Heritage Robotics Technologies

Heritage Collegiate, Lethbridge, Newfoundland, Canada

Staff:

Kyle Ash (17) - Construction Technician

Cally Best (16) - Public Relations Officer

Lauren Chatman (17) - Chief Executive Officer

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Garrett Holloway (17) - Payload Tool Technician

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Abstract

Heritage Robotics Technologies, also known as HRT, is composed of ten students who attend Heritage Collegiate in the town of Lethbridge, Newfoundland (NL), Canada (CA). Over the course of several months, we've developed the Black Bullet; a Remotely Operated Vehicle (ROV) with the ability to operate not only in the waters of the Atlantic but all over the world. The first design of our ROV (constructed with half inch PVC pipe), was waterproofed by a Rubbermaid tub, and our pay load tool was crafted by our CNC router and cut out on 3.175mm aluminum and 5mm lexan. Our redesigned ROV, now has motors mounted onto 6mm aluminum and our gripper is redesigned and built with lexan and aluminum. Our electronics are placed into a 12 x 31 cm PVC pipe and sealed shut. We assure you that our ROV will not only get the job done but it will be done safely.

The Black Bullet

Size: 50.6cm long X 40.7cm wide X 33.0cm high

Weight: 9.5kg

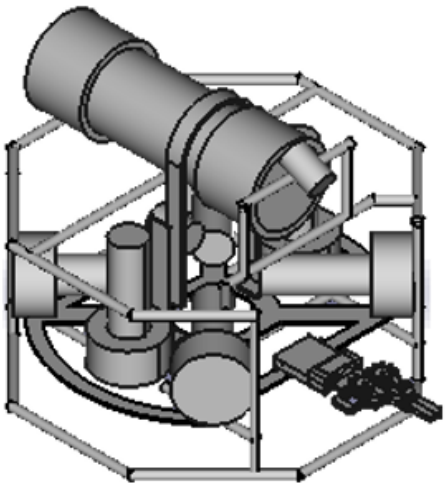
Cost: $1852.25

Theme

The Pacific Northwest area of Washington State is known for its beautiful and lively geography, sitting between the Olympic and Cascade Mountain ranges, their snowcapped peaks hiding temporarily dormant volcanoes and tectonic plates prone to earthquake activity. The combinations of volcanic eruptions and earthquakes have shaped this piece of North America, raising the mountains and creating rivers via the snow melt that flows into deep water lakes. Earthquakes also cause mudslides, landslides, and lahars that have wiped out large forested areas and re sculpted the terrain. A fjord ties the Seattle area to the rest of the world through the Pacific Ocean. Known as Puget Sound, this fjord was formed by these same earth-moving forces. Puget Sound is also susceptible to another earthquake effect: the tsunami. Seattle's history reflects a wide variety of businesses based on natural resources and the local geography, including fishing, farming, and logging. In addition to this, Seattle is the birthplace of Boeing, which is why Seattle is known as "Jet City." This only adds to the popularity of the Seattle and Tacoma ports that started booming during the Alaskan gold rush. These ports continue to be some of the busiest ports on the west coast today.

Project Management

Our team first met in September 2017 so we would be ready for the regional competition. We had a scheduled meeting every Sunday and Wednesday, and we always set time frames for everything to be completed in case of an unexpected malfunction. As a team each of our roles were based on our knowledge and expertise. Since this is the first time in three years that HRT designed an ROV and our budget was restricted we built our ROV by hand and on our CNC router reusing everything that we possibly could - from start to finish. At the same time, we designed a unique ROV as we take pride at HRT in originality.



ROV FreeCad Sketch

Safety

At HRT, we make safety our top priority. In the construction of the ROV we have determined three main areas that could be a hazard to ones safety. These areas would be the propellers, the electrical system and the team's safety in construction and operation of the ROV. The spinning propellers will stand as a hazard on the ROV. To prevent injury we have placed warning stickers as well as mesh guards on every motor. Not only the propellers pose a safety threat, the electrical system is another danger that we take caution in, since it's used in and around water. To prevent the risk of an electrical short circuit, we have meticulously covered all connections in heat shrink, liquid electrical tape and epoxy resin. The team will regularly check on all the joins of the wire and make sure that everything operates safely. We have also placed a 25 amp fuse on the positive side of our power supply in case of an electrical malfunction. As for safety practices in the construction of the ROV, we ensured that all our engineers and technicians used safety glasses when working with power tools. Open toed footwear and loose clothing are strictly banned. When considering the safety of those working deck side during the ROV operation, we put in place a tether management system. It includes a holder used to coil the tether and 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 mismanaged tether. We appreciate the MATE safety checklist which holds all ROVs to a high standard of safety before entering the water. At HRT, we have prepared our own checklist to further minimize the potential danger to our ROV operators. You may rest assured that when you work with HRT, you are working with a company that is not only reliable and conscientious, but has made safety our first priority on which we will never compromise.

