Heritage Robotics Technologies

PROVIDING ADVANCED UNDERSEA ROBOTIC TECHNOLOGIES FOR THE 21st CENTURY

Belisama

TECHNICAL REPORT 2019

STAFF	ROLES
Cally Best	CEO
Ava Dooley	Structural Design Engineer
John Williams	Control Systems Engineer
Kyle Dingwall	Payload Tools Engineer
Billy Newell	Payload Tools Technician
Amy Stephenson	Construction Technician
Jessica Stephenson	Construction Technician
Riana Simmonds	Construction Technician
Kelsi Prince	Public Relations Officer
Felicity Tremblett	Financial Officer
Amelia Greening-Pardy	Safety Officer

MENTORS Mr. Lyndon Williams and Mr. Harold Stephenson

HERITAGE COLLEGIATE, LETHBRIDGE, NEWFOUNDLAND AND LABRADOR, CANADA

Table of Contents

Abstract

HRT is a leading provider of underwater technology. This is our eleventh year competing at the MATE regional competition and, in seven of our previous years, we have advanced to compete internationally.

To complete the assigned tasks of this year's theme, "Innovations for Inshore: ROV Operations in Rivers, Lakes, and Dams", HRT has created our newest product, Belisama--a submarine, remotely operated vehicle. We have specifically designed this ROV to collect and analyze data, and also manipulate and install underwater equipment. Using FreeCAD (0.1.7) and our CNC router, our Payload Tool Engineer has designed and constructed a unique Trouter-Grouter to assist the ROV in repairing a dam and releasing trout fry. A unique geared gripper has also been fabricated to execute tasks by interacting with obstacles and equipment.

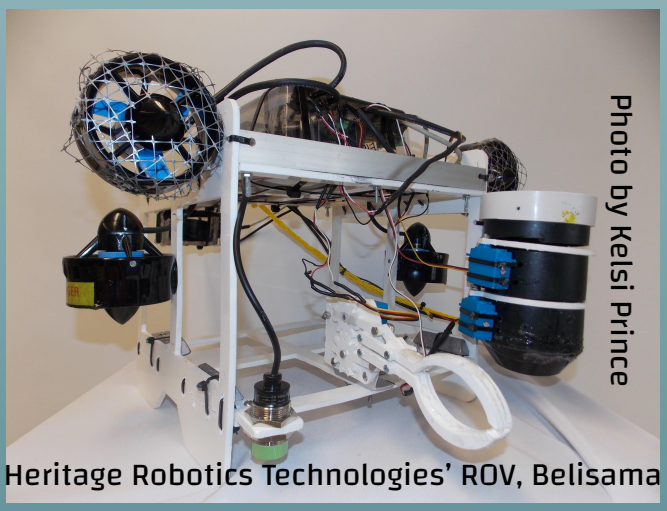


Photo by Kelsi Prince

Heritage Robotics Technologies' ROV, Belisama

To begin, the ROV will ensure public safety by inspecting a dam and using its Trouter-Grouter to repair any damage detected. HRT's gripper will then be used to repair a damaged trash rack. To maintain healthy waterways, a probe attached to the ROV will measure water temperature. Phosphate and pH levels will be determined by collecting a water sample using our gripper, which will also lift a rock to examine benthic species. Our multipurpose Trouter-Grouter will be used again to transport and release trout fry. The gripper will then be used to extract a degraded tire from the bottom of a river or lake, install a new reef ball, and preserve history by recovering a cannon used during the Battle of Kingsport.

Design Rationale

Design Philosophy:

Prior to constructing the frame of Belisama we considered many structural designs, weighing the pros and cons of each. We noticed that past ROVs at HRT have been very similar in design and, while they have performed very well, this year we wanted to create something that has never been seen before from our company. Instead of our traditional rectangle body, we designed a simple cube-shaped body for Belisama which has a much more open-concept design and allows our engineers to work freely with the space. There was an exceptional amount of attention paid to details in terms of the frame, down to the sleek, rounded edges, and the ergonomically correct handle design measured to the average finger size.

October
-Team reading of mission specs briefing.
-Discussed budgeting.

November
-Read request for proposal.
-Created a design for the ROV.

December - January
-Made the frame for Belisama
-Developed software.
-Created payload tools.

February - March
-Waterproofed the cameras.
-Assembled and completed the ROV.

April
-Tested the ROV, made adjustments and improvements.

May
-MATE regional competition.

