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Liam Acres: CTO and Pilot
Logan Crooks: Chief Electrical Engineer
Matt Glencross: Chief Mechanical Engineer
Will Paul: Electrical Engineer
Simon Qi: Electrical Engineer
Morgan Higginson: Mechanical Engineer
Fran Annan: Mechanical Engineer
Jeff Zhao: Software Engineer
Johnny Ye: CFO
Noah Mason: Safety Officer
Jonah Scott: Mentor
Colin Melia: Mentor

Nova Underwater Technologies

Technical Report

Charles P. Allen High School
Bedford, Nova Scotia, Canada
2016 MATE ROV Competition Ranger Class

Contents

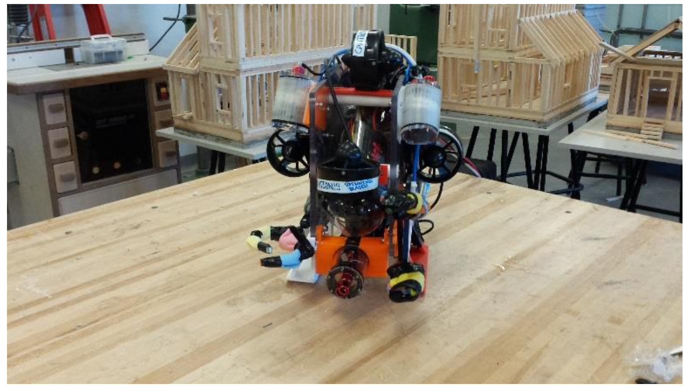
Abstract

We at Nova Underwater Technologies are proud to present the newest in our line of expertly crafted ROVs, *Cygnus*. Our goal with this newest device was to create a multipurpose instrument that adhered to the MATE quality of safety and functionality. *Cygnus* was built by a mixture of old and new team members, all of who are dedicated to providing a product that will result in maximum customer satisfaction.

We took the best ideas from our previous ROV and applied them to this newest project. We still have the same computing system that pairs a Netduino microcontroller with an Xbox 360 controller to allow for ease of use and precise movements. However, this year our system is being held in a completely new frame that is far more compact.

Of course, we kept our staple feature of six Blue Robotics thrusters that allow for six directions of travel and the full three axis of rotation, as we felt this was an important and useful feature. There is no limit to the maneuvers a client can perform, and no situation too extreme to perform them in.

Our on board devices have been improved greatly as well. *Cygnus* is equipped with two pneumatic claws, each designed to be multipurpose and incredibly versatile. We have also included temperature and depth sensors, so more information can be gathered about the environment. *Cygnus* has a solution for every task.



Cygnus, our ROV.

Design Rationale

A large part of working on a large project is to decide, as a team, what direction each piece should be taken in. Our team worked hard to find the best solutions to each issue that arose, and we believe that this shows in our quality of design.

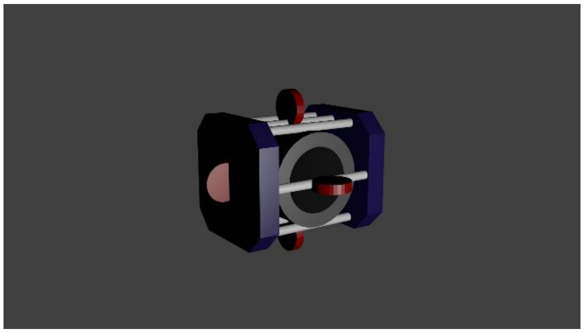
Our primary design rationale was based around testing everything to see what worked best. We built several prototypes of all of our components, leading to an improvement of both the quality of the final the product, and the overall knowledge of our team members.

Frame

No matter what features go into an ROV, they must all be housed in a single frame. To this end, a frame must be able to serve a number of features. The first is to properly protect the delicate parts of a machine. We have achieved this by using thick Lexan plates secured together with PVC pipes. This creates a sturdy structure.

Our electronics are housed in a tube that is supported in the frame. It is water tight and is sandwiched between the Lexan so that the electronics can not come to any harm.

What is immediately noticeable is that the tube is at a forty-five-degree angle. This was not part of our original design but was a feature we realised would conserve a lot of space.