Safety 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 arms are secure
	Cameras are secure
	Check tether and all wires for chafed wires
	Tether is connected securely to network switch, battery, and air compressor
	Joysticks are in normal starting positions
	25 amp fuse is present and closed
	3 amp fuse is present and closed
	Power cable in working condition
	Air compressor is set to 100 psi
	Air tube can handle 100 psi

Power on checklist

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

Team member safety

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

Accounting

Budget Planning

(All in Canadian Dollars)
At the beginning of the season a budget was prepared, through extensive research of resources and expenses needed for the project. We researched items we were certain we were going to use and included the cost in our budget. The design of the ROV was based around the motors that were used in previous years. This gave us some room to buy some new electronics that we needed. We made our own program to run the ROV and we used two joysticks that were used in previous years.

Item	Estimated Cost
CPVC pipe	$70.00
Self-Tapping Screws	$40.00
Motor Controllers	$460.00
Servo Controllers	$114.00
SBC 3	$180.00
Waterproof Servos	$260.00
Other Electronics	$54.00
Tether	$300.00
Claw Parts	$145.00
Goop, Water Wield	$90.00
Liquid Electrical Tape	$16.00
Electronics Housing	$50.00
Total	$1779.00

Project Cost

The complete budget can be seen below. The final price for Black Bullet came out to be about $1852.25, which was slightly over budget but still manageable. The extra expenses came from some miscellaneous items that weren't accounted for in the budget.
Our team's main source of income this year came from our school dance, vegetable hampers sale and a donation from regional competition supporters. The dance was a success, bringing in around $700 and the vegetable hampers brought in around $900, which totaled $1,600. The regional competition supporters donated $750, which brought our revenues to $2,350. Upon winning the regional competition we were given $20,000 by the sponsor of Newfoundland and Labrador regional MATE competition and we also sold tickets, which raised $5,000. The team member's contribution made a total of $5,000 as well. Also donations from businesses, made up another $5,000.
The travel costs for the trip totaled approximately $28,000, which covered plane tickets ($16,434.86) for all team members and three chaperones, five hotel rooms ($8,649.65) and three rental vans ($3,136.65). The cost of meals is estimated at $3,640.00.

Black Bullet 2018 Project Costing					
	Item	Type	Qty.	Cost	Total
Frame	½” CPVC Tee	Purchased	20	$1.09	$21.80
	½” PVC Pipe	Purchased	3	$5.99	$17.97
	½” PVC 90 Degree Elbow	Purchased	15	$0.59	$8.85
	½” PVC 45 Degree Elbow	Purchased	20	$0.89	$17.80
	100 pack #10x5/8” Pan Head	Purchased	3	$13.49	$40.47
Electronic Housing	CSA Approved 4” Hub Female imperial Pipe PVC Sewer Pipe	Purchased	2	$5.49	$10.98
	4”x10” Non CSA Solid PVC Sewer Pipe	Purchased	1	$14.99	$14.99
	CSA Approved 4” male Pipe Thread PVC Clean out Plug	Purchased	2	$4.19	$8.38
Claw	18”x24” 0.093 Clear Sheet Lexan	Purchased	1	$66.99	$66.99
	8”x24” 0.025 Aluminum Sheet	Purchased	6	$13.28	$79.68
Electronics	Phidget/Advanced Servo Controller	Purchased	1	$114.88	$114.88
	Phidget Motor Controller HC	Purchased	3	$153.17	$459.51
	Phidget SBC 3	Purchased	1	$178.70	$178.70
	Water Proof High Torque Servo	Purchased	5	$52.24	$261.20
	Sound Phidget	Purchased	3	$17.82	$53.46
	Narrow View Amber Camera	Donated	1	$1500.00	$1500.00
	Wide View Amber Camera	Donated	2	$1500.00	$3000.00
Tether	16AWG Wire	Purchased	4	$53.98	$215.92
	Ethernet Cable	Purchased	1	$18.99	$18.99
	Pneumatic Air Hose	Purchased	1	$62.99	$62.99
Controls	Lenovo ThinkPad T61	Donated	2	$149.00	$298.00
	Logitech ATK3	Reused	2	$38.00	$76.00
Thrust	SeaBotix BTD150	Reused	4	$700.00	$2800.00
	50Lb SCUBA Lift Bag	Purchased	2	$39.99	$79.98

Misc.	Marine Adhesive Goop	Purchased	4	$19.49	$77.96
	2oz Water Wield	Purchased	1	$15.49	$15.49
	118Ml Liquid Electrical tape	Purchased	1	$16.49	$16.49
	7mil x 3/4” PVC CSA Electrical tape	Purchased	2	$0.89	$1.78
	PVC All Purpose Cement	Purchased	1	$6.99	$6.99
Total Invested In Black Bullet (Purchased, Reused and Donated) $9526.25 Total (Purchased) $1852.25					
Printing	Marketing Display	Purchased	2	$100.00	$200.00
Travel	Airfare/insurance	Purchased	13	$1264.22	$16434.86
	Hotel Rooms	Purchased	5	$1729.93	$8649.65
	Rental Cars/Fuel	Purchased	3	$1045.55	$3136.65
	Meals	Purchased			$3640.00
Team Expenses	SeaBotix BTD150	Purchased	2	$700	$1400.00
Total Team Expenses $33461.16					
Team Income	Prize From Regionals	Donation			$20000.00
	Dance	Income			$700.00
	Vegetable Hampers	Income			$900.00
	Ticket Sales	Income	1000	$5.00	$5000.00
	Team Members Contribution	Income	10	$500.00	$5000.00
	Contributors	Donation			$5000.00
Total Team Income $36600.00					
Total Club Funds (Income – Expenses) $1286.59					

