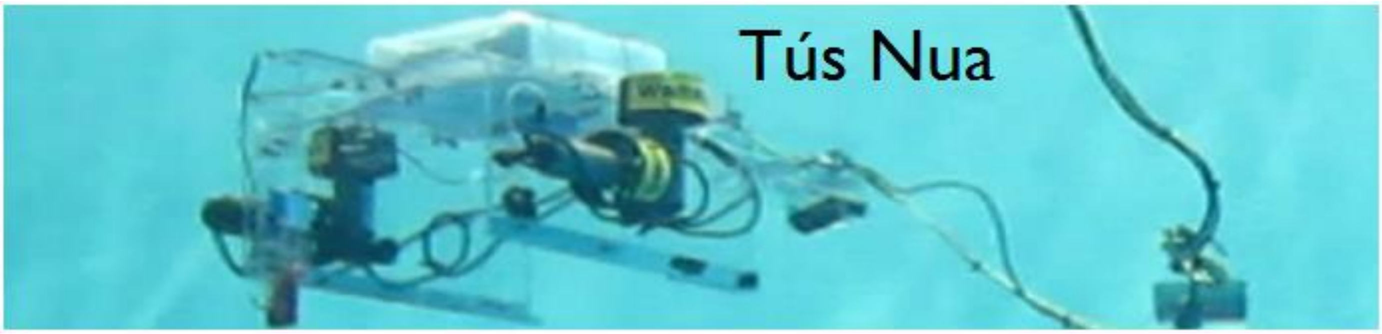
Heritage Robotics Technologies

2013 MATE International Competition Technical Report



(Back row – left to right)
Lucas Strong – Payload Tools Technician,
Braden Chaffey – CAD Specialist,
Patrick Holloway – Electrical Technician ,
Gregory Ash – Mechanical Technician,
Arne Maeland – Chief Systems Design Engineer.

(Middle row – left to right)
Zach Chatman – Structural Technician,
Sebastion Greening – CAD Specialist,
Spencer Holloway – Software Design Engineer.

(Front row – left to right)
Macailyn Pitt CFO,
Jenna Blagdon – Safety Officer,
Magdalena Maeland – Public Relations Officer,
Laura Blundon – CEO.

Heritage Collegiate
Lethbridge,
Newfoundland,
Canada,

Mentors: Mr. Terrence Maloney, Mrs. Suzette Strong, and Mrs. Lyndon Williams

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Abstract

HRT has been a provider of undersea robotic technology since 2006. We design and construct efficient, cost effective ROVs that answer the highly specialized needs of marine industries. For the past seven years our products have participated in the Mate Regional Competition in Newfoundland and Labrador, and in five of those seven years have seen international service as well.

This year's tender is based on the Ocean Observatories Initiative — a system of data collecting nodes on the ocean floor. You have asked us to provide maintenance on one of these nodes.

To that end we have created an ROV complete with an onboard computer system, with software written entirely by members of our team. This computer controls both propulsion and payload tool system, and is housed within our electronic control module, from which it interfaces with our onshore computer and joystick control.

To measure and graph the temperatures over time on the hydrothermal vent, we have created an electronic thermometer unit – complete with its own computer and Ethernet connection to the surface, and again programmed with our own in-house software.

If you are seeking an ROV that will meet the maintenance needs of ocean observing systems, then we are confident that there is no more efficient nor more cost effective solution than that which we provide from Heritage Robotics Technologies and our latest innovation - Tús Nua.