An early frame design mock-up, with the Blue Robotics thrusters in red.

Making our ROV as compact as possible was one of our first priorities. Being able to fit into small spaces is essential for exploring any environment. To this end, every part of the frame has been designed to conserve as much space as possible, and we believe we have succeeded in reaching this goal and have maximized the maneuverability of *Cygnus* by doing so.

Thrusters

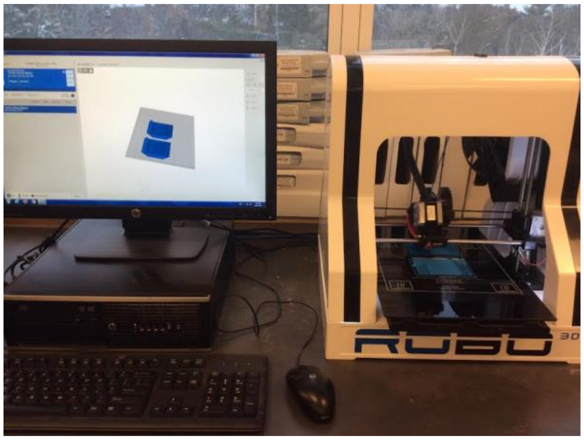
With our new model, we wanted to maintain our greatest selling feature: the ability to move in all directions and rotations. We have kept our six thrusters positioned evenly to provide horizontal, vertical, and lateral movements.

The ability to rotate in every direction is one of largest design challenges each year. Making a frame that can support this requires meticulous design and innovative thinking. Luckily, we were able to maintain our overall design rationale from last year. Some of the Blue Robotic thruster mounts for our thrusters did not fit onto the new frame, however, we were able to overcome this challenge by designing and then 3D printing custom mounts in order to fit them correctly onto the robot.

We used the same Blue Robotics thrusters from last year, as they were still powerful and efficient enough for any situation.

Articulators

Perhaps our biggest change and improvement from last year was our claws. We wanted to build an articulator that would be more versatile and reliable than our last design. To this end, we used 3D printer design software in order to create custom tools from 3D printed components. We have two different designs so as to cover any and all situations.

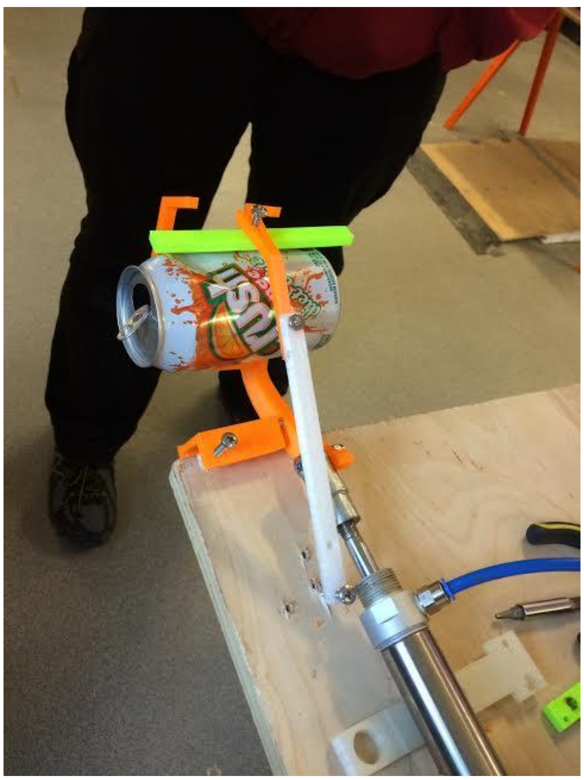


One of our many custom 3D models printing.

The first is a wide claw device that opens and closes to grasp objects of a small to medium size. The ends are a simple, yet effective shape so that no object is impossible to grab hold of. The power of this comes in its ability to pick up irregular, small objects that would be difficult to manipulate with a lesser design.

Our other device is designed for large objects that can be picked up by a handle or lever. It is designed like a swinging jaw that can be used in numerous different situations to retrieve whatever our customers need.

Both of these articulators are controlled using a pneumatic system. They are compact and easy to use. Working together, there is no problem that cannot be solved. They are attached to opposite sides of the ROV to maintain balance and avoid interference.