Design Rationale

Build vs. Buy

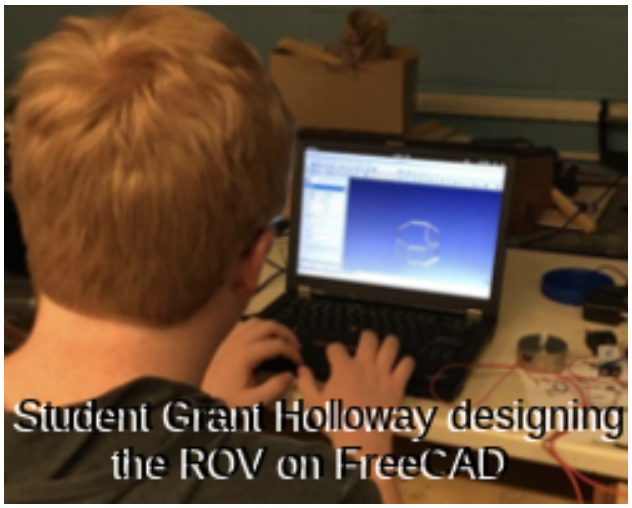
At HRT, we designed and built the Black Bullet from scratch, including all its parts such as its frame, the electronic housing, the payload tool and the waterproofed measuring tape. Everything was either hand made or cut out on our CNC router. This worked in our favor as we had a limited budget. Coincidentally, we are all hands-on students and we enjoy building things ourselves.

New vs. Used

One of HRT's mottos is to reduce, reuse, and recycle. At HRT we reused many different tools on our ROV. For example, we reused our motors from previous years, and our Servo Controllers and Motor Controllers are also reused. Infact they have been used daily in our Design and Fabricaton class so we knew we could rely on them.

Structure Design Process

For the competition we looked at multiple ROV designs from previous MATE competitions, including our own ROV's from previous years. Our old ROV's were made out of lexan with just a simple rectangle body which worked well for our team for many years. We placed second at the 2009 international competition in Boston and also in Seattle in 2013. This year we came up with a brand new design made from half inch PVC piping, which we liked because it was lightweight, strong and had a small amount of drag when moving through the water. We have a model of this years ROV made on Freecad 1.6, which is our program of choice when building scale ideas. Our robot is made with an octagon frame because it gives us multiple places to put different tools on the ROV. Our aluminum motor base was cut out on our CNC router to make it as precise as possible. Our ROV was completely hand made by team members from the unique gripper to the program that it runs on.

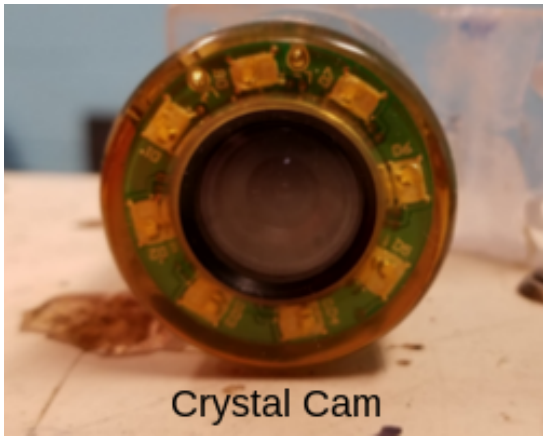

Student Grant Holloway designing the ROV on FreeCAD


Student Douglas Holloway using the CNC

Motors

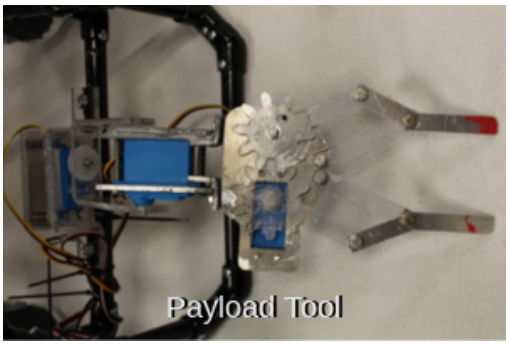
At HRT we use BTD150 thrusters from Seabotix. We chose these thrusters because we have used them in the past and have had great success with them. These motors at maximum peak of force provide 6.4ft/LBS at 12V, they have a total mass of 705g in air and 305g in water. We place the motors on the Black Bullet very precisely in a “X” configuration to maximize movement while doing tasks. We also have two vertical motors that get the ROV to and from the surface as fast as possible. HRT has written a program to minimize the amount of amps drawn by using seventy percent of the motors power, which will decrease the force to 4.48ft/LBS.