Structure:

Belisama's frame has been built 53cm long, 52cm wide, and 35cm high and is constructed of high-density polyethylene (HDPE) in a compact box-shaped design. Each part of the frame was created on FreeCAD (0.1.7) by our Structural Design Engineer and then cut out on our in-house CNC Router. Each of the four pieces of the body, when cut-out, fit together in precisely measured slits to form our sturdy, adaptable frame, like pieces of a puzzle. Rather than recreating the same bulky Lexan design that has been used by HRT in previous years, we built a new, unique option that experiences less friction while in motion and allows versatility for the layout of the ROV.

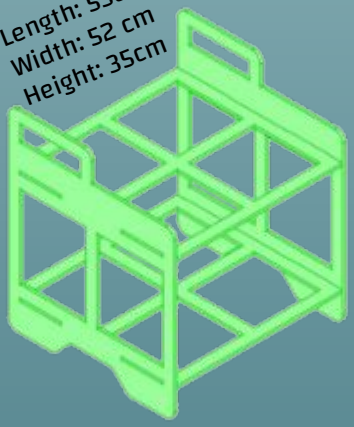


Diagram by Ava Dooley

Belisama's frame in FreeCAD

Buoyancy:

To support the weight of our 8 kg ROV, neutral buoyancy and stability is provided by our watertight container attached to the top of Belisama and also by some small weights secured to the bottom deck of the frame. This option proved to be the most effective and cost-efficient of previous ideas.

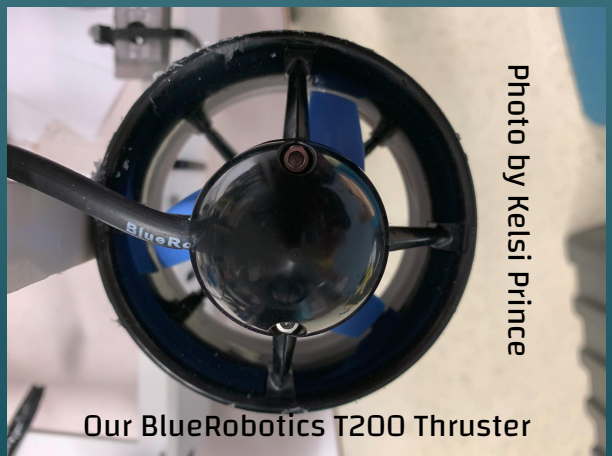


Photo by Kelsi Prince

Our BlueRobotics T200 Thruster

Propulsion:

Two vertical and two horizontal thrusters are positioned on either side of the ROV. These are BlueRobotics T200 motors which we operate at 70% power. All motors have been marked with bright yellow warning labels and are encased in plastic and wrapped in netting to ensure the safety of our crew members. By using four brushless motors, our ROV has been provided with maximum mobility and is able to function at a world class level.

Tether:

Since the power of our motors is controlled by the Electronic Speed Controllers (ESC), our 15.3 m tether is actually very compact. This prevents it from obstructing the mobility of the ROV. It consists of one set of power cables, an Ethernet cable, and pieces of foam to assist with buoyancy. It is securely attached to the ROV and is restrained by a small rope to avoid tension where the tether connects with the Electronic Control Module (ECM). To avoid safety hazards on deck, it's coiled neatly on a holder equipped with a reel.

Photo by Kelsi Prince

Belisama's tether and the floatation foam

Payload Tools:

HRT's Payload Tool Engineer has used servo technology to create a simple two-armed gripper on the front, and a Trouter-Grouter on the left side of our ROV. They were both designed with FreeCAD (0.1.7) and constructed of HPDE parts that have been cut out individually with HRT's CNC router as well as ABS pipe. The gripper is able to transport equipment to/from the surface with ease and place equipment with precision, while the Trouter-Grouter uses two servo-operated doors to carefully dispense the trout and the grout separately in task one and two.