Testing an articulator prototype.

Electronics

The electrical systems and the tether of *Cygnus* were built custom by Nova to fully service all of our R.O.V's needs while preforming underwater tasks. The tether consists of two pneumatic tubes, a positive electrical cable, a negative electrical cable, and an Ethernet cable. All of the parts comply with the MATE competition safety guidelines.

The power cable is made from 12, 10, and 18 gage copper wire, banana plugs at each end of the wires. A 25-amp fuse was also used on the positive wire near the power supply in case of the event of a power surge or failure of any electrical components.

CTO Liam Acres working on our core electronics tube.

Optics

We upgraded this model of our ROV to have four cameras. *Cygnus* is equipped with a forwards camera, a backwards camera, and two articulator cameras. This allows for the greatest control of both the ROV itself, and its on-board devices.

Having cameras on front and back allow for a pilot to operate in the most efficient way possible. Combined with our six directional thruster system, there is incredible versatility at the fingertips of the pilot.

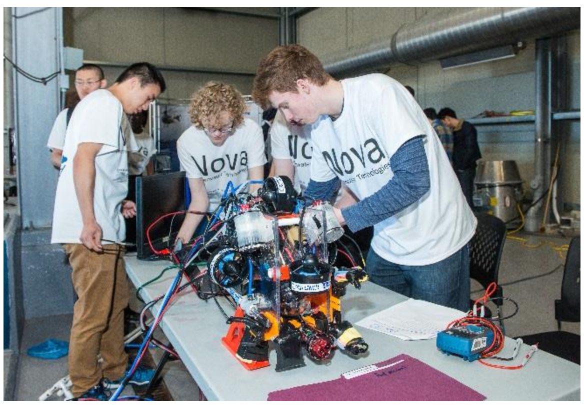
We waterproofed them in small tubes that we then epoxied in order to seal them. This allowed for clear vision and water safety.

We used the MATE certified sealing method to do this. This method involves the use of plumber's putty and epoxy to hold the camera into a transparent casing.

We then attached them using 3D printed camera mounts made with transparent PLA to allow for our lights to shine through.

Computing

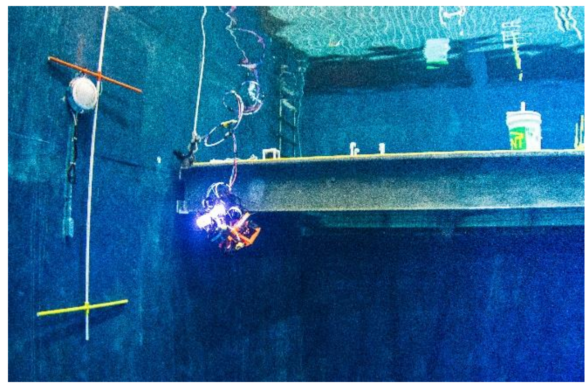
At Nova, we discovered that the best way to control the ROV from a distance was with a programmable microcontroller. We kept the same Netduino system as last year, as it worked perfectly.



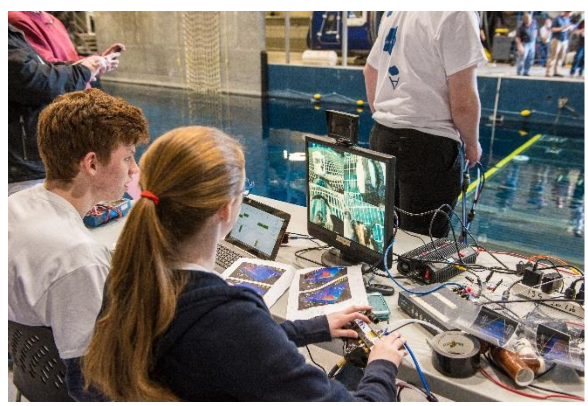
Final checks before insertion into the pool. MATE Regional Competition, 22 April 2016

This device is similar to the Arduino, but specialises in C# programming, a powerful language that opened up great opportunities for us on the programming side. This device was very compact, yet had multitudes of different onboard features, including thirty-one pin slots.