Cameras



With regards to the cameras, Crystal Cam in British Columbia donated three of their "Amber" cameras to work with, but they were not the only ones to donate cameras. Sub-C in Clarenville, Newfoundland also donated a camera. When we were wiring up the cameras we quickly discovered that the camera donated by Sub-C would not operate with a 12V (25 amp) power supply which we were required to use. Fortunately the ones that Crystal Cam in BC donated worked well and provided us with great picture quality. It gave us an in depth-visual advantage. However, when we were at the regional competition we experienced technical difficulties with one camera . Luckily we found the problem. Some wires had suffered abrasion from a zip-tie but we easily fixed it with some liquid electrical tape.

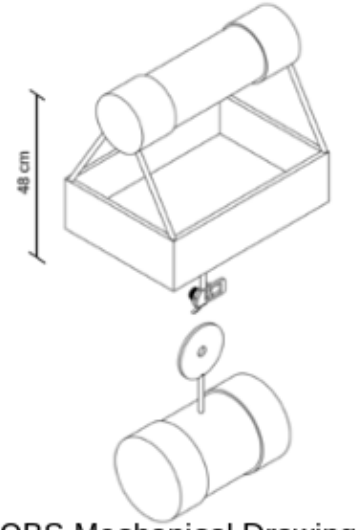
Payload tool



The claw is mainly constructed using materials such as aluminum and lexan. This allowed for a low cost custom gripper. The claw was designed on FreeCad(1.6),put on Artcam and then each piece was cut out on our CNC machine. The Arm was designed to adapt to different shaped objects. This is a gear gripper and is powered by waterproof servos. It’s designed to complete all the tasks required. It is a three servo gripper which is very compact and can rotate three hundred and sixty degrees, move up

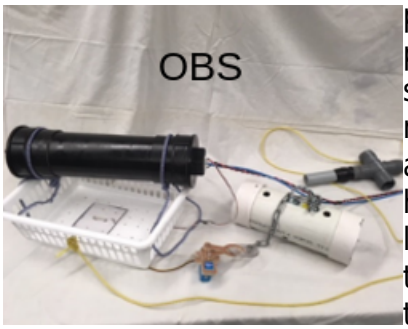
and down, and close and open. The gears are made of 5 mm lexan and the base is made of one eighth and one quarter aluminum. The ends of the claw are interchangeable so they can be more effective in different tasks.

OBS Design



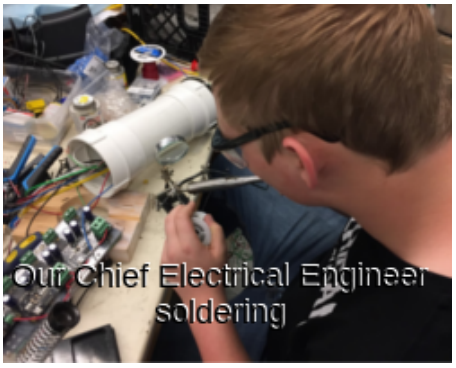
OBS Mechanical Drawing

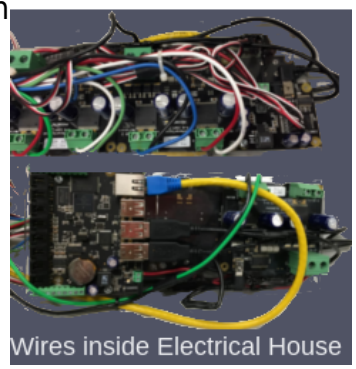
This is the first OBS that HRT has ever designed, and with it came many challenges. Originally, we wanted to use a magnetic release, but we had problems finding magnets of that strength. We then implemented an easy to make and use manual release. After the regional competition we wanted to step up our game with an acoustic release. To do this, we used a sound phidget to pick up and read sounds of different frequencies. We wrote a program so that when the phidget picked up a certain frequency at a speciific volume, a servo would then move to release the OBS from the anchor. The electronics to make this happen, with the exception of a servo located on the release, are located in a pipe that also serves as the inflation for the OBS. A small container is then located at the bottom of the pipe for the insertion of the cable connector.

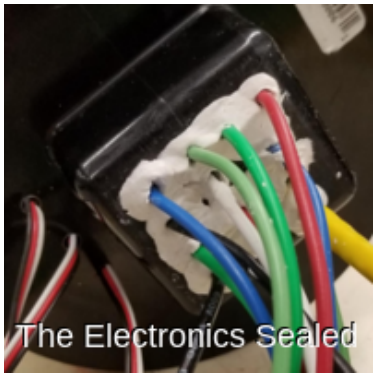


Electronics

The bulk of the electronics are in the electronics housing on top of the ROV. To keep all of our electronics safe while 5.18m below the surface we designed an electronic housing, which is made of a piece of 4-inch PVC pipe with two threaded end caps with integrated O-rings. We drilled eighteen precise holes in one end cap to run wires through. The 12 wires in the tube are 16awg running from the three Phidgets Motor Control HC to the motors, and three sets of servo wires which will run from our Phidgets Advance Servo 8-Motor to the three servos on our electronic payload tool. We use a Phidget SBC 3 to tie all of our electronics together, enabling our ROV to function properly. The main power comes from two 16awg wires, which split into five different ends, each for the power and ground to the electronics inside. To seal the holes in the end caps we used three tubes of marine goop and PVC cement applied around the holes to ensure they are sealed safely. For our OBS we are using

