing video quality. Happy Adventure's camera enclosure can be seen in Figure 11. Two cameras are positioned on the fore and aft sides of the chassis. This allows the pilot to view both ends of the vehicle. The third camera, located below the tooling skid, allows for a view below the ROV.

Eastern Edge has developed an all-new solution to enable the remote rotation of the cameras by sending power and camera signals over a standard Mini-DisplayPort cable. This is accomplished with a custom-designed adapter PCB, and custom-designed penetrators. The Mini-Displayport cables are plugged into the backplane board providing all power and signal lines for the cameras and servo motors. This reduces the number of cables entering each camera tube module to just one, allowing for clean cable management.

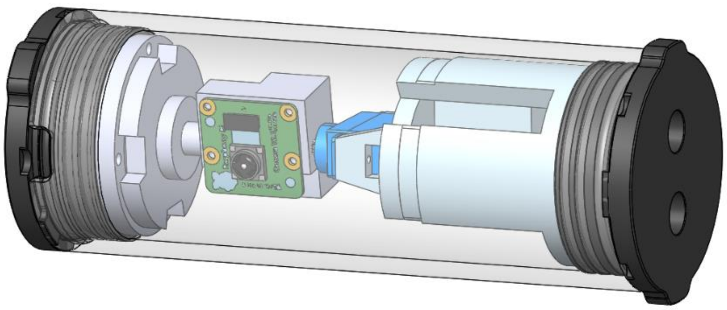

Figure 11: Happy Adventure's Camera Enclosures.
Photo Credit: Tim Squires

Tether

Happy Adventure's tether was designed by Eastern Edge and fabricated and donated to the Company by Leoni-Elocab, and has been used in many previous contracts. This tether provides Eastern Edge with all the requirements necessary for Happy Adventure, and re-using this component lowers the cost for the 2022 contract.

This tether, with a length of 12 m, contains two multimode fibre pairs for communication and two 14 American Wire Gauge (AWG) conductors for power. A cross section of the tether can be seen in Figure 12. The buoyant outer jacket makes the tether neutrally buoyant, aiding in tether management. Eastern Edge uses multimode optical fibres for their high bandwidth, reliability, electrical noise immunity, and lower mass when compared with copper alternatives.

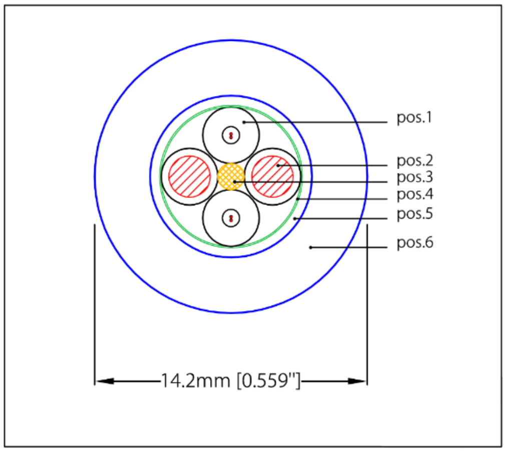

Figure 12: Tether Cross Section.
Photo Credit: David Drover

The team has devised a tether management protocol to both protect the fibre inside and minimize tether influence on piloting. To protect the delicate fibre from breaking or experiencing unwanted strain, the tether is flaked in a figure eight shape, seen in Figure 13. This minimizes twists more than a standard coil. To manage this, the team allocates two people on deck; one to maintain the figure eight, and another to add and retract tether to the pilot's needs. When not in use, the tether is flaked and kept organized with three cable cuffs.

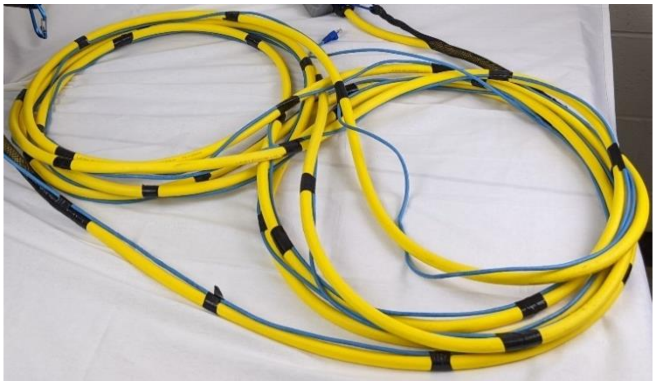

Figure 13: Flaked tether in figure eight shape.
Photo Credit: Julia Dawe

Software

Overview

Happy Adventure's software system is written in Python. The Company chose Python due to its simplicity and low barrier to entry. This results in less time to train new employees. The system has three computers: the topsides control computer, and the two on-board CM3+ modules. The system software consists of control and communications.