To waterproof the microcontroller we have it placed inside our main tube, along with various components. These other components include sub-controllers for each of the six motors and four power distributers. All of these together create an exact and simple to use control system that utilises the best in C# programming technology. The container is placed in the center of the ROV so as not to disturb the precise balance of frame and motors.

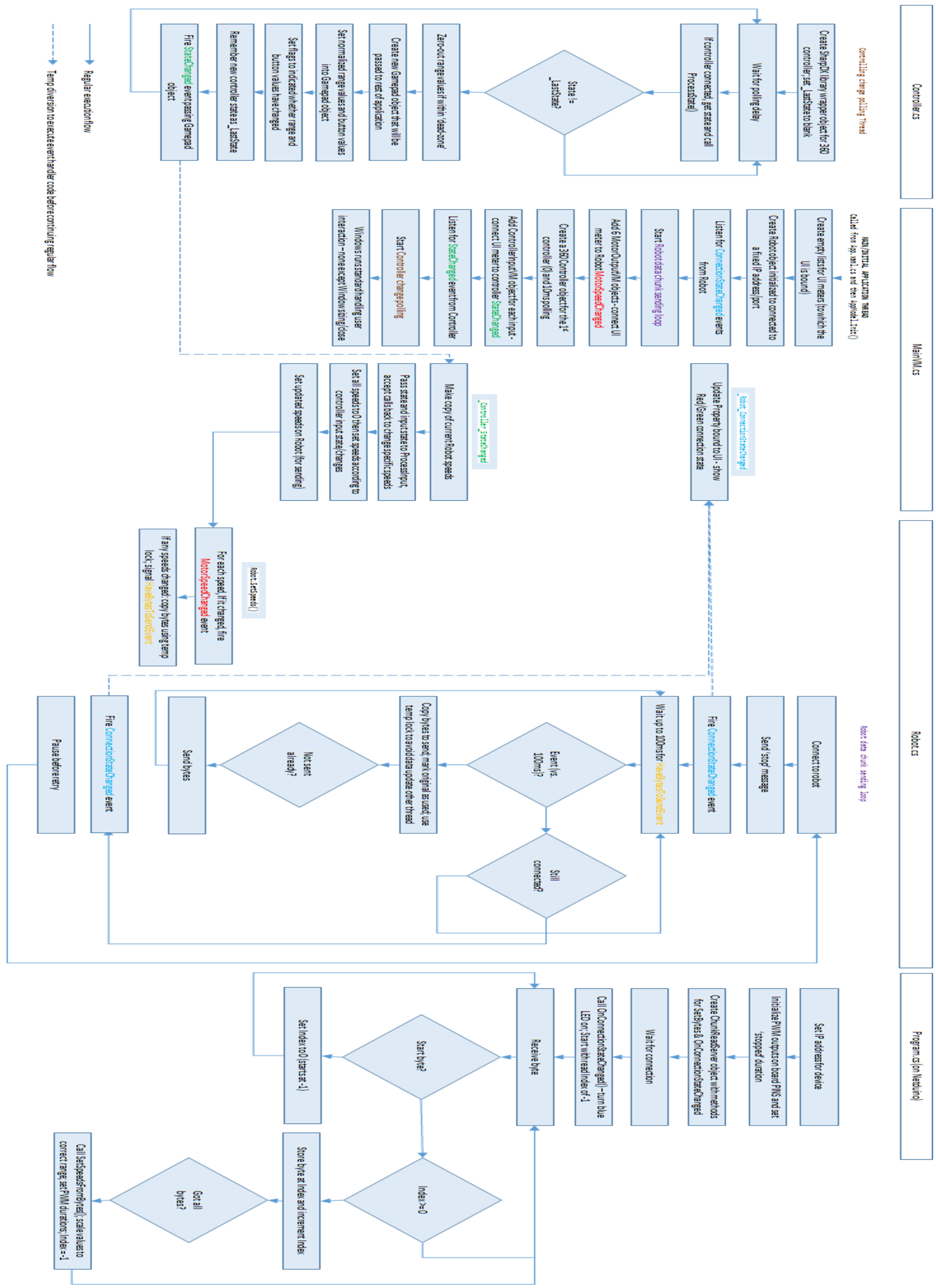


Cygnus in operation. MATE Regional Competition, 22 April 2016



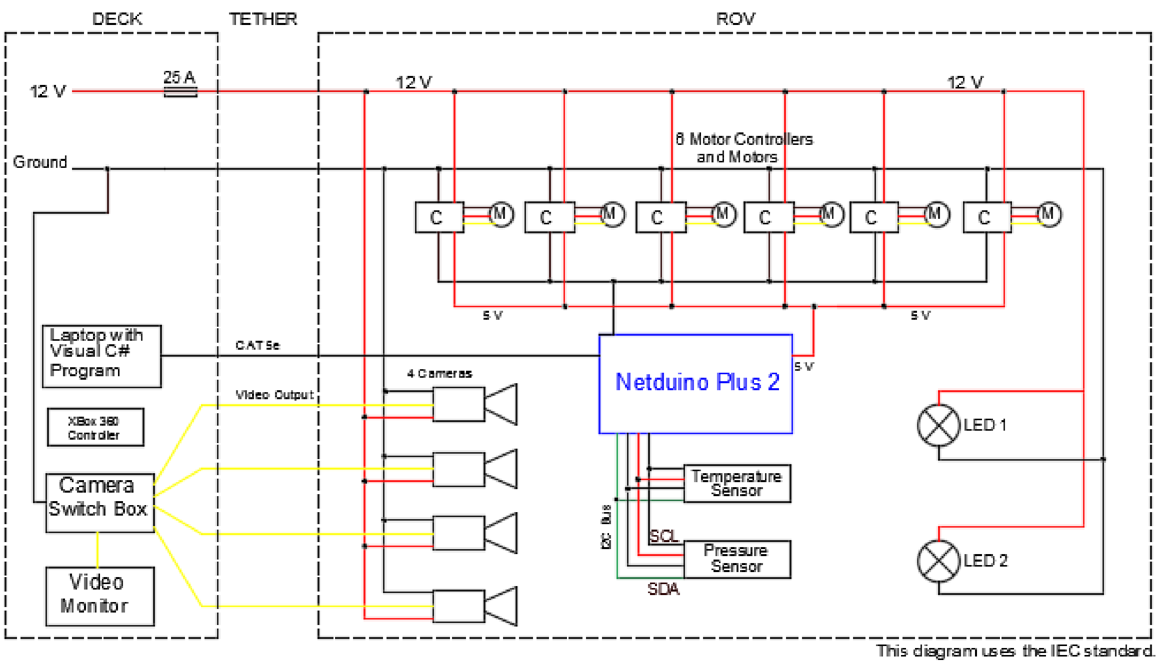
Pilots Morgan Higginson and Liam Acres at the poolside control station. MATE Regional Competition, 22 April 2016