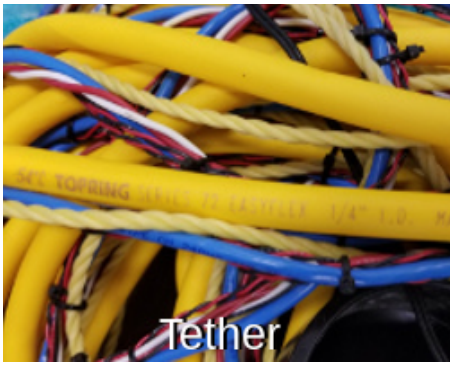

Our Chief Electrical Engineer soldering


Wires inside Electrical House


The Electronics Sealed

a scrapped computer speaker which will play a specific frequency to be picked up by a "Sound Phidget". All of the Black Bullet's electrical components, (except for the laptop, speakers and joysticks) can be purchased at www.Phidgets.com.

Tether


Tether

The Black Bullets tether is approximately 15.24m long and is comprised of nine pieces. There are two 20awg video power wires for the cameras. In addition, there are two 20awg video negative wires used to transfer the video to our two monitors on the surface. To supply power to the ROV we integrated into our tether a 16awg power wire and another 16awg wire for our ground. To get signals from our control center to the ROV we decided it would be easier to use an Ethernet cable rather than using bluetooth connections. For pneumatics to fill our lift bags we used a 15.24m long ¼ inch air hose which is rated at 300psi that we purchased at Princess-Auto for around $75 (Canadian dollars). For safety purposes we have a safety rope also integrated into our tether in case our wires burst. We also have a length of rope tied onto the tether directly as a tension relief strategy to ensure the wires remain sealed into the electronics housing.

Control System & Software


Our Control System

HRTs control system consist of two laptops and two joysticks. At HRT we also design all of our programs ourselves. Nothing is prepackaged, as it's all written by a team member. The ROV software, is designed to calculate flight data and maximum power from turbine speed. The laptops are ThinkPad models T410 and T61, both of which use Linux as their operating systems. As for our programs we used Python 2.7 to code everything from motor movement to how far the plane traveled. We used a set of functions to run our motors through joystick movement. We designated one joystick as our X and Y axis displacement, as well as a second joystick for Z axis displacement. Our joysticks also come with buttons designed to open, close and turn servo. We accomplished this by using widgets such as Pygame, Phidgets 22 and Tkinter.

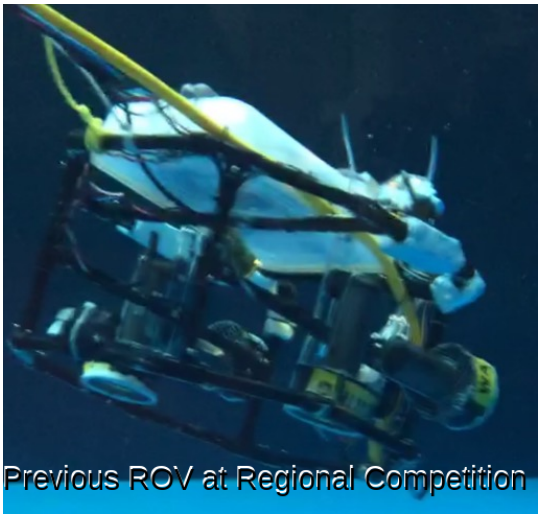
```
import Tkinter
import pygame
from Phidget22.Devices.DCMotor import *
from Phidget22.Devices.RCServo import *
from Phidget22.Net import *
Net.enableServerDiscovery(PhidgetServerType.PHIDGETSERVER_DEVICE);
```

Above is a portion of the Pilot's program. The Co-Pilot's laptop is appointed to the more mathematical side of the task. We programmed a series of functions in Python 2.7 to tell us our maximum power and placement of the plane. It's as simple as filling out a form. We created these programs to decrease the amount of time spent doing calculations on deck.

Buoyancy

The flotation of the Black Bullet wasn't neutrally buoyant with all the weight of the thrusters. The size of the electronics tub assisted with the buoyancy but we still required more, so we added some foam pieces. While testing in the school's tank we realized that we added too much buoyancy, so with some trial and error we neutralized the buoyancy by adding some weight to the stern to help with sinking. We drilled holes in the frame of the ROV to make it sink faster and with with less drag. While we were testing the ROV in the public swimming pool we realized that the buoyancy in the tank and the pool created different results. We had to assure that the buoyancy was suitable for the competition pool.