Figure 1: Finished product Tús Nua

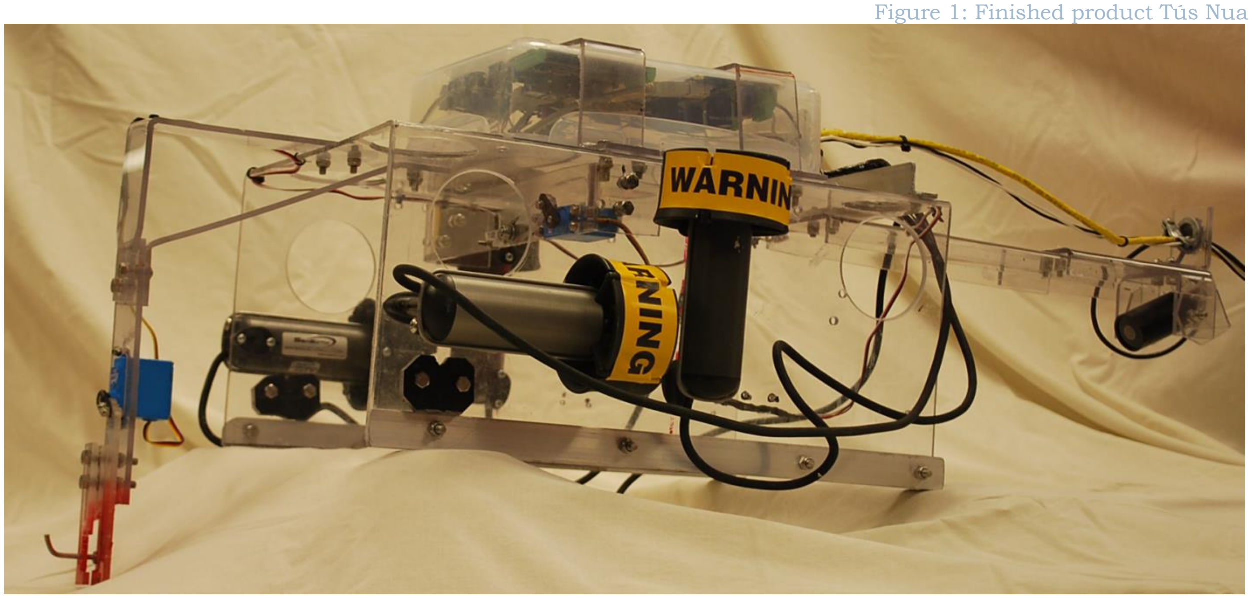
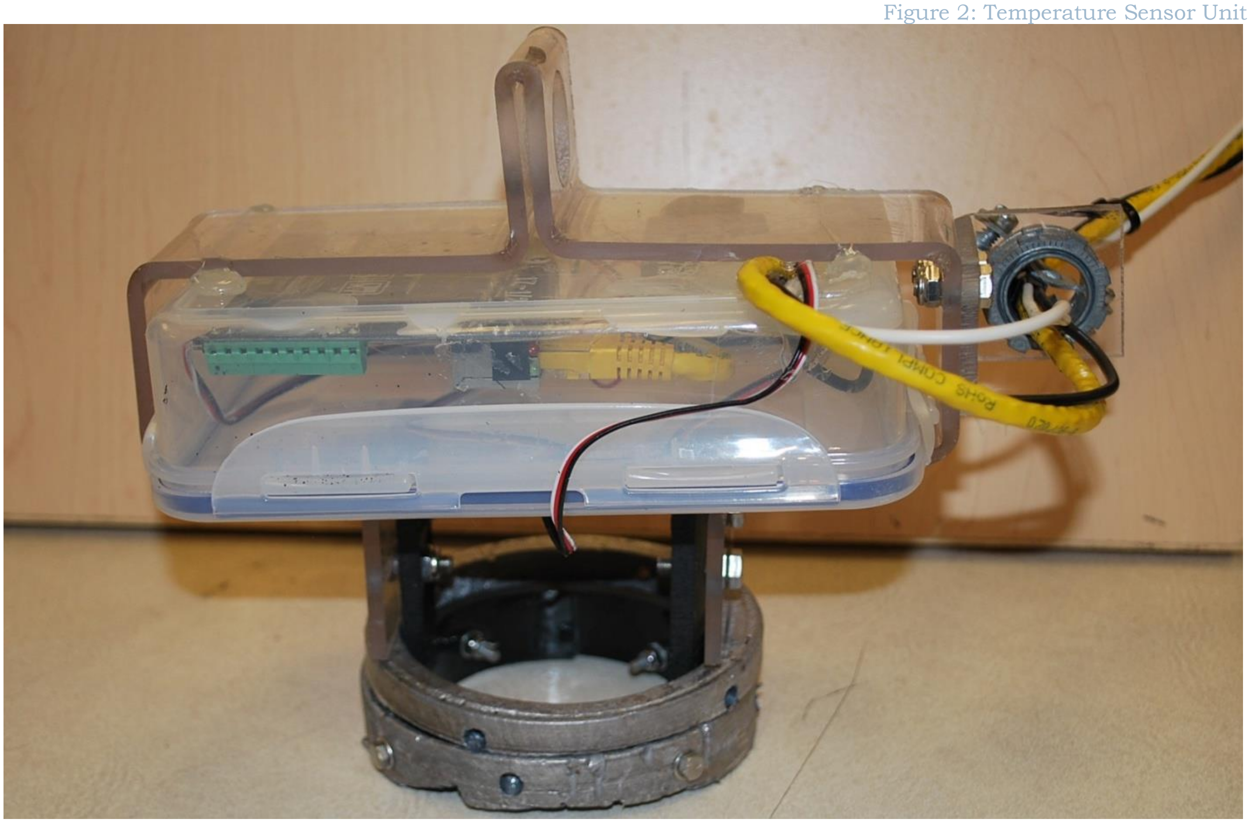


Figure 2: Temperature Sensor Unit



Theme

On September 20, 2010 Environment Canada forecasted that Hurricane Igor had been downgraded to a tropical storm. Within two days the coastal areas of Newfoundland were subjected to a category four hurricane - the most destructive hurricane to strike the island on record. While most of the world watched the devastation through their TV screens, many Newfoundlanders witnessed the storm unfold through their living room windows. While a lot of the damage could not have been prevented, communities could have been better prepared with a more accurate forecast.

For years we have had weather stations, radar, and satellites that are able to predict the weather, but land-based systems cannot reflect what is happening in the ocean. And it is the ocean that has the most significant impact upon the environment of our coastal areas. No one knows this better than Newfoundlanders.

Ocean observing systems may not be able to prevent such extreme weather events as Igor, but they can warn us. They can aid us in understanding our ocean environments, our impact upon them, and the consequences of that impact.

Ocean observing systems and ocean observing initiatives can only be an increasingly significant part of the foreseeable future. On a planet with such delicate interconnectedness, knowledge of our oceans and our impact upon them is vital to the future of all living things.

Figure 3: Hurricane Igor - http://rapidfire.sci.gsfc.nasa.gov

Design Rationale

This year's request for proposals called for ROV services needed to support the successful installation and maintenance of secondary infrastructure as well as the servicing of the existing structures and instrumentation on a University of Washington cabled observatory node.

These tasks include:

- *Installing the SIA into the BIA of a primary node then connecting the BIA to the backbone cable via the Cable Termination Assembly*
- *Deploying an ocean bottom seismometer and connecting it to the SIA for power and communications.*
- *Designing then installing a temperature sensor over a vent field and recording the temperature of the vent flow over time.*
- *Removing an Acoustic Doppler Current Profiler from a water column mooring platform for maintenance and service and replacing it with a new ADCP.*
- *Locating and removing biofouling from existing structures and instruments.*

A careful study of this request for proposals made it clear that such tasks would require precision movement and delicate payload tools.

In response, Tús Nua's design uses an onboard computer and underwater servo technology. The result is that this year we've created something entirely unique.

The name Tús Nua was chosen for just this reason. It is an Irish expression that means 'new start' or 'new way of thinking'.