Software Flowchart



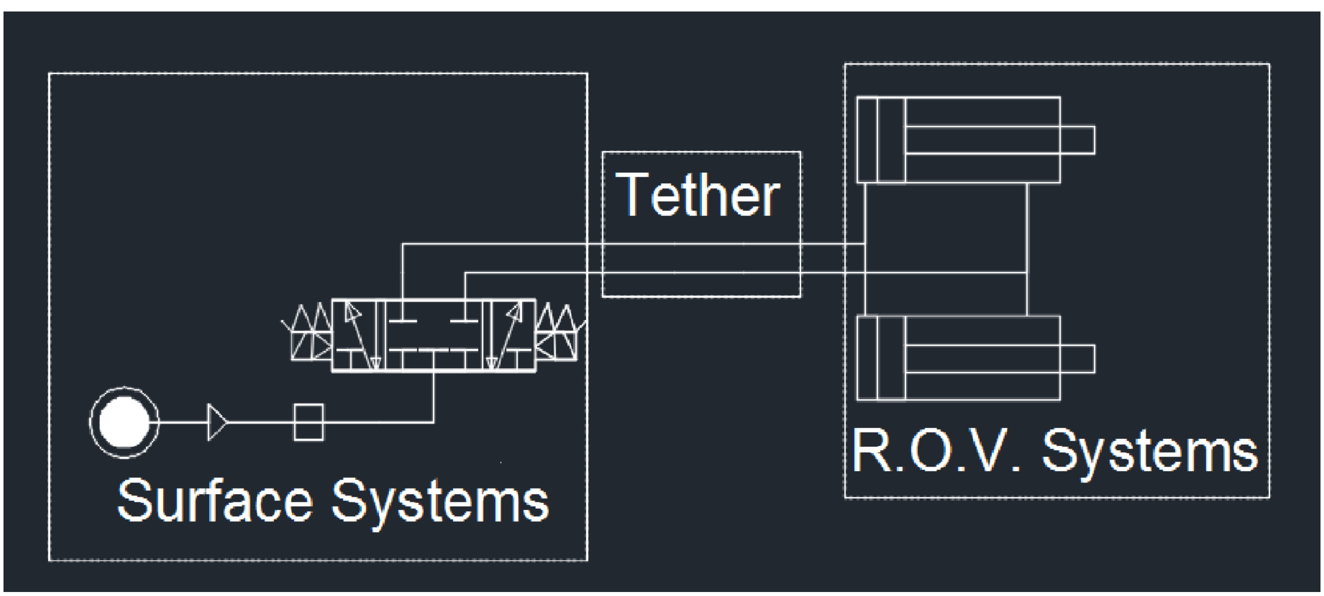
System Interconnection Diagram

Electrical



Overcurrent Protection = ROV Full Load Current x 150%
= 16.2 A x 1.5
= 24.3 A

Pneumatic



Safety Checklist

At Nova we value safety, and one of our top priorities is following all of the safety standards that MATE has come to expect from its competition participants. Here we list off some of the most key aspects that we have focussed on when it comes to having a safe work environment, and a safe final product.

Safety Practices

- Wore safety glasses when working with power tools.
- Wore face masks when working with things that made potentially toxic dust
- Power source was either set to "Off" or unplugged when not in use.
- All supplies were stowed safely away from people who were not authorized or trained to use the equipment.
- All people working with power tools were supervised and trained in the use of the tool before use.
- Had select persons who were to release and retrieve the R.O.V from the water.
- The controller was always disconnected unless the R.O.V was undergoing testing.

Electrical

- Only female power connectors were used to be sending power, male connectors received power.
- Fuse was used when R.O.V was tested.
- No exposed wiring is present on the R.O.V
- All waterproof connections were tested before power was allowed to pass through the connection.

Physical

- ROV was thoroughly checked for loose screws and other potentially harmful objects.
- All screw heads were covered with secure electrical tape to avoid scratching or otherwise damaging the surrounding area.
- All components were safely attached to avoid any possible harm to the ROV or its surroundings.

Challenges

Over the course of our time building the ROV, we at Nova encountered numerous challenges that we were able to overcome. Here we have two of the most notable that we learned the most from.

Technical Challenge

Last year our major challenge was working with Lexan to make a container. Although we eventually gave up on using this material for that particular purpose, we did get some experience using it. This year, our big discussion was on the topic of the frame.

We decided to use what we learned with the Lexan to make two side panels to hold our tube. This turned out to be a huge challenge. We needed to get the measurements very exact in order to not squeeze the tube, but to hold it tightly. It took us several designs to get it perfect, but the final product was well made.

The other issue with this frame was fitting the thrusters onto the PVC that held them together. At first we thought about cutting the regular stands, but eventually decided to 3D print new ones. 3D printing then became a primary option for all our designs, with large parts of *Cygnus* being made from printed material.

Team Challenge

Scheduling and communication was a major issue for our team this year. Especially involving the claw team. We would sometimes have different parts being made, tested, and designed at the same time, with limited ideas on how they would fit together.

We had to reorganise how our team worked in order to move at an efficient pace, and trying to maximize the time each group in the team got to spend with the 3D printer was some trouble. Often we were slowed down by the scheduling surrounding the printer.

However, we were able to solve this issue by creating proper lists of what needed to be printed and what priority each was. This process helped a lot and is something we will carry into next year.

Financial Information

Budget

At the beginning of the year we were donated $800 by the Nova Scotia Community College. We were aware at this time what components were already being donated and what we could re-use, and so based our cost projection on this. Due to our limited budget we had very few items we could buy.