Testing & Troubleshooting


Previous ROV at Regional Competition

Testing was a key element of the ROV building process; with trial and error multiple times to make sure everything was running smoothly. HRT has designed the entire ROV, so whenever there was a technical issue we figured out how to fix it. During the regional competition, we discovered that the placement of our motors didn't work as well as we hoped so we did some upgrades. We relocated the motors to enable movement in all directions. Our buoyancy was trial and error until we made it perfect. We also determined at regionals that our electrical housing (Rubbermaid tub) bent up quite a bit from the pressure of the water. We did some modifications and placed all of our electronics in the PVC pipe. After much testing we are sure that our ROV will be ready to face any task.

Challenges

Some of HRT's technical challenges stemmed from a magnetic release OBS and the overall buoyancy of the ROV itself. When HRT first designed our first prototype for a OBS we decided to make it a magnetic release. The release was made up of two circuits, a reed switch, a relay and an electric magnet. The first problem that occurred while building this release was the reed switches that we were using couldn't handle the electric current that

was passing through. We decided that we would make our own consisting of two thin pieces of magnetic metal and a plastic cylinder. The next problem we encountered was the lack of volts to switch the relay to release the OBS. Overall the magnetic release OBS was a difficult process. The buoyancy of our ROV created a number of issues, as the first time we put the Black Bullet in water we underestimated it's ability to float because it sunk straight to the bottom. We thought we had the buoyancy just right (in our 1.8 m tank) but then we realized that the amount of buoyancy needed in our tank would be way too much in a deeper pool. As a result we had to remove some of the buoyancy to make it just right. The biggest interpersonal challenge that our team had to face was finding the time to meet. Due to sports, jobs and other commitments it was a challenge to get together at the same time in the same place. As we became more involved with the design and construction of the Black Bullet it was clear that being a team member of HRT was a top priority for everyone.

Lessons Learned

As a team we learned that designing an ROV is quite difficult and requires countless hours involving computer programming/designing, hands on construction and engineering. As a team we've shared knowledge amongst each other on different topics. If someone was struggling a team member would always be ready to lend a helping hand. We all realized as a team that it's important to be organized and to manage our money and time wisely. It has directed about half of the team members towards studying engineering or computer sciences at post secondary. Overall, the experience is definitely a highlight of our high school years.

Future Improvements

Decreasing our total ROV's weight and size would improve it maneuverability. This year we used brushed motors which are bulky, heavy and require large H bridges. In future we would prefer to use brushless motors which are smaller, lighter, quieter and more efficient, drawing less electrical current.

Reflections

Kyle Ash: This is my first year as a member of the Robotics team and it was a blast! Joining HRT helped me develop many skills such as hands on skills,organization and working as a team. It has also made me realize that there are many careers associated with underwater technologies that I'm interested in. I am thankful to say that I was a member of Heritage Robotics Technologies.

Cally Best: I've always been interested in the engineering profession, and joining the Heritage Collegiate robotics team was my first exposure to hands on engineering. This is my first year participating in the MATE ROV competition, and since I have joined, the team has taught me so much about the mechanics of an ROV and how much work actually goes into it. I have learned the basics of programming, designing blueprints with FreeCad, and creating wiring schematics with Gimp. Through robotics, I have been given the opportunity to further expand my passion for technology, along with the motivation to strive for greatness. Getting involved in the robotics team has allowed me to gain an abundance of knowledge of electronics, programming, mechanical design, and ROVs in general. None of which would have been possible otherwise.

Lauren Chatman: Joining HRT was quite an experience, as it helped me develop hands on skills and confirmed that I wanted to become an engineer. I gained valuable knowledge in relation to overseeing a company, in my duties as Chief Executive Officer of HRT. Throughout this process I gained valuable leadership, organizational and interpersonal skills. Being a member of HRT has been the opportunity of a lifetime.

Douglas Holloway: Being part of Heritage Collegiate's robotics team had been a very unique experience. It has given me a lot of hands on experience with tools, computer programming and 3D modeling, the ladder of which has made me interested in careers involving 3D modeling. Though it has given me many headaches, robotics has just enforced my love to create things, which I have done throughout my time on the team, whether it has been a model or a program. It has been a very enjoyable experience and I am proud to be part of HRT.

Garrett Holloway: I have always been interested in designing and creating, as I have always wanted to become an engineer. I like the process of thinking about how something works and then creating it. However, it is difficult to find opportunities to engage in the engineering profession while still in high school. I have learned a great deal about designing since I've been with HRT. I've had lots of hands on experience working in the field. I enjoy being a part of the team and I'm thankful that I have the opportunity to compete internationally with a great group of people.

Grant Holloway: Joining the robotics team has been one of the best decisions I have ever made. With robotics you get so much hands on experience in many different engineering fields such as architectural and electrical. Myself, planning to be a future civil engineer will benefit greatly from skills I have learned within this program. I would like to thank everyone who devoted many hours to this project especially our mentors, because without them we would not have the opportunity to participate in this MATE competition.