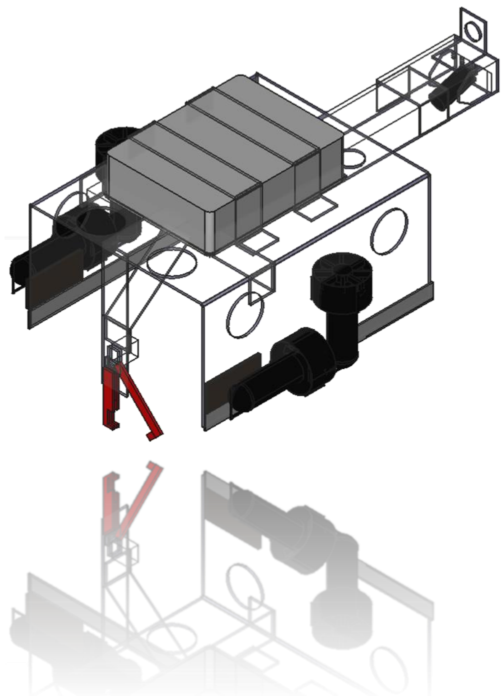
As you consider the innovations that have been incorporated, we are confident that Tús Nua, will not only impress you with the quality you've come to expect from HRT, but that the level of technology in this year's design will surpass anything you have seen to date.

Structure

Installation and maintenance of the secondary infrastructure called for the transport and positioning of some very expensive electronic equipment. The science interface assembly, the ocean bottom seismometer, and the acoustic Doppler current profiler for example.

As a result, Tús Nua is constructed of polycarbonate resin in an open ended box shape design. We made it 35 cm long, 30 cm wide, and 22 cm high. This not only provides structural integrity, but actually allows to the ROV to house the entire SIA safely within it.

Figure 4: CAD Drawing of Tús Nua. Notice the hollow interior which is able to house the entire SIA.



Control Systems

Perhaps the most significant innovation this year is the development of an ROV that houses its own onboard computer.

This offered three principle advantages. We believed this year's missions would benefit from a graduated control propulsion system, servo controlled grippers, and decreased tether size.

We've placed the computer along with all onboard electronic components in what we call our Electronic Control Module or ECM and then connected it to a surface computer and joystick via Ethernet cable.

In the past, ROVs have been controlled by direct wiring and simple switches. This meant full speed ahead or nothing at all. Those ROVs had trouble with precise maneuvers.

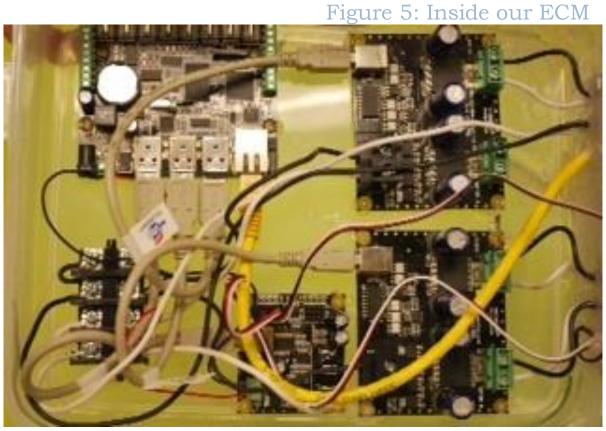
Tus Nua's software however, ties the position of our surface joystick to the amount of voltage sent through each motor controller. The result is that the slightest pressure on the joystick permits the tiniest movement of the ROV. Pushing the joystick fully forward, will still allow us to move full speed ahead, but precision movements are now possible as never before.

What's more, the onboard computer uses an advanced servo controller to control the servo grippers you've been hearing about already. Grippers are also controlled with the joystick for a seamless integration of all systems' controls.

Electronic Control Module

The Electronic Control Module is formed of a waterproof plastic container and houses our single board computer, two motor controllers and an advanced servo controller. Connecting these pieces also involves wiring, usb cables and bus bar. The unit is sealed with Marine Goop surrounding the openings that allow the power cables to enter, the power connections for the motors and servos to exit, as well as the communication Ethernet connection to return to the surface. It is the central part of our ROV and marks a significant advance in ROV technology for HRT. Yet it not only provides us with the housing for our electronics, but provides the double purpose as well – buoyancy.

Figure 5: Inside our ECM



Buoyancy

Buoyancy is created by the air within the ECM or Electronics Control Module. The ECM also controls our stability, as it is high on the ROV, and by adjusting its position for and aft, we can ensure that our ROV is completely level in the water. Lead weights have been added to make the ROV neutrally buoyant at mission depths.

Electrical

Tus Nua operates on 12 volts DC and less than 25 amps provided through the tether to the ECM on the ROV. A bus bar distributes the power to a single board computer, a servo controller, and two motor controllers. Our software tells the servos when to open and close grippers, as well as tells the motor controllers how much power to send to which motors. (See Appendix 1 for electrical schematics.)

Because we control the power to the motors with our onboard computer, our tether is very compact. It has only one power feed, an Ethernet cable and the camera cable. It is securely attached to the ROV, and coiled neatly on a holder.

Our temperature sensor unit as well is powered through a tether, but limited to 3 amps. Its tether has only the two power wires and an Ethernet cable.

Propulsion

Two vertical and two horizontal motors are positioned on either side of the ROV. The motors are a SeaBotix model BTD150. They can run up to 19.1V and have a peak bollard thrust of 2.9KGF.

We took a great deal of time, trial and error in determining the correct positioning of the motors. Clearly we wanted the vertical thrusters as close to the centre of the ROV as possible. The forward thrusters however, were initially placed too far aft and resulted in an exaggerated swing of our multi-purpose gripper when turning. In the end we settled on a position very close to midships for the for thrusters as well.

Figure 6: Seatbotix BTD 150 Thruster - Courtesy of http://www.seabotix.com

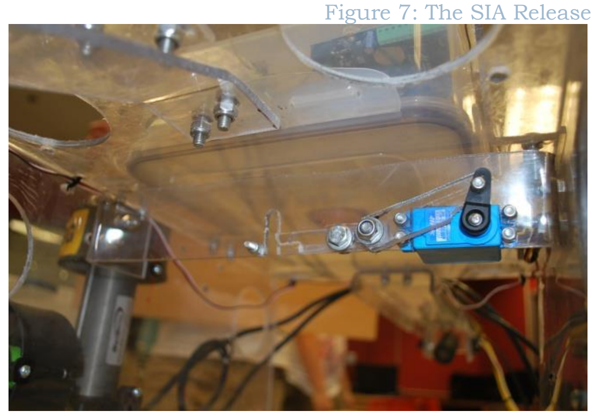
Payload Tools

We used servo technology to create two precision grippers: a multipurpose gripper and SIA release. Servo technology allows us to put a motor in place that will open and close the fingers of the grippers and so pick up and deposit the components of the node in precise locations.

The multipurpose gripper is positioned lower than the frame of the ROV so that it is able to pick up such small components as a power plug or OBS connector from the bottom.

The lateral shift finger was designed for the SIA release and takes up very little space within the interior of the frame.

Figure 7: The SIA Release



Both grippers are controlled by Hitec HS-5646 waterproof servos controlled by an advanced servo controller within our ECM and manipulated by our joystick ashore.

Together the grippers allow us to perform all required tasks again and again, from transporting the ADCP to removing the biofouling on the node's infrastructure.

Figure 8: Hitec HS-5646WP Waterproof, High Torque Digital Servo courtesy of http://www.robotshop.ca

Sensors

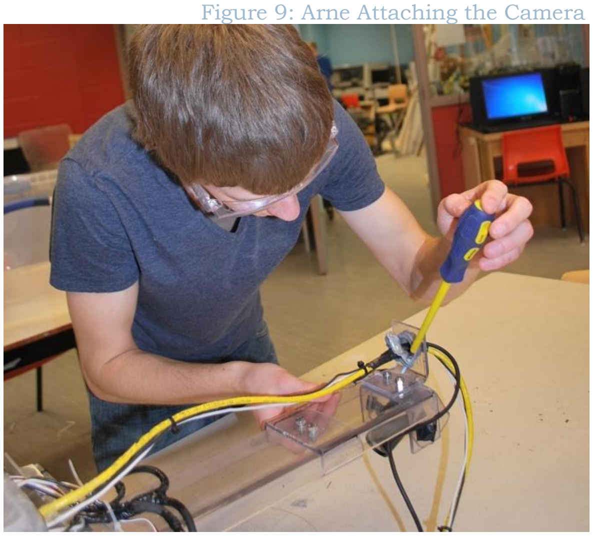
Our sensors include the camera, temperature sensor, and servo feedback.

Our camera is a Blu-Vue high resolution colour underwater camera. This camera is designed to produce high 560 TVL picture resolution even in low lighting conditions and hazardous environments. We mounted it aft to give us a clear unobstructed view of all operations.

For our temperature sensor we used a Phidgets 1124 precision sensor, which has a temperature range of -30 to 80 degrees Celsius. It lies underneath our Temperature Sensor Unit's ECM which houses its own single board computer.

Finally the servos provide us feedback on their position and confirm the grip we have on the objects held by our payload tools.

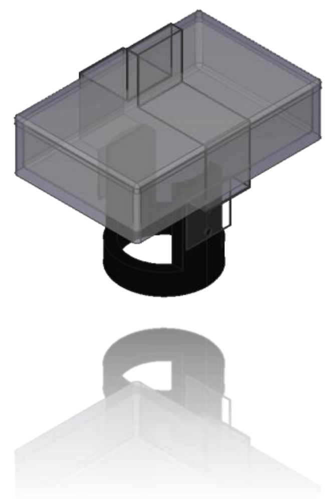
Figure 9: Arne Attaching the Camera



Temperature Sensor Unit

In order to measure and graph the temperature from the hydrothermal vent HRT created a specialized temperature sensor unit.

Figure 10: CAD Drawing of our Temperature Sensor Unit



This unit has its own ECM which houses a single board computer connected to the surface via Ethernet in its tether. The air within the ECM was an obstacle to be overcome and as a result ballast was placed on the bottom in the form of lead rings which we poured ourselves from molten lead. Lead was chosen as it proved ballast with minimal volume. It was necessary for us to have as little beneath the ECM as possible so as not to obstruct our view of the hydrothermal vent.

The temperature sensor unit is transported to the bottom and positioned by our multipurpose gripper on the for of our ROV.

Programming

The control system for Tus Nua relies on a computer program written in a programming language called Python. Python is an open source language which proved to suit our needs well, since it has a clear syntax and is powerful enough to work with all of our components. Our laptop uses a Linux distribution called Xubuntu.

When the program on the laptop is started, the Tkinter, Pygame, and Phidgets modules are imported. We then communicate with the single board computer on Tus Nua to establish a connection with our Phidgets. If this connection fails, the program returns an error. Next, we initiate Pygame and connect to our Logitech joystick. After this we create our Tkinter GUI, consisting of labels which display information from our Phidgets.

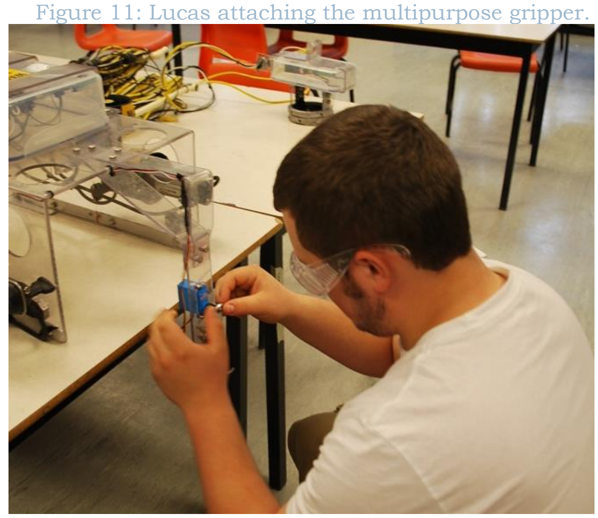
A function runs every 10 milliseconds, which receives all Pygame events. The events are caused by movements on the joystick axis and the joystick buttons. The program then processes these events and uses the information to tell the Phidgets what to do. The program then configures our GUI, updating the state of the Phidgets. Lastly, the program clears all Pygame events as to not overload our processor. (See Appendix 2 for software flow diagram.)

Our temperature sensor also has its own onboard computer. For this, we needed a second onshore laptop to communicate with the singe board computer. A Phidgets 1124 precision temperature sensor is connected and attached to the bottom of our temperature sensor unit. When this program is started, it gets the sensor value from our Phidgets temperature sensor, converts it into degrees Celsius, and then displays it on our Tkinter GUI on the laptop.

Summary

All components of Tús Nua have been designed to address the four required tasks, with the multi-purpose gripper doing the bulk of the work. The SIA release gripper holds the SIA securely within the frame of the ROV for transport to the bottom, and the multi-purpose gripper takes over from there.

Figure 11: Lucas attaching the multipurpose gripper.



Challenges

We have faced many challenges throughout the construction of Tus Nua. One such was trying to waterproof our ECM. Our ECM is a watertight sandwich container, with holes drilled in one end. These holes served as a problem, as we had to somehow stop water from entering through these points.

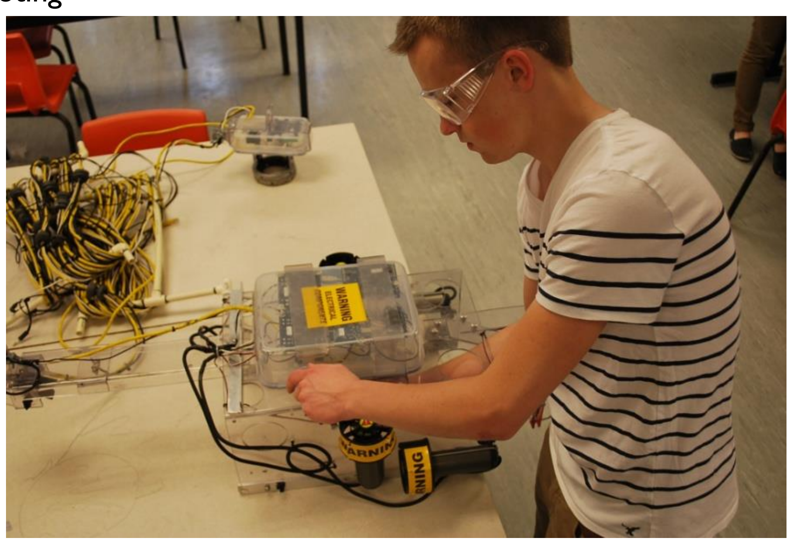
Initially, we tried filling the holes with hot glue, then spraying the whole area with spray-on flexible rubber sealant. After adding more and more hot glue, and countless layers of the sealant, we realized this would not be the solution.

We then tried some waterproof silicone. We applied it on the inside and outside of the cable entry points. However, there was still a leak! We came to the conclusion that it must be coming in through the seal of the container, which we must have accidently damaged throughout our troubleshooting process. We then removed the cover altogether, pushed the opening against a piece of polycarbonate resin, and sealed the rim with our waterproof silicone. We were quite excited we found that this was a success. The only problem was that we couldn't access our components inside our ECM if something went wrong.

So, we scrapped our ECM and made another. This one was waterproofed a little differently, though. The first thing we did was ensured the container was, in fact, waterproof before holes were drilled. Then we utilized a new product called Marine Goop to fill our cable holes. This turned out to be the perfect solution for our cause, and after all the hours spent in the trial and error phase, we were glad to find a solution.

Another challenged we faced, as a company, was finding times when everyone could meet. We realized quickly that this project could only be done well if everyone worked together. Unfortunately, this was not always the case. Often it was that multiple members would be unable to attend to our meetings, and this hindered our productivity. We overcame this by compensating for everyone's schedules, and also by setting up our meetings a week ahead of time, so people could plan ahead and compensate.

Figure 12: Patrick attaching the ECM.



Troubleshooting Techniques

Troubleshooting proved to be a major challenge that we had to overcome in order to succeed in the missions. Since we use computer programming to control our ROV, we had to do a lot of troubleshooting with the software. If the code was the tiniest bit incorrect, we had to look through our code and locate the problem. Since we use Python as our programming language, it gives us an indication if there is an error in the code and which line it is located in. We constantly tested the software which helped us discover the problem as soon as it occurred.

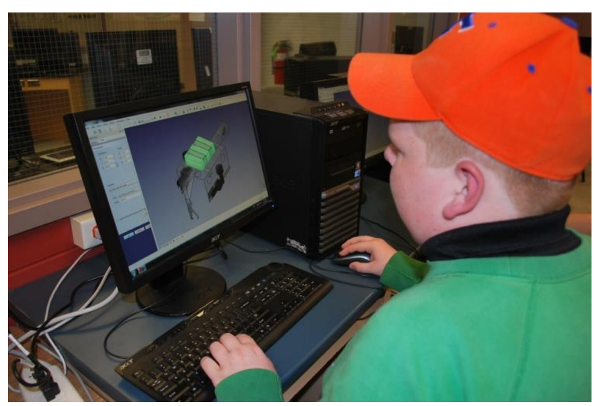
Not only did we focus on testing the control system for the ROV, but waterproofing the container which holds the circuitry also posed some serious testing. We tried many different methods, and ensured that we wouldn't damage our control system while doing so. Eventually, after much trial and error, we were able to waterproof the container.

Our ROV would have never met our standards without the constant testing of its systems. We spent many hours testing our ROV in our own tank, as well as in our community pool. We could test the waterproofing and our control system at the same time, which saved a lot of time to troubleshoot any problems we had to face. In this way we had a lot of time to perfect the ROV, and make sure that the systems would never fail.

Lessons Learned

Over the year, we have tried to face every challenge with confidence and adversity. With the amount of problems we've had this year, as well as the mindset we put towards everything we faced, we learned many new things. One thing we learned this year was our main troubleshooting technique. With our ECM entirely underwater, we noticed quickly that we would have to go through an entire precautionary test after every change. Since one of our greatest challenges involved the waterproofing of the ECM, for days on end we would make a changes to our anti-leak system, go to the small pool we have located in our school and find a leak. This lead to the practice of testing all of our equipment after each change we made. The idea of constant testing helped us locate any

Figure 13: Braden designing the structure on FreeCAD



complication as soon as it happened, instead of having to deal with multiple unknown problems all at a later date. This trouble-shooting technique became very crucial to the operation of our ROV once we began to near the end phases of construction.

In the past, when we had built our ROV's, we began very late in the year. We have noticed this to be one of our major problems when creating the ROV. Starting off later in the year leaves us with less time for testing, sometimes causing us to not get any testing done at all. We have ended up losing the opportunity to improve our ROV. We noticed this drastic mistake at the end of last year and have definitely learned from it. This year, we began construction of our ROV many months before the competition. Our ROV had been fully finished over a month before the competition date. We had now given ourselves the option to test Tús Nua many times. Not only was our operator fully trained with our ROV by the time of the competition, but we were able to change our ROV and increase its ability to complete the mission tasks. Beginning at an earlier date became one of the key assets to the success of our final product.

Future Improvements

This year we have built our most innovative ROV ever. It is capable of accomplishing all assigned tasks with time to spare. Although it performs to our companies needs, there are improvements to be made. One in particular is the inability for our ROV to move laterally due to the fact that we have only 4 motors, 2 placed vertically and 2 placed pointing forward. To improve this we could add 2 strafing motors, allowing us to move laterally. The advantage of moving laterally is the ability to adjust the ROV's orientation without having to reverse and circle around into the same position.

Reflections

Completing this project was a rewarding experience for all team members involved. Relentless hours of work and tireless effort contributed toward making this project a great success. Each task and meeting has been no less than rewarding and there was a certain feeling created by building an ROV that was truly gratifying. As a team we got to live, work, and feel like real engineers. The planning, perfecting, determination, and pressure all contributed towards making this experience extraordinary. The knowledge obtained from creating this ROV has been endless. Something was taken away from each and every completed task. It gave us the feeling of a real life scenario. We had to get it done, and we had to do it right. The way we pulled together as a team ensured the workload was spread out evenly, and our ROV was constructed with the utmost care and consideration. For this reason, the feeling of teamwork is definitely the most rewarding experience of all.

Safety

At Heritage Robotics Technologies, safety is our highest priority. We have identified three main areas of concern when it comes to safety. They are the propellers, the electrical system, and general safety practices in the construction and operation of the ROV.

The spinning propellers pose an obvious threat on the ROV and to the ROV operator. To prevent this we have placed warning stickers and guards on each motor, and included awareness of their potential danger in our operator safety checklist.

The electrical system is another danger - particularly as it is in and around water. To prevent the risk of electrical short circuit, we have meticulously covered all connections in heat shrink and liquid electrical tape. We also placed a 25 amp fuse on the positive side of our power supply and a 3 amp fuse on the connection to our Temperature Sensor Unit.

As for safety practices in the construction of the ROV, we ensured that all technicians used safety glasses when working with power tools. Open toed footwear and loose clothing were strictly prohibited.

When considering the safety of those working deck side during ROV operation, we put in place a Tether Management System. This includes the holder on which we coil the tether, but it also includes a protocol by which we insist that operators are aware of the tether at all times to ensure that it is not loose about their feet. We have made every effort to see that no one is ever injured as a result of a mismanaged tether.

We appreciate the MATE safety check which holds all ROVs to a high standard before entering the water. Yet here at Heritage Robotics Technologies, we have prepared our own checklist to further minimize potential danger to ROV operators. (See Appendix 3 for Safety Checklist.)

We at HRT have made every effort to insure all safety precautions were followed. Safety is a priority at HRT that we never compromise.

Figure 14: Greg working on the Multi-purpose Gripper. Notice the safety glasses.

Budget

We began this project on a somewhat restrained budget; but were able to secure some funding through monies raised by two school dances and a vegetable hamper sale. This provided us with working capital of $3,956.00.

Our construction costs could be divided into seven areas:

1. Polycarbonate resin for the frame,
2. Miscellaneous hardware,
3. Wiring, solder, and sealants,
4. Submersible camera,
5. Electronic components,
6. Surface side laptops and joystick,
7. And motors.

It was this last component that caused us the most concern. The motors we believed necessary for Tus Nua's operation would come at a cost of no less than $2442.14 - a figure that would break our limited budget.

An appeal to the administration of Heritage Collegiate was made, and our school came through for us. Their donation allowed us to purchase the motors, and we were able to complete the project on time and on budget.

When you work with Heritage Robotics Technologies, you work with a fiscally responsible company, able to serve your needs within your budget.

Figure 15: Table of Revenues and Construction Costs

Revenue		
Halloween Dance		$984.00
St. Patrick's Day Dance		$832.00
Vegetable Hamper Sale		$2,140.00
	Sub-total:	$3,956.00
School Donation		$900.00
	Total	**$4,856.00**
Construction Costs		
Polycarbonate Resin		$195.00
Hardware		$130.59
Wiring and Cabling		$167.98
Electronics		$928.00
Surface Side Computer		$398.00
Camera		$576.95
Motors		$2,442.14
	Total:	**$4,838.66**
	Balance:	**$17.34**

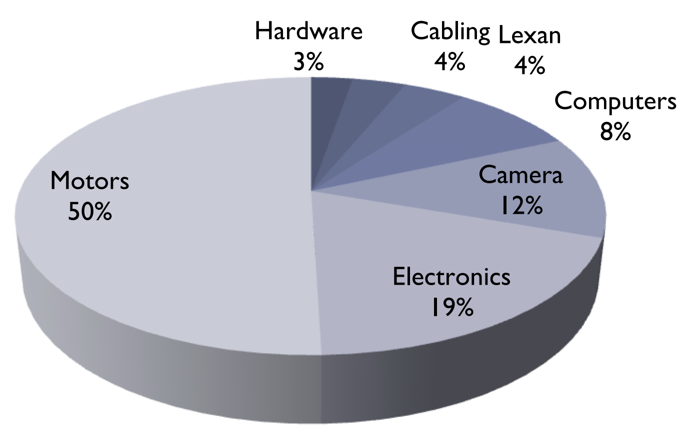
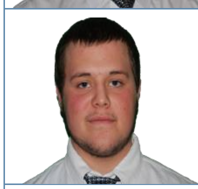
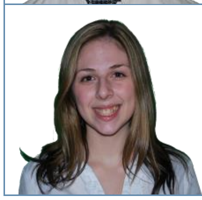
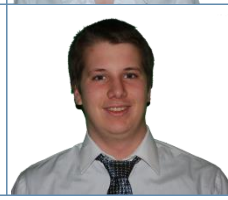


Figure 16: Expense Chart - Our motors were our largest expense.

The Team

This year our team consists of 12 members, aged 15 through 18 – eight of whom are returning competitors. These members include our engineers, our technicians, our safety officer, financial officer, and of course our CEO.

 Magdalena Maeland Communications Officer Career Goal: Geneticist Grade: 11	 Greg Ash Mechanical Technician Career Goal: Mechanic Grade: 10
 Arne Maeland System Design Engineer (Pilot) Career Goal: Engineer Grade: 12	 Laura Blundon Executive Officer Career Goal: Engineer Grade: 12
 Patrick Holloway Electrical Technician Career Goal: Engineer Grade:12	 Braden Chaffey CAD Specialist Career Goal: Draftsman Grade: 11
 Spencer Holloway Software Design Engineer Career Goal: Programmer Grade: 12	 Sebastian Greening CAD Specialist Career Goal: Draftsman Grade: 11
 Lucas Strong Structural Design Engineer Career Goal: Engineer Grade: 11	 Jenna Blagdon Safety Officer Career Goal: Teacher Grade: 11
 Macailyn Pitt Financial Officer Career Goal: Accountant Grade: 11	 Zachary Chatman Structural Technician Career Goal: Engineer Grade: 11

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Acknowledgements

Heritage Robotics Technologies would like to thank everyone who helped make this year's ROV competition possible; and in particular MATE itself and their wonderful staff for organizing the event.

The Eastern School District, the Town of Musgravetown, Clarenville Ford, and Anthony Insurance along with Mr. Dwight Howse of the Marine Institute have our appreciation for providing financial aid toward the costs of our travel expenses.

We acknowledge also our families for their continued support throughout the project, as well as paying a huge portion of our travel.

As well, the administration of Heritage Collegiate should be recognized for their kind donation towards the Seabotix Thrusters.

Last but not least, a very special thank-you to our mentors Mrs. Strong, Mr. Maloney, and Mr. Williams who gave us advice and encouragement, and then stood back while we found our way.

Appendices

Appendix 1 – Electrical Schematic

Figure 17: ROV Electrical Schematic

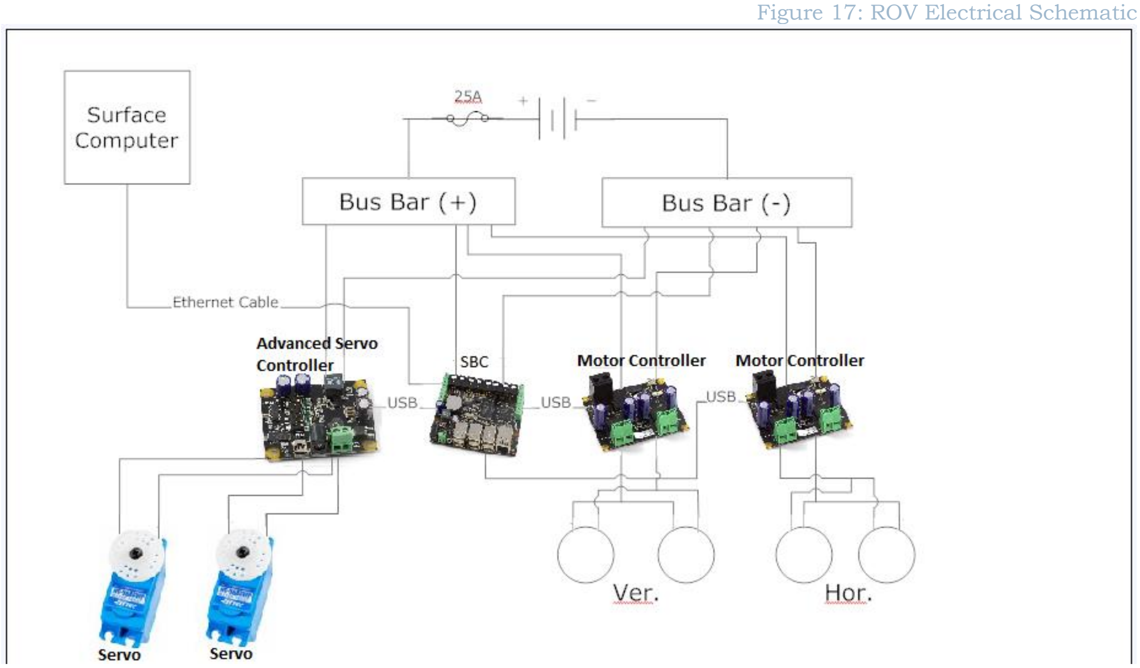
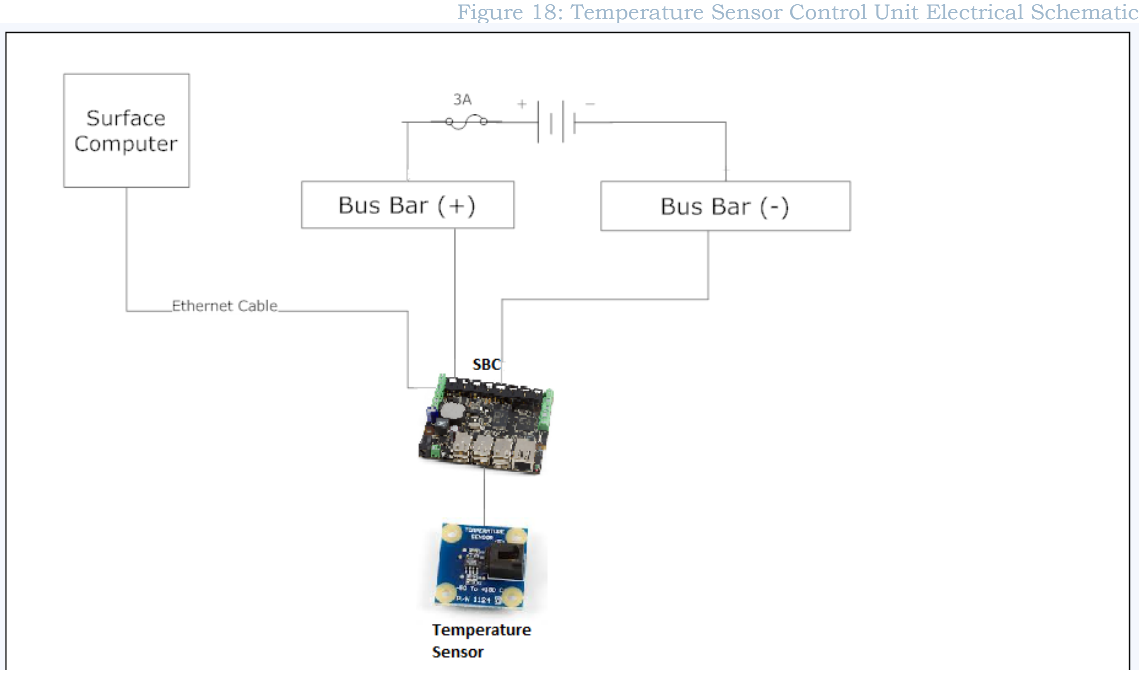
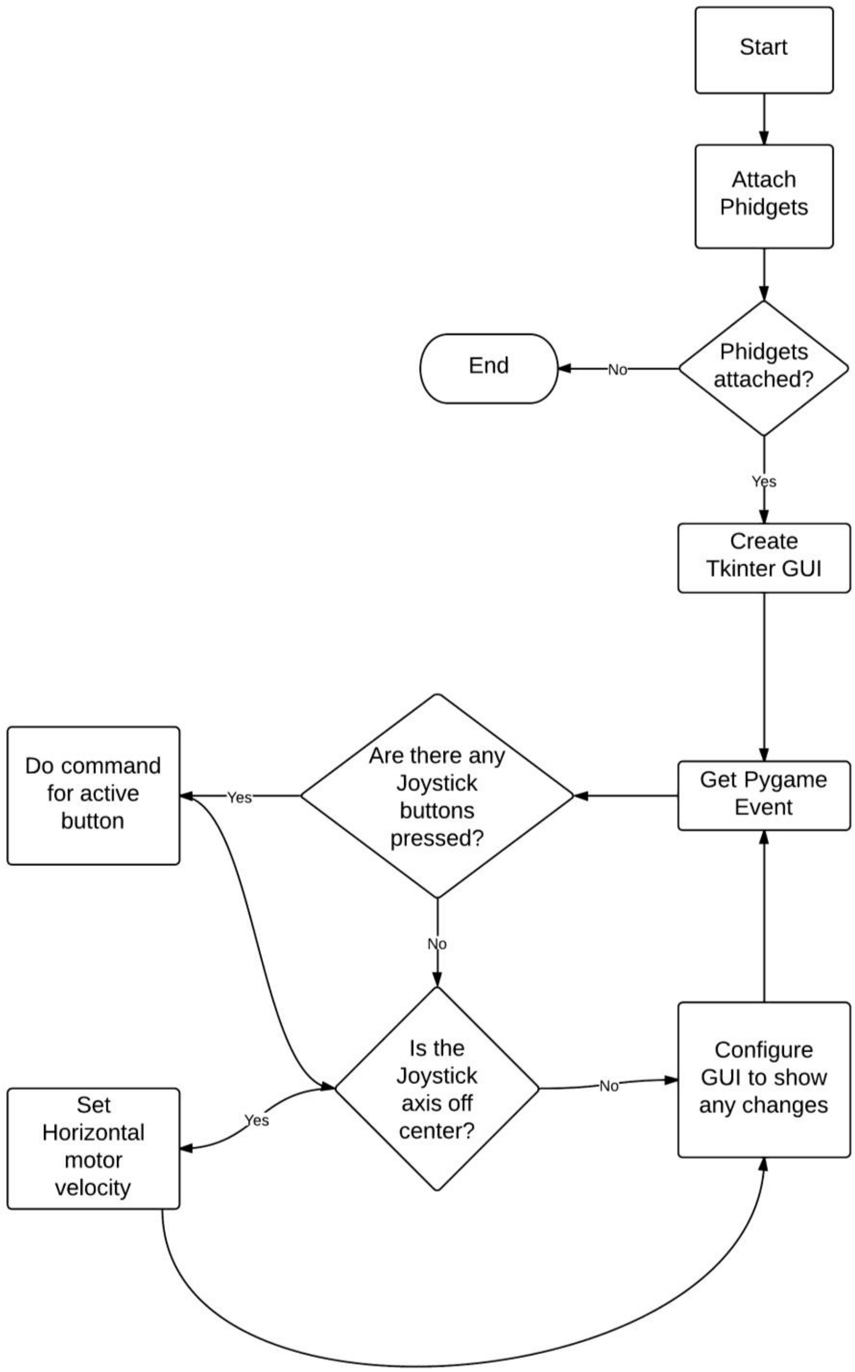


Figure 18: Temperature Sensor Control Unit Electrical Schematic



Appendix 2 – Software Flow

Figure 19: Software Flow Diagram



Appendix 3 – Safety Checklist

ROV Operator Safety Checklist

Team member checklist

	Safety Glasses
	Proper footwear that cover toes
	Life jackets on each member

Before Connecting Power

	No signs of obvious damage
	All motor mounts are secure
	All propellers are securely attached to motors
	Nothing is obstructing propellers
	Spin propellers to check free movement
	Motor guards are present
	Gripper arm is secure
	Camera is secure
	Check tether and all wires for chafed wires
	Tether is connected securely to computer
	Joystick is in normal starting positions
	25 amp fuse is present and closed
	Power cable in working condition

Once Power is Connected Before Operation

	All motors are operational and free of vibrations
	Joystick controls what they are intended to control
	Operators are aware of tether and appropriate tether management protocol