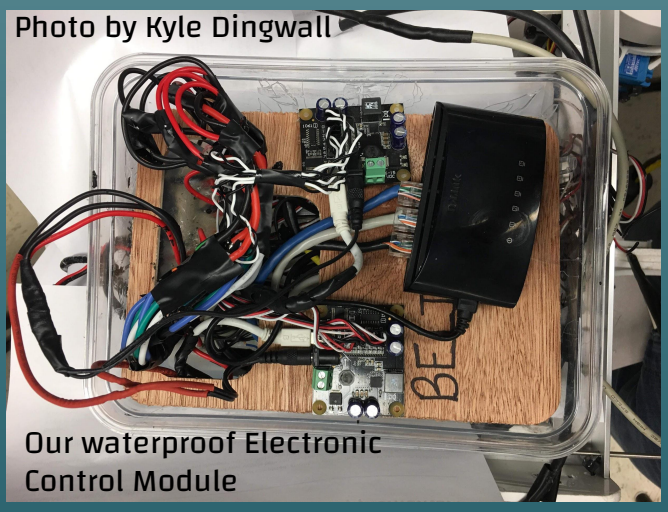


Photo by Kyle Dingwall

Our waterproof Electronic Control Module

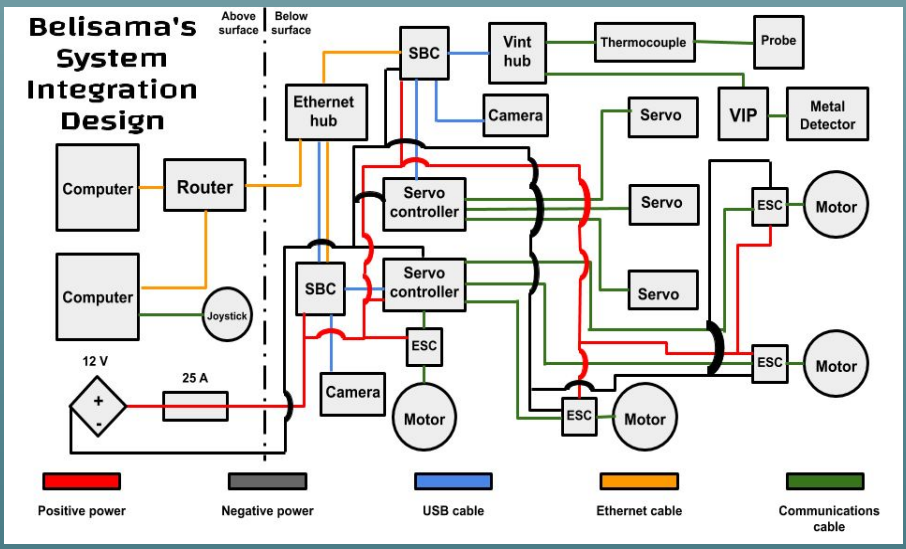
Electronics:

Belisama operates at 12 volts DC and less than 25 amps provided through the tether to the electronic control module or ECM. The power is distributed to three single board computers, two advanced servo controllers, and four speed controllers for our motors - which are all located onboard the ROV inside the clear waterproof container. All is controlled by joystick and in-house software. Our ROV has two cameras, both are Logitech HD Webcams model B525. One is positioned to the back of the ROV above our gripper, giving us a clear view of the objects we must interact with. The other is mounted on the side of the ROV and provides us with a view of the left-side surroundings, this is the camera we use for inspecting the transit line. Our ROV is also equipped with a Phidgets K-Type Thermocouple Probe (temperature sensor) and a Autonics PR30-15DN Inductive Proximity Sensor (metal detector) on the bottom deck of our frame.

Software:

Our company always codes our own software, we never buy any premade kits. After designing our robot we needed to then manipulate our servos and motors to our specific needs, using the programming language, Python 2.7, and a couple of modules we were able to quickly put together a well-built program.

Our software is handwritten line-by-line by our members using Python 2.7 and modules such as Tkinter, Pygame and Phidgets22. We are able to manipulate three servos and four brushless motors without the use of a prepackaged kit bought online. For our ondeck controls we use a single Xbox controller connected to a single Lenovo laptop with an operating system of Linux, specifically Elementary OS . This Lenovo laptop holds the code and connects to the router onboard. This router relays back to our two SBC 3s that wire to our phidgets. Phidgets including our two advanced servo controllers and VINT Hubs, the VINT Hub is what collects our data such as the temperature from the K-Type Thermocouple (temperature sensor) and our Proximity Sensor (metal detector) to detect if an object is metallic.



Fuse Requirements:

SBCs.....0.02 A each x 2 = 0.04 A
Servo Controllers.....0.02 A each x 2 = 0.04 A
Thrusters.....3.00 A each x 4 = 12.00 A
Servos.....0.80 A each x 3 = 2.40 A
Total amperage at 12.....14.48 A
Fuse.....14.48 A x 1.5 = 21.72 A / **25.00 A**

Mission Specifics

Trouter-Grouter:

The Trouter-Grouter is designed for two specific sets of tasks. It is able to place the grout into the cracks, as well as release the trout fry without harming them. Although we could've done these task in multiple steps, we created a design that was capable of doing both tasks presented in a timely manner. Using servo technology we created this unique tool known as the Trouter-Grouter. We designed this tool using FreeCAD (0.1.7) and constructed it of HDPE parts that were individually cut out using HRT's CNC router and ABS pipe. The Trouter-Grouter uses two servo-operated doors to carefully place grout and trout for tasks one and two.