Riley King: Joining HRT was a different life experience for me. It was very enjoyable and a great bit of fun. It taught me so many different skills like wiring and building the props.

Working with HRT made me think about different career choices. I am proud to be a member of Heritage Robotics team.

Liam Nash: Joining HRT was a life changing experience. It taught me valuable life skills such as being an integrated team member and organizational skills. I realized that wiring and soldering wires are something I enjoy. HRT has introduced me to some interesting career paths such as an electrician and even a welder. I learned the value of being a team member and an appreciation for the contributions of my amazing teammates. I am thankful and proud to say that I was a member of Heritage Robotics Technologies.

Danny Penney: Financing has always interested me, and joining HRT and becoming the CFO has opened my mind to the world of managing money. Learning to create a budget and organizing fund-raisers opened new opportunities for our team. It allowed us to upgrade the Black Bullet and compete internationally. Even though I sometimes felt like pulling my hair out when things don't work out as expected it has been an enjoyable experience and I'm very proud to be a member of HRT.

John Williams: Being a member of HRT was a pleasure. However, during the construction of the ROV it seemed as if each complication became more and more difficult to overcome. With determination and teamwork, we overcame all of the obstacles we faced.. Throughout the process I realized that programming is something that I am interested in and I hope to one day become a Software Engineer.

Individual Roles

Kyle Ash, grade 12, Construction Technician, 17 years old, wants to be a Commercial Pilot. Kyle helped with multiple tasks and was always there to suggest different types of designs for the ROV and other products.

Cally Best, grade 11, Public Relations Officer, 16 years old, wants to be Architectural Engineer. Cally design the Marketing Poster Board along with the System Integration Design.

Lauren Chatman, grade 12, Chief Executive Officer, 17 years old, wants to be a Mechanical Engineer. Lauren put the technical report together, organized the team, and helped others with individual tasks. She overseen the entire production.

Douglas Holloway, grade 12, Software Design Engineer, 17 years old, wants to be a Video Game Art and Design Engineer. Douglas wrote the coding and designed the OBS' acoustic release.

Garrett Holloway, grade 12, Payload Tool Technician, 17 years old, wants to be a Mechanical Engineer. Garrett designed and built the payload tool (robotic arm). Each piece was designed on FreeCad 1.6 and then cut out on our CNC.

Grant Holloway, grade 12, Architectural Engineer, 17 years old, wants to be a civil engineer. Grant helped with the design of this years ROV, and helped others with individual tasks while constructing the ROV.

Riley King, grade 12, Design Engineer, 17 years old, wants to be a Heavy Equipment Operator. Riley helped with the overall design of the ROV and made sure everything was buoyant.

Liam Nash, grade 12, Design Engineer, 18 years old, wants to be a Heavy Equipment Operator. Liam took on the electrical layout on the ROV, and made sure they were safely sealed.

Danny Penney, grade 12, Chief Financial Officer, 17 years old, wants to be a Heavy Equipment Operator. Danny overseen the financial part of the process, organized the funding needed for the production and was there to help with other task.

John Williams, grade 11, Safety Officer, 16 years old, wants to be a Software Engineer. John is our Co-Pilot who handled the mathematical part of the tasks, he also wrote a mathematical program in order to do so.

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•Mary Browns
•NAPA
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•Computers for Schools NL http://www.computersforschoolsnl.ca/
•Crystal Cam Imaging Inc. http://crystal-cam.com/

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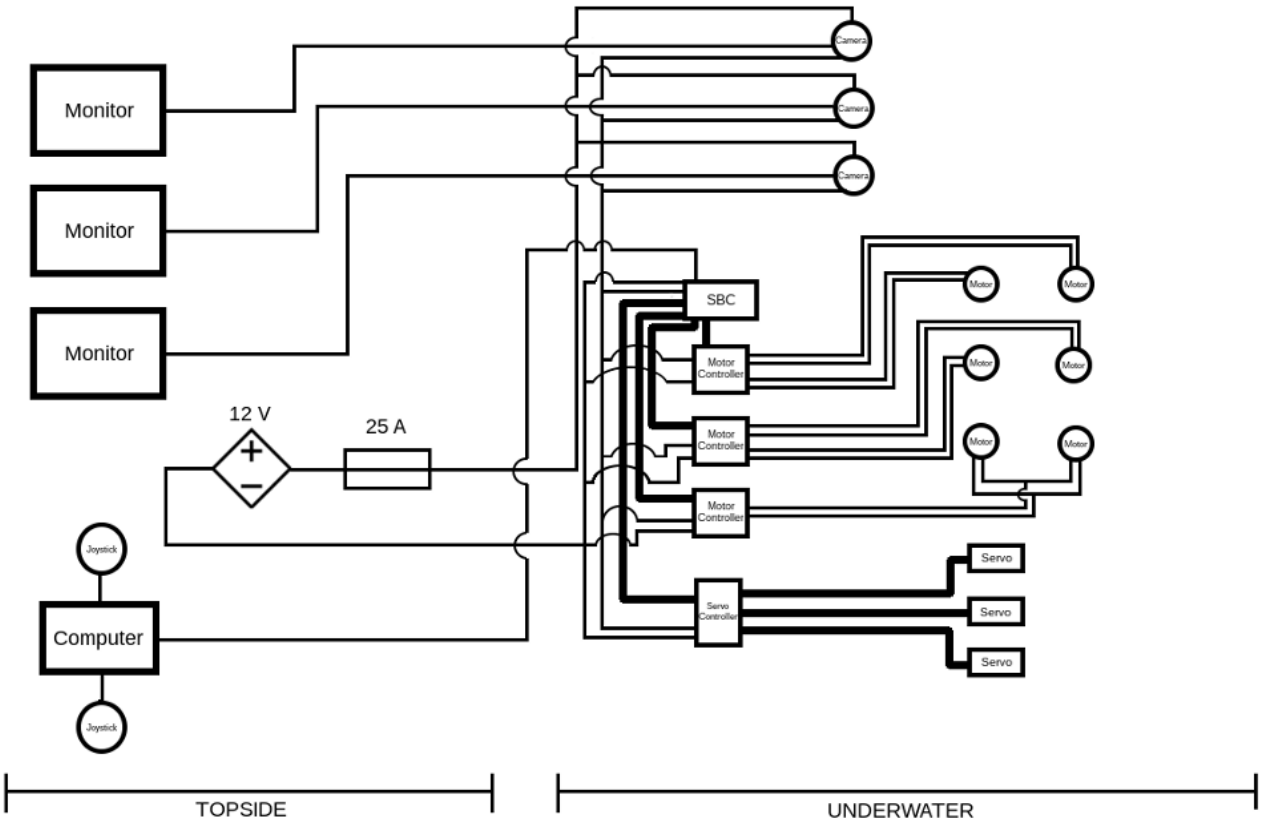
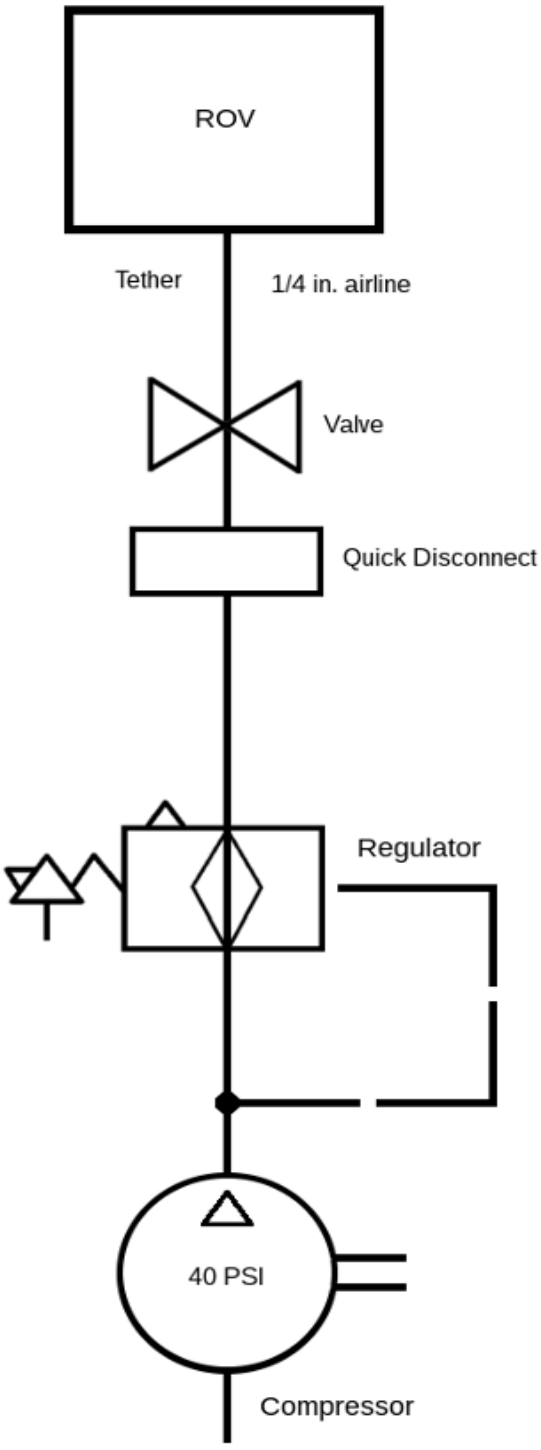
Phidgets.com, for: Programing knowledge.
https://www.phidgets.com/
MATE, for: Information on how to develop everything all together.
https://www.marinetech.org
Heritage Robotics Tech Reference, for: How to use different computer software.
http://mrwilliams.elementfx.com/roboticstechreference/index.php
Robot Shop, for: information on our servos and other electronics.
https://www.robotshop.com/en/catalogsearch/result/?dir=desc&order=relevance&q=underwater&rq=underwater+servo
Python.org
https://www.python.org/

Appendices

System Integration Design



Pneumatic Diagram



OBS System Integration Design