Item	Estimated Amount	Balance
Color Quad Processor	$150.00	$650.00
Cameras	$100	$550.00
Waterproof Tube	$400	$150.00

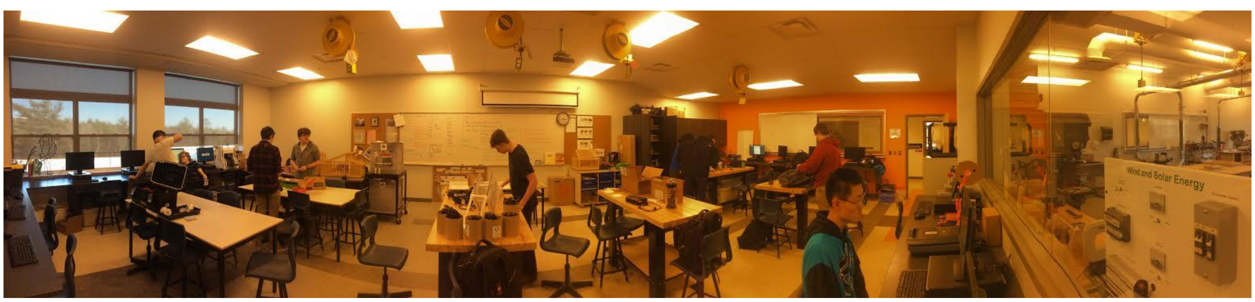
We kept $150.00 in our budget for unseen expenses, some of which did arise by the end of the project.

Project Costs

Due to our limited budget, a significant quantity of our parts were re-used or donated. We felt this necessary to create a high quality ROV. All of our re-used parts were tested to ensure they still had maximum performance.

Item	Amount	Vendor	Balance
Reused from Last Year			
PVC	$23.37	Home Depot	-
Epoxy	$20	Home Depot	-
Red Male bullet connectors x2	$21.99	Princess Auto	-
Red Female bullet connectors x2	$5.99	Princess Auto	-
Blue Male bullet connectors x2	$0.20	Princess Auto	-
Blue Female bullet connectors x2	$5.99	Princess Auto	-
Yellow Male bullet connectors x2	$7.99	Princess Auto	-
Yellow Female bullet connectors x2	$11.99	Princess Auto	-
Hose air ¼”	$11.99	Princess Auto	-
DCV 45CFM 5W3P 12VDC PNEU	$49.99	Princess Auto	-
1/8 NPTM x ¼ hose straight	$2.19	Princess Auto	-
¼” NPTM x ¼” hose	$2.19	Princess Auto	-
Silencer 1/8” NPT Brass	$2.99	Princess Auto	-
CYL SS END MNT 25mm x 100mm	$2.99	Princess Auto	-
CYL SS END MNT 25mm x 100mm	$34.99	Princess Auto	-
¼” hose Y	$5.49	Princess Auto	-
Male TANG ROD END 10mm	$5.49	Princess Auto	-
Bought This Year			
-	-	-	$800
Color Quad Processor	$154.40	B&H Photo Video	$645.60
2 Cameras	$94.97	Sparkfun	$455.67
Bolts	$53.22	Kent	$402.45
Loctite Silicone sealant x2	$34.42	McMaster-Carr	$368.03
Tube	$348	Blue Robotics	$23

Donated			
Lexan	$30	CPA	$30
3D Printer Material	$35	CPA	$65
6 Blue Robotics Thrusters	$934.54	CPA	$999.54
Tube	$100	Ace of Clouds	$1099.54
Glass Dome	$40	Ace of Clouds	$1139.54
2 Cameras	$94.97	Ace of Clouds	$1234.51
4 Small Tubes	$26	Ace of Clouds	$1260.51
Network Cable tester	$4.09	Ace of Clouds	$1264.60
Wire cutter	$2.30	Ace of Clouds	$1266.90
Xbox 360 controller	$59.95	Ace of Clouds	$1326.85
UTP cat5e cable 250FT	$53.79	Ace of Clouds	$1380.64
18GA White 100FT	$17.45	Ace of Clouds	$1398.09
12GA Primary Wire 100FT Red	$25.64	Ace of Clouds	$1423.74
10GA Primary Wire 100FT Red	$36.71	Ace of Clouds	$1460.44
12GA Primary Wire 100FT Black	$24.43	Ace of Clouds	$1484.87
10GA Primary Wire 100FT Black	$35.87	Ace of Clouds	$1520.74
Pistol Grip Wire Stripper	$18.99	Ace of Clouds	$1539.73
Professional Crimp Tool	$14.99	Ace of Clouds	$1554.72
E Power Box	$107.75	Ace of Clouds	$1662.47
Netduino Plus 2	$68.00	Ace of Clouds	$1730.47
Asus Transformer Book	$299.99	Ace of Clouds	$2030.46
Monitor	Unknown	Saul Hughes	$2030.46