The Trouter-Grouter closed (first) and opened (second

Photos by Ava Dooley

Belisama's custom gripper

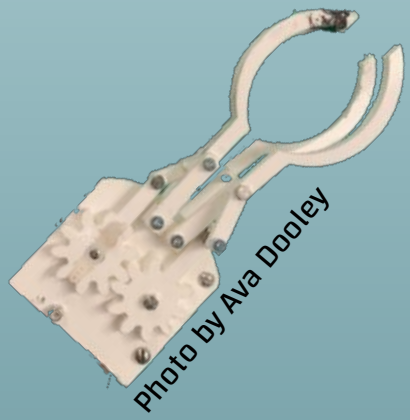


Photo by Ava Dooley

Gripper:

The gripper is specially designed to complete multiple tasks. It is capable of picking up the old trash rack and replacing it with a new one. It can also remove the rock to display the benthic species, pick up the cannon, pick up the tire and even bring the phosphate and pH test to the surface with ease and precision. Our gripper is also made using servo technology and designed on FreeCAD (0.1.7) and cut out of HPDE parts individually cut out using HRT's CNC router.

Sensors:

Belisama is equipped with multiple sensors including a thermocouple to precisely measure the temperature for task two, it can measure as precisely one one-hundredth of a degree. Belisama also has a metal detecting sensor which we use to accurately decipher the canon shells from old debris. Our pilot drives our ROV over the cannon shells/debris and we can read the true/false value to see if it is metal or nonmetal.

Camera Position:

To accurately travel the transect line and map/measure the cracks located on the wall, Belisama uses a side camera. This way we can easily travel forward along the transect line, locate and map the cracks on the wall accurately, this is much easier than trying to turn the ROV and maneuver it sideways using side thrusters.

Belisama's frame with the position of the second camera circled

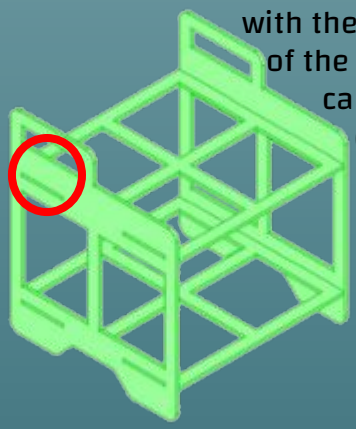
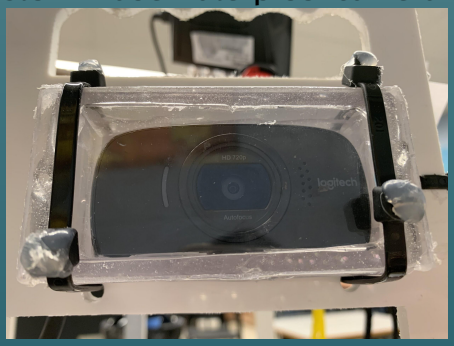


Photo by Ava Dooley

Our custom-made waterproof camera case

Fabrication

Photo by Kelsi Prince



Waterproofing:

When considering ideas for housing our electronics while also keeping them dry, we always kept cost in mind. The most convenient and cost-effective option we discussed was simply keeping them in a plastic tupperware container. Through thorough testing, we determined that the container we chose, a low-cost L&L snap container, was actually extremely durable and kept every drop of water out. Our two cameras are not waterproof on their own, so we designed custom waterproof camera boxes that fit perfectly and keep out any traces of water. All of the joins on the boxes were double sealed with epoxy and the waterproof container was sprayed with NeverWet when all the electronics were put in place. We've tested our product for hours in water of various depths to ensure that our electronics are safe and dry.

Materials:

The composition of Belisama is mainly Lexan and HDPE. We knew from past years at HRT that Lexan was reliable but we explored the option of a new material, HDPE. This material, which we purchased in sheets, is not only almost half the cost of Lexan, it cuts very well on our CNC router. We used this for the entirety of the frame with the exception of aluminium rods for stability. Both of these materials are cost-effective but we used them very effectively.

New vs Reused

A team member hard at work designing

Photo by Ava Dooley

This year we have established a new and improved remotely operated vehicle: Belisama. The majority of Belisama's components are new, as we are constantly developing new software and payload tools. Everything has been designed specifically to complete the unique desired tasks of this year's competition. In previous years, HRT has designed rectangular shaped ROVs made of Lexan, propelled by SeaBotix BDT 150 motors. This year, we have opted for a box-like frame constructed of HDPE and have purchased four new BlueRobotics T-200 thrusters as our method of propulsion. Only a few components were salvaged from previous years. This includes two SBCs and two advanced servo controllers located inside the ROV's electronic control module (ECM). In addition to that, four waterproof servos were reused on the gripper and Trouter-Grouter. Reusing these components prevented us from exceeding our budget and allowed our company to introduce a new, reliable, cost-efficient product. With an abundance of new technology, HRT can ensure Belisama's capability and dependability while completing any required task.

Build vs Buy

HRT has fabricated many in-house components – each with a unique, functional design which could not be commercially purchased. Only the components with complicated functions that exceed HRT's fabrication capabilities were purchased. Instead of turning to commercial companies to buy each feature of Belisama, HRT has fabricated our own frame, software and unique payload tools. Each part fulfills our company's required specifications of high performance, low cost, and most importantly: reliability. Our ROV's HDPE frame has been designed using FreeCAD (0.1.7) and cut out using our company's CNC router. It's unique, adaptable design allows us to make any necessary adjustments to accomplish any desired task. Our distinctive software has been coded from scratch and tells each servo to open or close our payload tools on command. It also controls the amount of power to be sent to each brushless motor. HRT has also designed and constructed an original geared gripper with a hook-like arm. This provides us with the ability to manipulate and interact with underwater obstacles. In addition to a new geared gripper, HRT's Payload Tool Engineer has created a Trouter-Grouter which has been specifically designed for this year's competition tasks.

Safety

Company Safety:

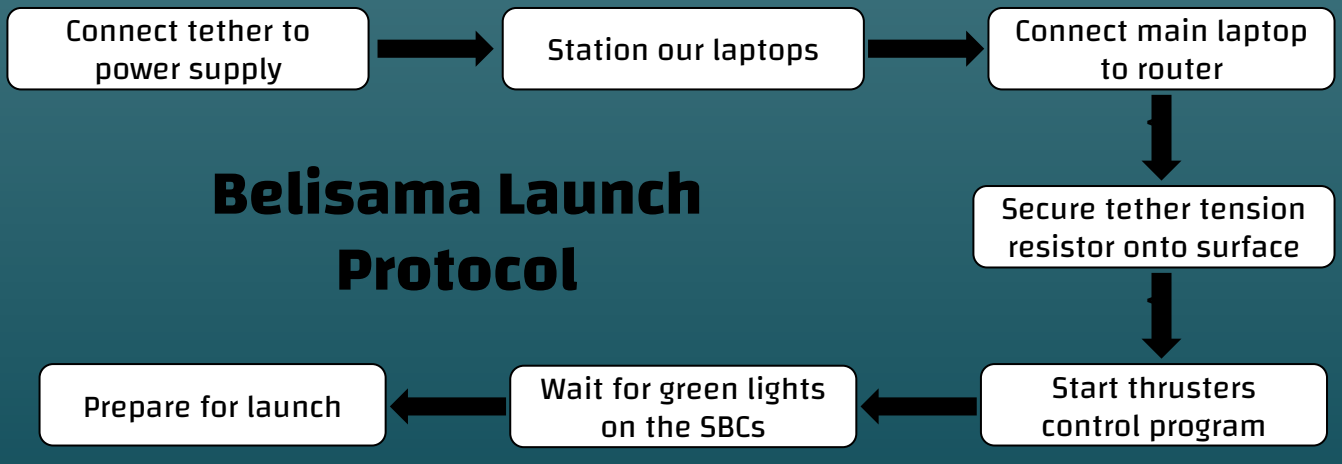
At Heritage Robotics Technologies (HRT), safety is of the utmost importance. We've worked vigorously to ensure the safety of all team members, marine organisms, and the public. In the fabrication area, safety glasses, gloves and masks were worn when dealing with chemicals to prevent inhalation and prevent any potential hazards. Loose clothing, long sleeves, and open toed shoes were strictly prohibited. It was also enforced that long hair be kept up at all times.

Safety Features:

We've made numerous safety features to Belisama that keep all possible hazards to a minimum, such as:

Safety Features	Description
Warning Labels	All thrusters are appropriately labeled with bright warning signs, an extra precaution to ensure no personnels touch the propellers.
Thruster Shrouds	The thrusters are double-wrapped in durable, plastic netting to significantly decrease the chance of being injured by the propellers.
No Sharp Edges	Belisama has been thoroughly inspected to ensure there are no sharp edges. Any found were sanded and covered with glue or epoxy.
Handle	The handles of Belisama are perfectly calculated to the radius of the average person's hands. This makes it incredibly easy to get a good grip and reduces the risk of dropping the ROV.
Tether Management System	The Tether Management System is a repurposed garden hose reel. It keeps the tether neatly wrapped around during travel and while on deck. It prevents the potential tripping hazard on deck and easily allows the tether men to send out and pull back tether as necessary.

Belisama Launch Protocol



Safety Checklist

Power Off Checklist

	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 tethers 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
	3 amp fuse is present and closed
	Power cable is in working condition

Power On Checklist

	All motors are operational and free of vibrations
	Joysticks control what they are intended to control

Team Member Checklist

	Safety Glasses
	Proper footwear that cover toes
	Life jackets on each member
	Proper footwear to prevent slipping on the deck

Testing/Troubleshooting

A team member testing the thrusters

Photo by Ava Dooley

Before the ROV was tested in water, we checked it "in the air" to further reduce potential problems in the pool. We ensured that the motors, sensors, and payload tools were functioning properly. HRT then conducted several trials in our in-house pool where the complete ROV was tested. Our pilot gave feedback on control systems, accuracy of payload tools (like the gripper and Trouter-Grouter), how well the sensors worked, and other external factors that could affect the ROV. During long periods of pool testing, we also checked the ROV for any leaks. A major issue that we had to troubleshoot was how to set up the joysticks in order to manipulate the motors. Whenever we have a problem, we always start at the most obvious solution. If the most obvious and easiest solution doesn't work, we come up with the next least complicated solution. This method of problem solving proves to be most effective. Using our problem solving method, we created a program that was able to match up a certain axis of the joystick.

Prototyping

In the early stages, we considered many designs for the Trouter-Grouter. We narrowed it down to two options and built both to see which would be most effective. The first prototypes consisted of scrap pipes, plywood doors, servos. We ruled out one of the designs as it contained an extra servo that was not needed. After much testing, HRT also determined that the prototype HDPE gripper did not close enough and the actual gripper should have a tighter grip.

Challenges

Interpersonal:

Only two members were returning to HRT this year. Therefore, most members had no experience prior to building Belisama. To guarantee our success and the future of the team, we had to invest time in training new members. The fastest way to train members is just to let them work on tasks and figure it out for themselves. The issue with this was the severe drop in quality of work. To combat this, the work was checked vigorously by the returning members. The newcomers and returning members also had many meetings, discussions, and workshops to increase knowledge in many areas. Six members out of eleven are seniors, which meant that this school year was crucial in terms of studies and applying for university. This greatly reduced the amount of time for robotics. We had to ensure that the time that we did have available was used efficiently, so we assigned specific roles and tasks to each individual. Therefore, if some members were not available, we could still be productive.

Technical:

In the beginning, our ROV was controlled by 16 Port Advanced Servo Controllers. We had many issues with this. After several miserable days of troubleshooting, HRT decided to revert back to older 8 port Servo Controllers. We tried many things to fix the issue such as trying different 16 Port Advanced Servo Controllers, switching out servos, and changing the programs. Reverting back to the 8 Port worked out in the end, as they were more reliable and took up less space in the electronics container.

Lessons Learnt

Management:

Towards the last month before the regional competition, we realized that we were extremely behind. One of the most important lessons we have learned was to meet deadlines as time management is essential for success. Our future team knows that it is better to start earlier in the year to ensure proper progress on the ROV.

Technical:

Pulse width modulation was a brand new technology to HRT. When we got the motors, we had the task of finding the appropriate connection from the electronic speed controllers to the advanced servo controller. Understanding this new technology will serve our future team well.

Development of Skills:

New members have learned a variety of skills in areas such as fabrication, using FreeCAD (0.1.7), Gimp, and coding. Returning members further refined their skills and had the learning experience of mentoring new members. Although every member was involved in all parts of making Belisama, each member had an area in which they became particularly skilled. Many of our senior members have decided to apply for marine/robotics technology courses in University since joining the team.

Future Improvements:

In the future, HRT plans to add a “hover” function using a ultrasonic range finder. While completing missions tasks, the operator currently has to actively keep vertical height off the pool while operating the payload tools. By adding the range finder, the operator can focus more on completing the tasks. Time management is something HRT constantly struggles with and has to be addressed. For next year, HRT decided to stick with a schedule and timeline in order to meet deadlines and prevent last minute changes that could threaten the performance of the ROV.

Finance

Budget Planning:

A company budget discussion

Photo by Ava Dooley

Our mission at Heritage Robotics Technologies is always to provide world-class products to the 21st Century, but this comes at a cost. One of our top priorities for constructing a high-functioning ROV is keeping the cost as low as possible and, as a company who builds their entire robot from scratch every year, this is a challenge. We discussed amongst ourselves and consulted our mentors about a budget we thought was very realistic based on our fundraising efforts which gathered just over $7 000. We decided a budget of $5 000 for the materials was sufficient and we aimed to be well under this number in the end.

Photo by Ava Dooley

Team members selling tickets

Fundraising Efforts:

Our fundraising efforts include (but are not limited to):

-Robotics summer camp -Selling tickets
-Hosting dances -Canteen services
-Selling vegetable hampers

HRT Financial Report

Fundraising Deposits

Date of Deposit	Amount	Total Deposits
Sept. 24th, 2018	$773.00	$773.00
Oct. 15th, 2018	$1 738.00	$2 511.00
Oct. 15th, 2018	$523.00	$3 034.00
Oct. 17th, 2018	$30.00	$3 064.00
Oct. 26th, 2018	$810.85	$3 874.85
Nov. 7th, 2018	$735.85	$4 610.70
Nov. 15th, 2018	$200.00	$4 810.70
Dec. 12th, 2018	$755.00	$5 565.70
Dec. 20th, 2018	$365.00	$5 930.70
Jan. 7th, 2018	$900.00	$6 830.70
Jan. 9th, 2018	$310.00	$7 140.70

Total deposits: $7 140.70

Heritage Robotics Technologies Financial Report

Expenses

Date	Details	Notes	Cost	Balance ($7 140.70)
Oct. 16th, 2018	Solid Carbide Insert Straight Router Bit (x6)	Purchased	$187.74	$6 952.96
Oct. 30th, 2018	Meranti Board (x4)	Purchased	$67.54	$6 885.42
Nov. 30th, 2018	Meranti Board (x5)	Purchased	$82.17	$6 803.25
Jan. 7th, 2019	Marine Goop	Purchased	$17.24	$6 786.01
Jan. 17th, 2019	Primary Red Wire (x2)	Purchased	$55.18	$6 730.83
Jan. 17th, 2019	Primary Black Wire (x2)	Purchased	$52.88	$6 677.95
Jan. 17th, 2019	Solder Rosin (x6)	Purchased	$44.78	$6 633.17
Jan. 17th, 2019	Insulated Male Tab Terminal	Purchased	$15.62	$6 617.55
Jan. 17th, 2019	Insulated Ring Terminal	Purchased	$2.63	$6 614.92
Jan. 18th, 2019	Shrink Tubing (x6)	Purchased	$16.49	$6 598.43
Jan. 18th, 2019	Jigsaw Blade	Purchased	$7.23	$6 591.20
Feb. 2nd, 2019	Electrical Tape	Purchased	$9.17	$6 582.03
Feb. 2nd, 2019	Jigsaw Blade	Purchased	$7.23	$6 574.80
Feb. 14th, 2019	Marine Goop (x2)	Purchased	$34.48	$6 540.32
Feb. 15th, 2019	High-Density Polyethylene Sheets	Purchased	$143.75	$6 396.57
Feb. 15th, 2019	Lexan Sheets	Purchased	$258.75	$6 137.82
Feb. 27th, 2019	Heat Gun	Purchased	$45.99	$6 091,83
Mar. 7th, 2019	Proximity Sensor (x2)	Purchased	$106.74	$5 985.09
Mar. 7th, 2019	K-Type Probe Thermocouple (x2)	Purchased	$48.81	$5 936.28
Mar. 7th, 2019	Thermocouple (X3)	Purchased	$160.11	$5 776.17
Mar. 7th, 2019	PhidgetSBC4 (x3)	Purchased	$548.96	$5 227.21

Mar. 7th, 2019	Phidget Cable (10 cm, 15 cm, 60 cm, 120 cm, 180 cm, 350 cm)	Purchased	$19.83	$5 207.38
Mar. 7th, 2019	Network Hub	Purchased	$27.58	$5 179.80
Mar. 7th, 2019	Epoxy (x6)	Purchased	$10.35	$5 169.45
Mar. 11th, 2019	Heavy Duty Gluesticks (x2)	Purchased	$45.98	$5 123.47
Mar. 11th, 2019	Glue Gun (x2)	Purchased	$34.48	$5 088.99
Mar. 11th, 2019	Back Saw (x2)	Purchased	$22.98	$5 066.01
Mar. 11th, 2019	Mitrebox (x2)	Purchased	$29.88	$5 036.13
Mar. 11th, 2019	Pan Head Screws (x2)	Purchased	$9.87	$5 026.26
Mar. 13th, 2019	Versatile Input Phidget (x2)	Purchased	$129.57	$4 896.69
Mar. 18th, 2019	Wire Cutters (x4)	Purchased	$16.33	$4 880.36
Mar. 18th, 2019	Carbide Flat Cutter	Purchased	$59.10	$4 821.26
Mar. 18th, 2019	Waterproof Servo (x6)	Purchased	$374.88	$4 446.38
Mar. 18th, 2019	VINT Hub Phidget (x2)	Purchased	$179.40	$4 266.98
Mar. 19th, 2019	Marine Goop	Purchased	$12.64	$4 254.34
Mar. 18th, 2019	Tupperware Container	Purchased	$22.99	$4 231.35
Mar. 22nd, 2019	Heatshrink	Purchased	$14.36	$4 216.99
Mar. 22nd, 2019	Connect Quick (x2)	Purchased	$4.59	$4 212.40
Mar. 22nd, 2019	Red Wire (x2)	Purchased	$39.58	$4 172.83
Mar. 22nd, 2019	Black Wire (x2)	Purchased	$39.58	$4 133.24
Mar. 26th, 2019	12V Battery	Purchased	$85.08	$4 048.16
Apr. 4th, 2019	Hose Clamp	Purchased	$12.37	$4 035.79
Apr. 29th, 2019	Screws (x2)	Purchased	$6.30	$4 029.49
Apr. 29th, 2019	Shrink Tubing (x2)	Purchased	$21.97	$4 007.52
Apr. 30th, 2019	Hacksaw Blades	Purchased	$3.67	$4 003.85

Apr. 30th, 2019	Foam Pipe Insulation (x2)	Purchased	$1.82	$4 002.03
May 1st, 2019	Shrink Tubing (x2)	Purchased	$5.50	$3 996.53
May 3rd, 2019	Epoxy	Purchased	$13.21	$3 983.32
May 3rd, 2019	Kwik Bonding Compound	Purchased	$14.94	$3 968.38
May 3rd, 2019	Cable Ties	Purchased	$10.46	$3 957.92
_	Underwater Fishing Camera (used for testing)	DONATED by principal, Mr. Stewart Churchill	$230.00	$3 957.92
_	Logitech Cameras (x2)	REUSED	$183.98	$3 957.92
_	Brushless Motors (x4)	REUSED	$777.40	$3 957.92

Total cost (including donated items): $4 374.21
Total expenses (excluding donated items): $3 182.78
Remaining balance: $3 957.92

ROV Specific Costs

Brushless Motors (x4)	$777.40
Logitech Cameras (x2)	$183.98
PhidgetSBC3 (x2)	$276.00
Servo Controllers (x2)	$195.50
VINT Hub Phidget	$89.70
Network Hub	$27.58
K-Type Probe Thermocouple	$24.41
Thermocouple	$53.37
Proximity Sensor	$53.37
High-Density Polyethylene Sheets	$143.75
Lexan Sheets	$258.75
Cable Ties	$10.46
Marine Goop (x6)	$103.44
Waterproof Servo (x3)	$187.44
Phidget Cable (10 cm, 15 cm, 60 cm, 120 cm, 180 cm, 350 cm)	$19.83
Tupperware Container	$22.99
Heatshrink	$14.36
Electrical Tape	$9.17

Total cost: $2 451.50

Travel Expenses

Item	Cost	Total
Airfare/ Insurance (x11)	$1 300	$14 300
Hotel Rooms (x3)	$114	$342
Rental Cars/Fuel (x2)	$700	$1 400

Total cost: $16 042.00

Acknowledgements

Heritage Robotics Technologies would like to thank everyone who helped make this year's ROV competition possible. We would like to dedicate a special thanks to MATE and the Kingsport Aquatics Center for organizing the competition, and also to the Marine Institute for nominating HRT for the wild card. To all of the companies and individuals who gave donations, we couldn't have made it this far without your help. To our parents and guardians, your constant support is most valuable. Last but not least, a very special thanks to our mentors, Mr. Williams and Mr. Stephenson, who have sacrificed countless hours of their time to help make our experience successful.

Photo by Mark Frye

References

https://www.bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster/
(BlueRobotics Thruster) *used for specs
https://www.phidgets.com/?tier=3&catid=21&pcid=18&prodid=1032
(Phidgets Servo Controller) *used for specs
https://www.phidgets.com/?tier=3&catid=1&pcid=0&prodid=969
(PhidgetSBC) *used for specs
https://www.pinterest.ca/pin/821203931782631178/
(Rainbow Trout Art by Spencer Williams) *used for cover background