The topsides computer is an interface between the user and the ROV. It takes input from the control device (ex. joystick) and graphical user interface (GUI) and sends the corresponding action to the ROV. The two CM3+ modules share control of the all peripherals such as: thrusters, sensors, and cameras. The communications section of the software handles message passing between the three computers.

Control Software

The control software features a multi-threaded architecture to maximize the computational capabilities of the topsides computer and both of the ROV's onboard computers. Due to the scalable electrical system, the two CM3+ can access the same communication buses. Therefore, both modules are capable of dynamically sharing the computational load. For example, if an onboard computer becomes overwhelmed, it can transfer the load to the other.

Happy Adventure's software is event based. Code is executed based on input events from a user, or when a message is received from another computer. This optimizes the processor usage of the control software as there is only code execution when required.

The software of Happy Adventure is designed with the user in mind. The pilot has access to an extensive profile editing tool. Each aspect of their flight can be tailored to their liking. For instance, the pilot can configure the software to use any button on up to ten types of joystick and controller options. With an easy-to-use joystick control mapper, the pilot can change their settings while in operation. This means there can be multiple configurations for different pilots saved to the system. There is no need to restart or pause the software to update the changes.

Communications

Happy Adventure features a modular communications network. Integrated into the software of Happy Adventure is a program called the messenger. Each device in the ROV network has an instance of the messenger. The messenger can be used to send data to any device on the network or broadcast data to all devices using an IP multicast. IP multicast is a transfer method which is used to send data to multiple devices along a single data stream [3]. This allows for a simple and scalable communication network, without overloading any of the communication channels. A diagram of this interconnectivity can be seen in Figure 14. Data is transmitted using user datagram protocol (UDP). Using UDP over other protocols allows for decreased latency; a critical requirement of applications such as ROV control and real-time video.

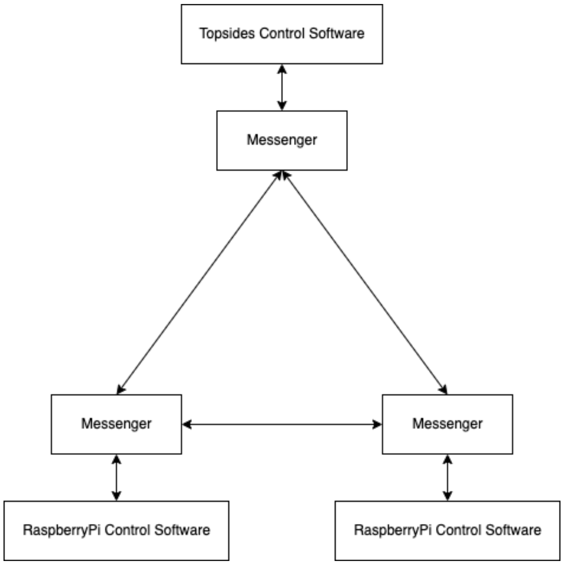

Figure 14: Network Interconnectivity Diagram.
Photo Credit: Andrew Troake

Graphical User Interface

The GUI of Happy Adventure is built using the open-source project QT. QT is a framework which allows developers to design dynamic interfaces without having to develop any of the backend graphical processing. This allows for easy development of a cross platform control software, without the Company having to write specific software for different hardware and operating systems. The GUI features several tabs which serve different purposes. Some of these tabs include the main control page for controlling the ROV, a debugging page for viewing live error or warning messages, and the profile editor to easily add, remove, and edit control profiles. A screenshot of the GUI is shown in Figure 15.

The video feeds from Happy Adventure's cameras are integrated directly into the GUI. This allows the pilot to toggle between camera views as needed during operations. The software of Happy Adventure is capable of displaying all ROV telemetry such as control information and diagnostic information.

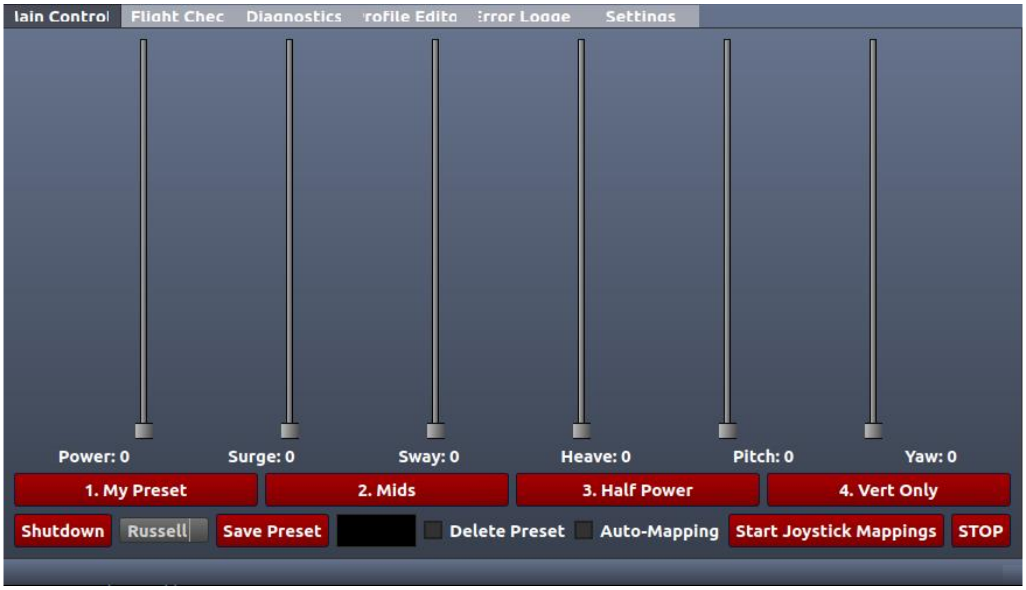

Figure 15: Screenshot of the GUI.
Photo Credit: Andrew Troake

Payload and Tooling

Forklift

The Forklift, shown in Figure 16, is designed for the placement, transport, retrieval, and manipulation of various objects during operation. This tool consists of two stationary HDPE hooks mounted to the bottom of the tooling skid of the chassis. This tool is scalable as additional hooks can be added for contract requirements. The tapered ends and the low mounting points allow the forklift hooks to slide beneath objects while moving along the sea bed and carrying them to their desired positions. They also include a strong magnet to accomplish tasks which require additional force to move or carry a ferrous object.

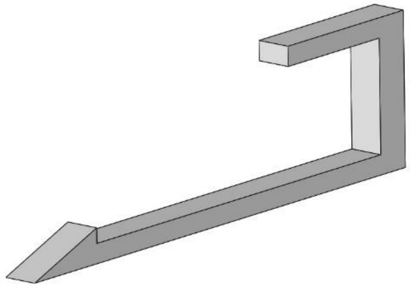

Figure 16: 3D model of Forklift Tool. Photo Credit: Tim Squires

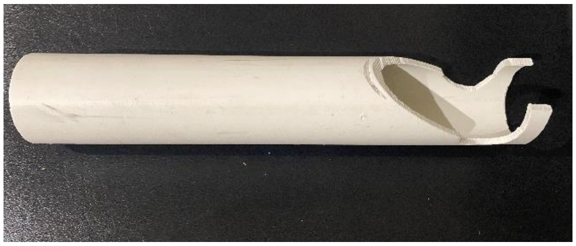

Figure 17: The Walrus Tool. Photo Credits: Bedir Acar

Walrus

The Walrus, shown in Figure 17, is a stationary hook that provides strong and secure lifting capabilities while retrieving and transporting objects underwater. The hook is constructed from a carved PVC pipe attached to the tooling skid. It provides support against bends from heavy objects compared to other manipulator designs due to its round shape helping to distribute force across a greater cross-sectional area.

Light Brites

Happy Adventure has two front-mounted LED lights on the port and starboard side. These lights are made from repurposed cabinet light strips encapsulated in clear epoxy. The tooling card is capable of controlling the light's brightness to illuminate specific areas identified by the image recognition software. The light brites can be seen in Figure 18.

Figure 18: Light Brites. Photo Credit: Bedir Acar

Figure 19: Vertical Profiler Holder. Photo Credit: Bedir Acar

Vertical Profiler Holder

The Vertical Profiler Holder secures, carries, and releases the Vertical Profiler as required by the RFP. It is made up of an electromagnet, shown in Figure 19, fastened to the interior walls of the chassis and sealed in epoxy to function underwater. This electromagnet is coupled with a magnet inside the vertical profiler to attach it to the chassis allowing for easy release of the profiler.

Vertical Profiler

The design for the vertical profiler was inspired by standard floats typically used for collecting large quantities of data relating to ocean climates. For the 2022 contract, the vertical profiler is required to be released from the ROV into a designated area, and complete two full water column profiles within a limited time span. It is crucial that the device is capable of traveling the full required depth in the water to collect accurate and useful data for climate analysis [4].

Eastern Edge determined that an acrylic tube was an effective device for holding and waterproofing the electronic based system required for the vertical profiler. A buoyancy engine was created using a syringe and a DC motor. The DC motor adjusts the syringe to create negative or positive buoyancy in the device. The buoyancy engine provides adjustable density by collecting water in the syringe and then discharging water. This change in density allows the vertical profiler to sink or float. The vertical profiler is attached to the chassis using the vertical profiler holder. The final design of the vertical profiler can be seen in Figure 20.

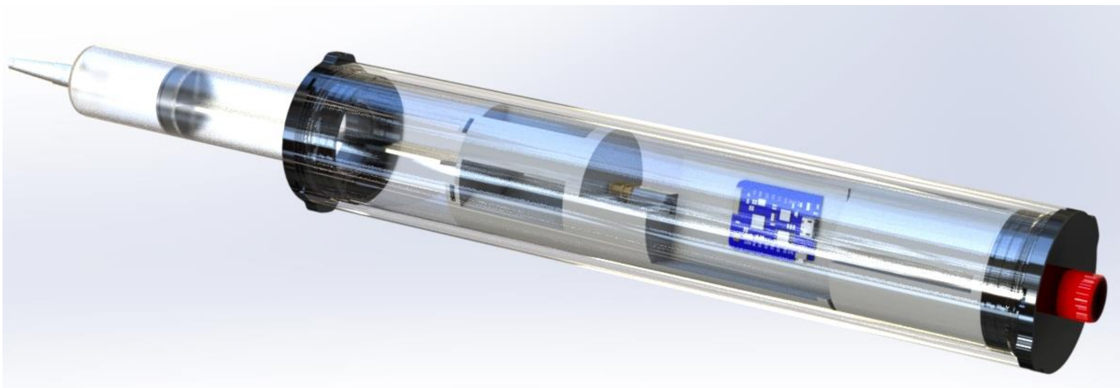

Figure 20: Vertical Profiler Render. Photo Credits: Bedir Acar

The vertical profiler is powered using four AA Alkaline batteries in series, providing an operating voltage of 6 V. The batteries are located in a 3D printed support, housed inside the tube. The batteries are strategically placed inside the tube to allow for easy replacement. It also includes a 6 A fuse to stop any unsafe currents which could damage the DC motor. The SID for the vertical profiler can be seen in Figure 21.

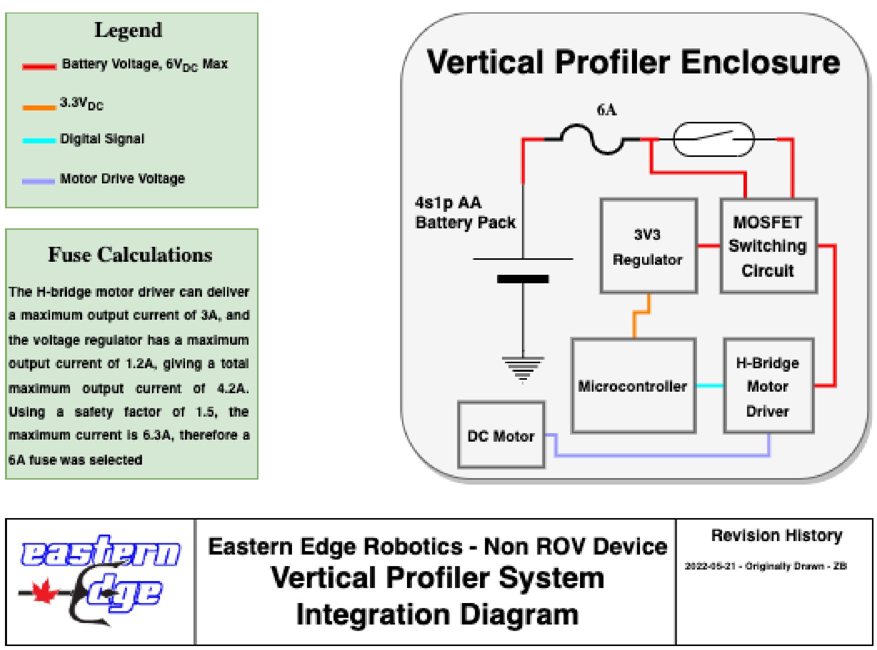

Figure 21: Vertical Profiler SID. Photo Credit: Zachary Bennett

Critical Analysis

Testing and Troubleshooting

Eastern Edge recognizes that a testing and troubleshooting procedure must be implemented and is key to creating a reliable product. For this reason, the Company's protocol is to test and troubleshoot components and systems prior to complete integration. By testing components and systems independently, any problems that arise can be isolated and resolved quickly and efficiently without jeopardizing the entire product. All electrical components were bench tested with the onboard and topsides systems prior to integration with the ROV. The software was tested on the Company's previous ROV product, Calypso which was modified as a test platform for the new system designed for this contract. This simplified debugging as employees have access to known working software.

Calypso was also used to test the capabilities and compatibility of new tools required for the RFP. This ensured that the tools could be design and tested throughout the development of Happy Adventure. Tools created for the RFP could also have their effectiveness analyzed over a longer period of time. This allowed for more iteration and refinement of tooling to ensure reliable, efficient operation. Once a design was tested, and the necessary modifications had been made, a final design was then produced, fabricated, and tested once again. This procedure was continued until the requirements set by the Company had been met.

One instance of troubleshooting which proved the merits of the Company's focus of serviceability was during the bench testing of Happy Adventure. An issue was encountered with the communication between the CM3+ card and the PWM generator of the high-power subsystem. The system's design with provision for spares allowed the team to connect to a spare connector on the same bus to probe the signal. By probing the signal, it was determined that the message being sent was corrupted. Upon further investigation an Integrated Circuit (IC) was determined to be corrupting the message. After the IC was replaced, the corruption stopped and the generator ran without issue.

Happy Adventure has been designed with diagnostic sensors and tools for live troubleshooting in the case of an operational issue. Integrated throughout the electrical system are various voltage and current sensors. This allows for full monitoring of power distribution throughout the ROV and alerts if any unknown power spike is detected. Happy Adventure also features a leak detection sensor so the ROV can be safely shut down before damage to the electrical system occurs.

Future Improvements

Reflecting on the year, Eastern Edge has had many challenges due to the ongoing pandemic. A major challenge the Company faced was the continuation of knowledge from missing two years of competition (2020 and 2021). Senior employees were graduating and the retention of employees was difficult. Because of this, the team needed to find new ways to pass down knowledge to junior employees so the Company can continue to be successful. In future years, the Company aims to continue fostering an environment where senior employees take a mentorship role to allow knowledge retention within the Company.

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Appendix A – Operational Safety Checklist

Operational Safety Checklist

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

MATE International ROV Competition 2022, Explorer Class

JSA Completed? ☐ Yes ☐ No Date completed: ____________________

Employees Involved: ____

____

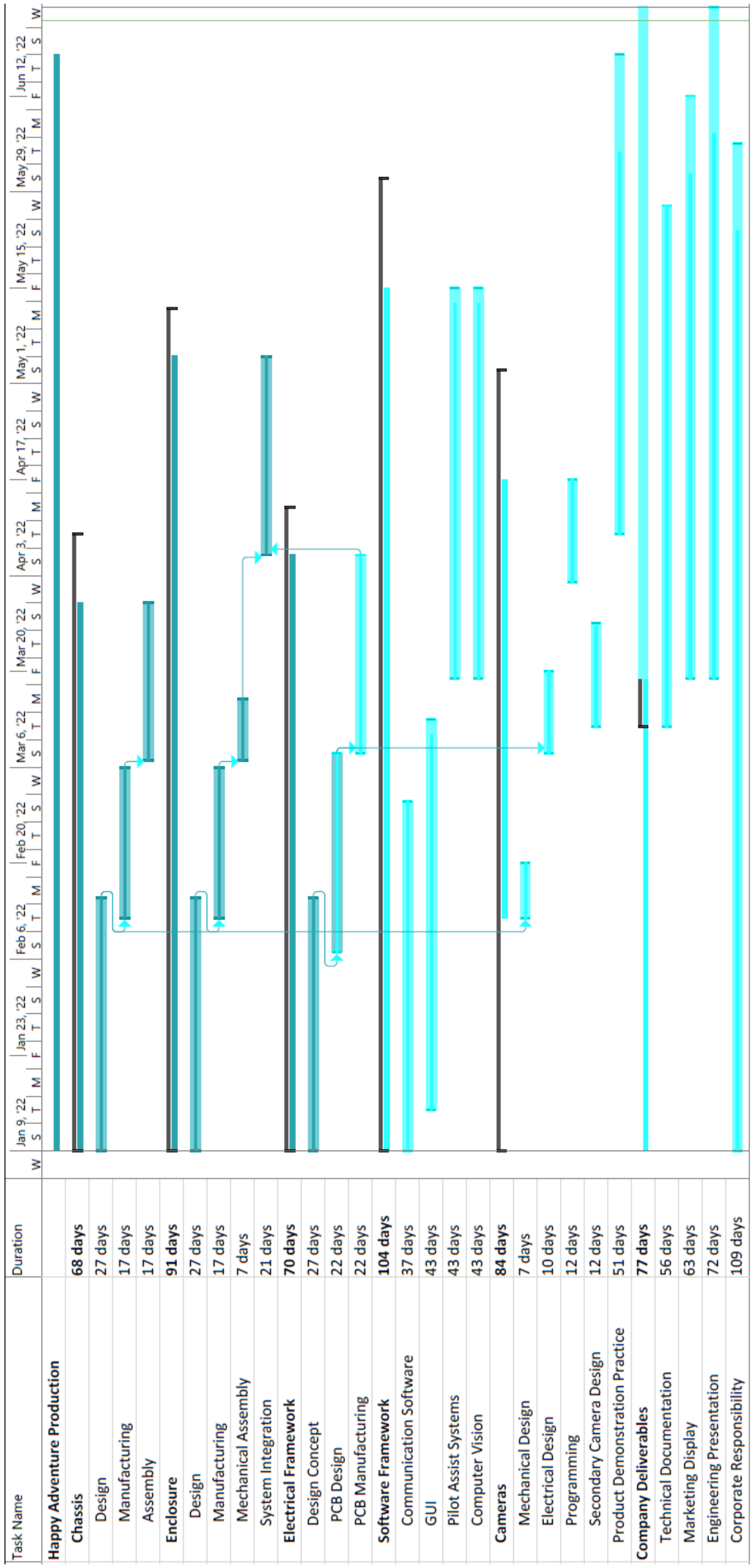
____

Pre-Mission Safety Checklist	
Complete?	**Task**
	Tether is neatly coiled and clipped in company standard figure 8
	Vehicle power switch is in 'OFF' position
	Deck Crew is wearing Eye Protection, Personal Floatation Devices and Work Boots
	Topsides is fully charged and spare charger is brought
	Access hazards are removed
	Air compressor is properly adjusted and hooked up with releases unhindered

Teardown Safety Checklist	
Complete?	**Task**
	All power sources safely powered off and disconnected
	Tether is neatly coiled and clipped in company standard figure 8
	Excess water removed from vehicle
	Access hazards are removed
	Access air is releases from air compressor

Operational Safety Hazards
No hands on vehicle without software locked
No excess tether left uncoiled on deck
Be cautious of slip hazards generated by water from vehicle, tether, etc.
Keep wet objects/personnel away from Topsides
Any cabling or connections should be both secure and tidy
Use proper lifting techniques when carrying equipment from work area

Appendix B – Project Schedule



Appendix C – Happy Adventure Project Costing

ROV Fair Market Value			
		Price	**Description**
Electronics	Backplane Board	$188.91	New
	12v Power Board	$233.18	New
	Tooling Board	$200.16	New
	Compute Module Board	$144.86	New
	ST-Link programmer	$18.36	New
	Non-Budgeted Items	$100.00	New
	Electronics Total	**$885.47**	
	T200 Thrusters	$537.00	Re-used
Mechanical	T200 Thrusters	$537.00	New
	ESCs	$210.00	New
	Hardware	$317.18	New
	High Density Polyethylene (chassis)	$266.95	In Stock
	Tether (12 m)	$331.92	Donated
	Cameras	$348.05	New
	Enclosure	$531.27	New
	Aluminum	$40.00	New
	Mechanical Total	**$3,119.38**	
Payload	Lift Bag	$234.38	New
	Vertical Profiler	$178.88	New
	Misc.	$234.38	New
	Non-Budgeted Items	390.63	New
	Payload Total	$1,038.26	
	Total	**$5,043.11**	

Appendix D – Happy Adventure System Integration Diagram (SID)