A panorama image of our workroom, with team members working on various projects.

Lessons Learned

The potential for improvement this year from the last was vast. We learned a lot from last year, and even more this year.

Our scheduling has improved by a lot, and we found that we were completing projects at a more efficient rate. Having people split into teams that each had their own smaller projects helped to do this.

We learned a lot about 3D printing and modelling in order to make parts. Our claws, and most of our joining points have been printed. It is amazing what we discovered we could do with the right tools.

The main lesson we learned from this year was the importance of prototyping and testing. Almost all of our components we 3D printed ourselves, and so had to be extensively tested and redesigned.

We learned the importance of this process and how it helps create the best product. Most of all, it taught us not to be afraid of making mistakes in our designs, because every mistake was an opportunity for improvement.

Future Improvements

The main problem that we had was fitting all of our tools onto our frame. We built around housing the electronics in the most compact way possible.

This led to some problems with the claws. In the future we think we will figure out where everything needs to go before beginning to build anything, and design the parts around this idea.

The specifics of this will involve using scale diagrams and precise measurements in order to predict the placement of over component. Once we have this, we can inform our engineers of how small they have to make their component. We will be able to create better designs earlier on and not have to go back and change parts once we go to attach them to the main frame.

This will require more forethought, which comes from the experience we gained this year.

Reflections

Throughout the year the team had a great experience while participating in the robotics program. We learned many new things about electronics, construction, safety and teamwork. Every student who joined had a new and unique experience in their own way. Here we have the reflection from a few members of our team.

Johnny – This year I was unable to contribute as much as I wanted to because of the increased workload in school; however, I found robotics to be a most thrilling experience for the time that I was here. We were able to work upon the things that we have learned last year in order to create a better robot than the year before. Furthermore, we were able to gain new members that we taught so that our robotics team can continue to develop as a whole. It was a deeply emotional time.

Logan – I enjoyed meeting and working with my friends from last year and the people who joined this year. The skills I learned during this club will be incredibly valuable for me in the future.

Liam – This year was a great year for the robotics team. We were able to get the items we wanted to get last year but couldn't because we didn't have enough time. In addition, the experience was fantastic, new members brought the team together and brought new ideas. I can't wait to join again next year.

Will - I joined this group to learn more about robotics in general. I learned a lot and had an awesome time.

Morgan – This year has been so much fun! I loved learning so many new things and meeting so many unique people. I can't wait to start our robot for next year, making improvements on our robot and making even better memories.

Matt – I enjoyed working with advanced technology and being part of a team. I looking forward to keep working on this next year.

References

Mike Duggan, NSCC – *competition assistance*

Blue Robotics website – *general tutorials*

MATE website – *online resources*

Underwater Robotics: Science, Design & Fabrication – *additional information*

SparkFun website – *camera tutorials*

Acknowledgements

We at Nova would like to thank every person and corporation that helped us make our ROV a reality. We would like to thank **Marine Advanced Technology Education (MATE)** for organising this event, and **Survival Systems Training Limited** for hosting the regional competition. The **Nova Scotia Community College (NSCC)** has our overwhelming gratitude for contributing funds and allowing us access to their pool for testing. We would like to give a big thanks to the company **Ace of Clouds** for donating money and parts. They helped us greatly in our construction. Finally, we would like to thank our mentors **Jonah Scott** (teacher) and **Colin Melia** (industry mentor) for their great help, as well as our high school **Charles P. Allen** for providing us with our facilities.

Special thanks to our corporate partners: