Technical Report

Ranger Class

Submitted by:

Team NORTH

Inuksuk High School

Tectonitron

Team N.O.R.T.H Members:

Sarah Ali, Eric Blair, Ritchy Collin, Zachary Cousins, Chris Guo, Allan Heath, George MacKay, Lewis MacKay, Conor Mallory, Jessamyn Mallory, Seané Printup

Mentors:

Kim Parsons, Joey Rhodes, Norbert Turpin

Team NORTH

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Abstract

The following technical report describes the Remotely Operated Vehicle (ROV), *Tectonitron*, which was designed and created by Team NORTH from Inuksuk High School in Iqaluit, Nunavut, Canada. By compiling notes and pictures from previous competitions, and through various testing, the team built an ROV that is capable of completing the 2008 mission tasks and surpassing last year's performance and presentation.

Tectonitron was designed and built over a period of nine months to complete the mission specifications of the 2008 Marine Advanced Technology Education (MATE) competition. The theme of the 2008 competition is *Diving the Deep: Uncovering the Mysteries of Mid-Ocean Ridges* and is hosted by the Scripps Institution of Oceanography at the University of California, San Diego, California. There is one mission with three tasks outlined for the Ranger class, and *Tectonitron* was designed to complete these tasks (collecting vent crabs, collecting samples from a black smoker, and measuring the temperature of hydrothermal vent fluid).

This report includes: a detailed overview of *Tectonitron* and its components, the challenges Team N.O.R.T.H faced, lessons the team has learned, a description of a scientist and research project that uses ROVs to study mid-oceanic ridges, an electrical schematic and flowchart for ROV software, a budget sheet, reflections and experiences, and finally, a thank you to everyone that helped us get where we are today.

Design Rationale

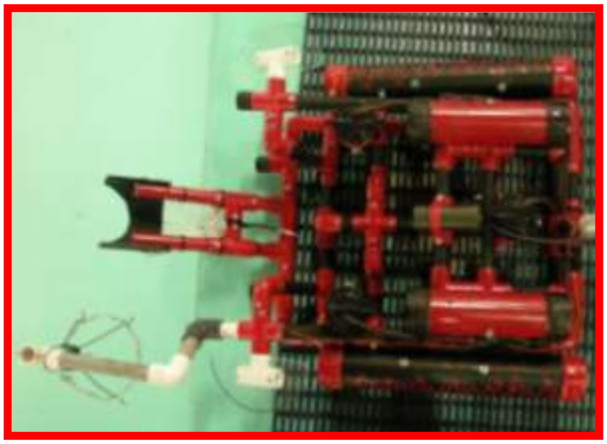
Figure 1: Top view of *Tectonitron* frame.

The name of our ROV this year is *Tectonitron*. The name comes from the tectonic plates that move to form hydrothermal vents.

Frame: The frame of *Tectonitron* (Figure 1) was constructed out of 1.25 cm PVC pipe. Team NORTH used this material because it is readily available and can be easily cut into the shapes and sizes we needed for our designs. PVC is also strong, lightweight and easy to attach to other parts of the ROV. We did not melt the PVC so there were no safety concerns; instead we used a variety of PVC elbows and T's to manipulate the shape.


Figure 2: Phidgets and electronic speed controllers in control box

Control System: *Tectonitron,* unlike ROVs from previous years, is not controlled by momentary switches. Thanks to a new mentor, the team was able to create a radically new control system. Using "Visual Basic" language, the team programmed 5 Electronic Speed Controllers interfaced to a laptop and a Logitech Extreme 3D Pro joystick and 2 Phidget 4X4X4 interface boards (Figure 2). Unlike momentary switches, which were awkward to operate, the new control system allows the pilot to operate the ROV comfortably with increased precision. The new control system also allows the ROV to be equipped with multiple sensors that can be monitored using the computer, giving Team NORTH an added advantage during the missions.

Video Camera: The ROV uses a DSP underwater camera with a 3.6 mm lens (Figure 3). This camera was chosen because it has an excellent underwater view and can see well even in dim lighting conditions. The camera is small, lightweight and encased in a hard shell for protection. The camera is mounted on our robot using a PVC bracket which can be manipulated to achieve the best view of the tools and mission props.


Figure 3: DSP Underwater Camera

Figure 4: Tether showing extra motor wire, buoyancy, temperature sensor, and camera wire.

Tether: The tether selected for our ROV is 15 meters long and consists of nine, 18 AWG conductors with a tenth 18 AWG wire running alongside for a total of 5 pairs to attach to 5 motors. Also running along the outside of the tether are the wires for the camera and the temperature sensor. (Figure 4). The tether is visible underwater and there are pieces of insulation attached along the entire length to achieve neutral buoyancy. We did order and receive a new tether with 10 wires and steel-mesh reinforcements, but due to its weight and inflexibility, we were forced to switch to the old tether.

Tether Connector: We created a waterproof connection that is designed to protect the connections between the motors and the tether. It was filled with silicon to ensure the connections are waterproof. If the tether was pulled without the connector, force would be transferred to the connections and, because this is the weakest point in the tether, the stress could cause these connections to fracture and pull apart. The cover protects these connections and also keeps the tether from coming too close to the robot and possibly getting caught in the motors.

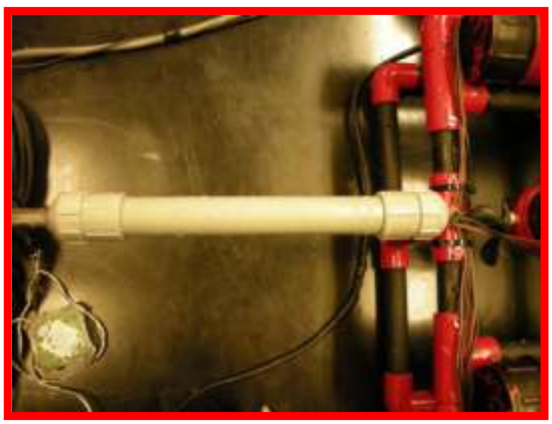

Figure 5: Waterproof tether connector

Thrusters: Team NORTH used five Mayfair Marine 1000 GPH bilge pump motors for our thrusters (Figure 6). These 12 V thrusters draw less than one amp out of water and about 5 amps underwater. We attached a four bladed plastic propeller with a 70mm diameter to each thruster. Using a simple pull test, each thruster was rated with a maximum thrust of 30 N. The thrusters are small and are placed in the most efficient areas on the ROV. The ROV has two horizontal motors to control forward motion and yaw, and three vertical motors to control roll, pitch and altitude. Two vertical motors are placed in the front and one in the back. The extra power in the front stabilizes the robot and also provides extra upward propulsion needed for the tool *Armius scrapius.*

Figure 6: 1000 GPH Mayfair Marine Bilge Pump

Tools:
Having a separate tool for each of the mission tasks results in too many extruding parts on the ROV. This increases the likelihood of tools interfering with each other or getting caught on the mission props. With this in mind, the team designed two simple tools that are capable of completing all the mission tasks quickly and effectively. The multipurpose tool's name is derived from its original use (an arm that scrapes samples from the black smoker) and we call it *Armius scrapius.* The tool created for the temperature sensor is called *Sensorius guidius* as it guides the sensor to the vent fluid.

Task 1: *Collect 3 vent crabs, return them to the surface*
Creating a tool for picking up crabs was one the biggest design challenges faced by the team this year. The model crabs had no firm, protruding parts where a tool can place a hold. Since the sea floor was not smooth, we ruled out designs for a horizontal shovel. We also ruled out a motor powered claw because *Tectonitron's* vertical motors could not deliver enough downward thrust to operate it. Once again, the team turned to real-life scenarios for the answer. To catch real crabs, the best way to attract them is with bait (Figure 7). The team designed a tool with "bait" that appealed to the crab's metal eyes and appendages. A magnet was placed in the net behind the shovel (Figure 8 a). With a magnet strong enough to lift a hammer, the ROV simply needs to place the net over a crab for either the metal eyes or legs to connect. The sheer strength of the magnet allowed multiple crabs to be attached, eliminating the need for repeated surfacing (Figure 8 b).

Figure 7 Photo of crab found around deep sea vents. Photo taken from "Venture Deep Ocean" http://venturedeepocean.org/life/other_animals.php

Figure 8 b: *Armius scrapius* with magnet

Figure 8 a: Magnet lifting 3 crabs simultaneously.

Task 2: *Collect 3 samples from of a black smoker, returning them to the surface*

Figure 8 Front-end loader
http://www.denvergov.org/

The concept of *Armius scrapius* came from watching front-end loaders removing compacted snow around the city (Figure 9). After seven months of winter, large piles of ice, rock, and gravel, deposited around the city are removed by front-end loaders; it was noted that the scraped surface left by the loaders' shovels are always smooth. The shovel of the ROV follows a similar design. It efficiently removes the rocks from the black smoker model. After measuring out an ideal angle of contact for the shovel, the bottom rim of the shovel is cut to create an edge that can wedge under a rock (Figure 10a) much like the teeth on the rim of the loaders' shovels. Once the circular rim of *Armius scrapius* makes contact with the side of the black smoker, repeated bursts of upward thrust from the front vertical motors push the edge of the shovel under the rock samples and pry them loose. The circular rim of the shovel fits neatly around the side of the smoker, preventing any loose rocks from escaping and directs them down into a net positioned directly behind the shovel (Figure 10b), where they will remain for the duration of the mission.

Figure 10 b *Armius scrapius*

Figure 10 a *Armius scrapius* in action scraping samples from black smoker

<u>Task 3</u> *Measure the temperature of hydrothermal vent fluid*

Mounting a sensor that can take the temperature of a jetting stream of water was a challenge. The stream of water is coming from a 1.25cm PVC pipe, and getting the ROV to insert a sensor proved difficult even with the increased sensitivity of the joystick. Hovering over the stream was equally tricky as the pilot fought a losing battle against the current to remain still. So, just as the tube worms and mussels that live around the flowing hot water of the hydrothermal vents and stick to the black

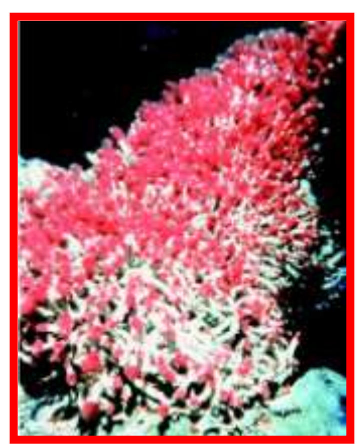

Figure 11: Tube Worms at the base of a Black Smoker
http://www.waterencyclopedia.com/Ge-Hy/Hot-Springs-on-the-Ocean-Floor.html

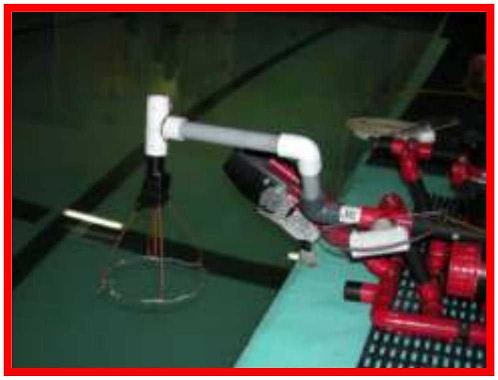

Figure 12a *Sensorius guidius* attached to *Tectonitron*

Figure 12b *Sensorius guidius* in action obtaining temperature of vent fluid

smokers, (Figure 11) *Tectonitron* would also stay in one place using the tool *Sensorius guidius*. *Sensorius guidius* would find the stream at the top of the black smoker and remain still while the Omega temperature sensor did its work. To do this, the tool was built to cover the top of the black smoker, directing the stream of vent fluid towards the temperature sensor (Figure 12a). As the jet shoots upwards, it flows directly onto the sensor (Figure 12b) and a reading appears on the Visual Basic Programming screen (the temperature sensor was connected to the program using a temperature sensor Phidget).

Troubleshooting Techniques

Figure 13: Allan preparing last year's ROV for a test run.

Last year, precious time was lost because the testing of tools could not be done until the ROV was complete and operational. To avoid testing tools at the last minute, the team kept the ROV from last year's competition functional, and tested the new tools at the pool while the new ROV was being designed (Figure 13). While a number of adjustments had to be made to the old ROV in order to accommodate the new tools and camera angle (a few T and 90^o joints were added) it was much less time consuming than waiting for the new ROV to be built (the ROV was taking time because the team was learning programming). Not only did the old ROV provide the team with information regarding the effectiveness of our tools, its inability to perform the new mission tasks also showed us the kind of design needed to perform them.

To save time in ROV construction we came up with a new, efficient way of designing and building the ROV. Instead of physically building the frame, we used a 3D drafting program called Vectorworks. In this program, PVC of any size or shape can be rendered and manipulated to form a new frame in minutes (Figure 14) . This allowed us to have a good look at the frame design, tool placement and camera angle and make needed changes on the program before committing to building the ROV. Moreover, 3D renders allow the dimensions of each individual piece of the ROV to be precisely measured and be used as blueprints during the physical construction.

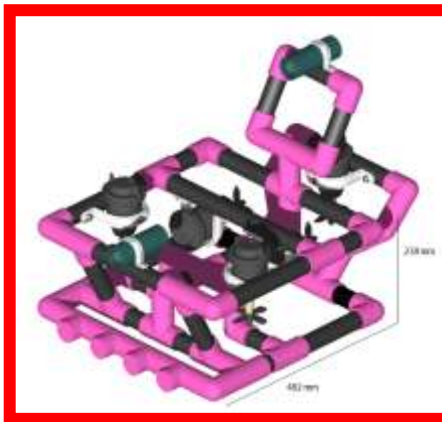

Figure 14: 3D rendering of a *Tectonitron* prototype

Challenges Faced

Team NORTH faced an assortment of challenges this year including financial challenges, technical challenges and those concerning team member availability (for fundraising events, working on the robot etc.).

Our biggest challenge was raising $43,000, the largest amount of money we have ever needed to raise. Travel expenses accounted for most of this cost but we also used computer programming to control the robot this year which increased costs as well. Raising this money was difficult and the team recognized that we would have to come up with fresh ideas to make money, as well as relying on previous fundraising ideas such as raffle tickets and approaching businesses. We decided that a key component to raising this sum would be to increase the team's publicity and attract supporters from the community.

To increase publicity, we set up a booth at the Nunavut Mining Symposium (held at Inuksuk High School), where we showcased the robot and the team answered questions. We created an information brochure (see Appendix 1) and passed them out to potential supporters. Our most successful campaign was at the Nunavut Tradeshow where we set up another booth (Figure 15) and also created an eye catching poster (Appendix 2) to get people interested in

Figure 15: Members of Team North at the Nunavut Tradeshow display booth.

underwater robotics. Baffin Regional Chamber of Commerce (BRCC) really helped get our faces “out there”. They covered the cost of printing the brochures, our new poster and bought the team shirts, jackets and hats (showcasing our new logo designed by team member Chris Guo) as well. At the tradeshow, the team was auctioned off (to do chores for an afternoon) for a whopping $2700.00 (Figure 16). The local paper also ran an article about the team in early June and the team was interviewed and featured on an episode of the Discovery Channel’s *Daily Planet* last fall (as part of a weeklong series on Canada’s North). Once our name was out there, we had no trouble raising the money.

Figure 16: Team North being auctioned at the Nunavut Tradeshow

Team NORTH’s physical location was again problematic this year. Most materials we used needed to be ordered and shipped from the “south”, and the time for shipping materials here is lengthy. We have learned to store things and always plan ahead and try to anticipate likely materials that will be needed for the upcoming tasks. However, the ROVs advancement frequently depended on a piece of material we didn’t have, and our team would have to make due until it arrived.

Finally, getting all members of the team to attend to the meetings was once again a challenge. Our team is comprised of some of the top academic, artistic and athletic students in our school. All members are involved in multiple activities. Also, most students on the team have after school jobs. This made it very difficult to meet at the same time (even for team pictures!) (Figure 17).

Figure 17: Conor Mallory cleverly fitting himself into a missed team photo

Lessons Learned

One key lesson we learned this year is "simpler is better". There are many opportunities for things to go wrong when building an ROV, therefore the simpler it is built, the easier it is to fix. We learned this the hard way of course. We were concerned with *Tectonitron*'s appearance and built a handsome robot but had to make so many changes that we created twice as much work to maintain the looks of the robot in the end.

Sometimes, someone had an idea that didn't sound feasible and they had to prove the idea would work before the team would bite. We learned quickly that "well done is better than well said". For example, two members of the team wanted to build a motor operated claw (nicknamed "Crab Grabbler") and the other members discarded the idea until they saw the first prototype of the claw. In the end, however, we went back to simpler is better concept and used a magnet to capture the crabs.

We learned that people won't give you money unless they know who you are and what you are about. We received a lot more support this year once we got our faces "out there".

We have grown tremendously this year and over the past three years. The new team members were willing to learn and the old team members were willing to teach. With all of this knowledge transfer we are excited to see what we can accomplish in years to come.

Discussion of Future Improvements

In the previous two year's "Discussion of Future Improvements" we stated that the biggest improvement we wanted was to program the ROV using computer software. Finally we had success! We found a new mentor, Norbert Turpin, an acoustics engineer, who worked for a company that used ROVs offshore. He helped expand our knowledge in programming to the point where we could successfully program our ROV. It was a rough road, and we still don't have all of the glitches ironed out, but it is working!

One improvement we would like for next year is to cut the team from 11 members to 6 or 7 members. This would reduce scheduling conflicts for meetings and would allow more members to be involved in more components of the ROV (construction, programming, electrical, Tech report, poster etc.) instead of subgroups working on specific aspects of the projects. It is very important that all members on the team are thoroughly familiar with all aspects of the project, especially since the team will be getting new mentors next year and will be expected to know what to do.

ROVs and Mid-Oceanic Ridges

Figure 18. Dr. Russell McDuff[2]

In 1973, Russell McDuff (Figure 18) completed his bachelor's degree in chemistry. In 1978, he completed his doctorate in Oceanography from the Scripps Institution in San Diego. After finishing his doctoral studies, he became a postdoctoral fellow at the Massachusetts Institute of Technology. By 1999 Dr. Russell McDuff was a professor and named associate director of The University of Washington's School of Oceanography in 2004[1].

When Dr. McDuff is not busy teaching in the classroom he spends his time doing research. Some of his research activities include marine geochemistry, hydrogeology of the ocean crust, crust-seawater chemical exchange, seafloor hydrothermal systems, and scientific computing. Most of his research is done in the regions of the Northeast Pacific and Juan de Fuca Ridge[2]

Dr. McDuff watches over highly funded projects[3]. Some of his most recent projects include:

- Thermal Output of a Hydrothermal system: Water Column Studies[3]
- Fluxes of Heat and Salt from Endeavour Segment Vent Fields: Discrete Measurements as a Test of the Sea[3]
- Coaxial Segment: Consequences of a Diking Event[3]
- Precise Measurement of the Heat Flux from a Hydrothermal Vent System[3]
- Use of the Jason/Medea-Sea Cliff-Laney Chouest to study crustal accretionary processes.[3] (Figure 19)

Figure 19. Jason vehicle being launched from RV *Atlantis* in the Guaymas Basin, Sea of Cortez.[4]

Dr. McDuff played a large role in testing whether an ROV could be used in his scientific studies of the ocean floor [4]. More specifically he and his team tested the ability of the ROV Jason/Medea to do fine scale sea floor research on the Endeavour segment of the Northern Juan de Fuca Ridge[4].

The Jason/Medea ROV

The Jason/Medea ROV was previously used for sunken ship finding (Figure 20)[4]. It was designed and built by WHOI (Wood's Hole Oceanographic Institution) Deep Submergences Lab and is now used to help scientists have access to the sea floor without ever leaving the ship[6].

Figure 20. The Jason Remotely Operated Vehicle during engineering tests on the dock at Woods Hole, MA.[5]

It is a 2 body ROV system with power and command supplied from the ship. The Medea section acts as a shock absorber and provides light and a bird's eye view of the ROV Jason[6]. It was first launched in 1988 and has been used in hundreds of dives to hydrothermal vents[6].

McDuff operated Jason in automatic mode using real-time displays on shore and collected different measurements on the sea floor[7]. This opened the door for other deep sea research scientists by allowing them to "see" the sea floor from almost anywhere and collect data[7]. Since Dr. McDuff's evaluation of Jason's usefulness in this type of research, more scientists have used the ROV to study mid-oceanic ridges[7].

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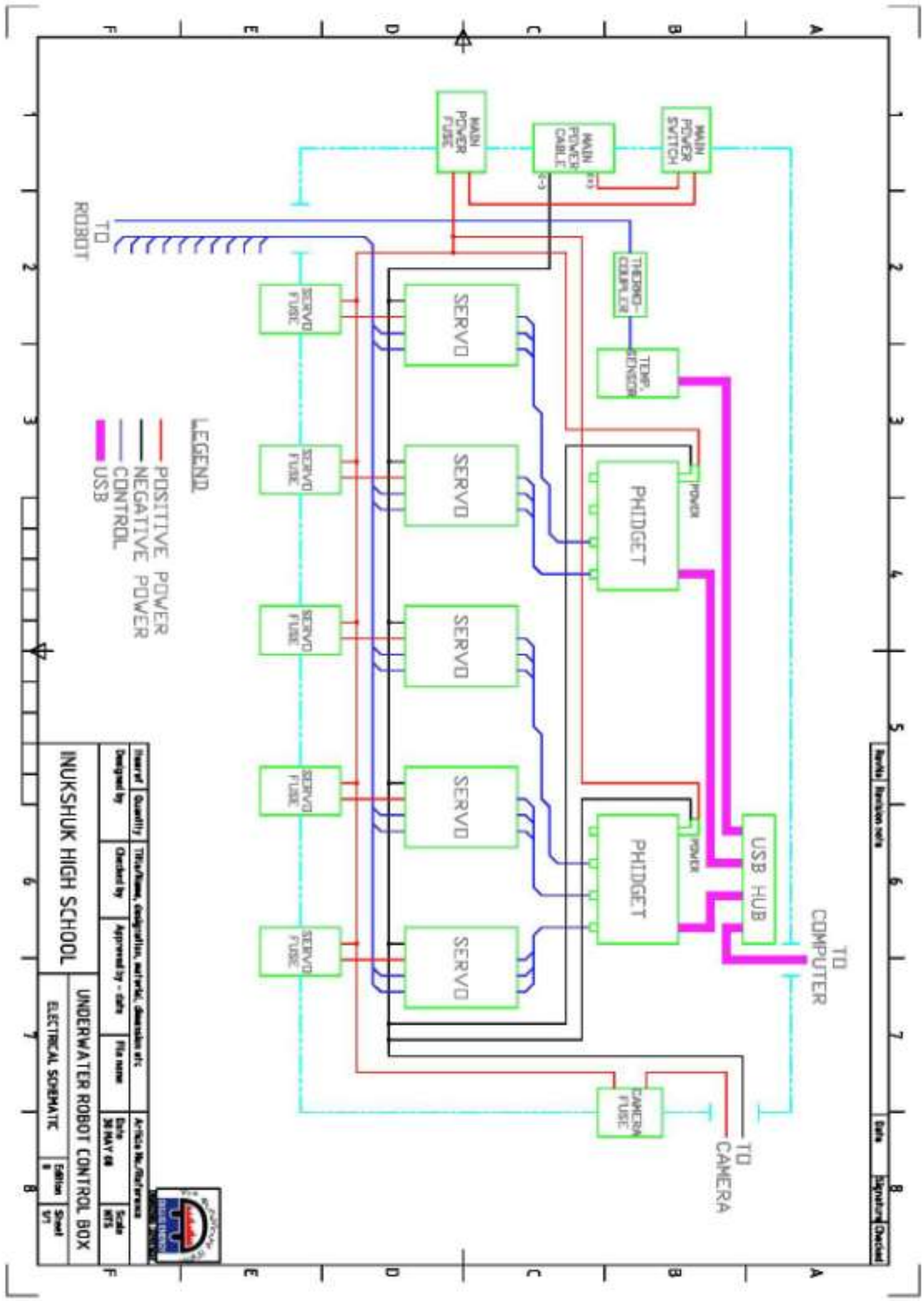
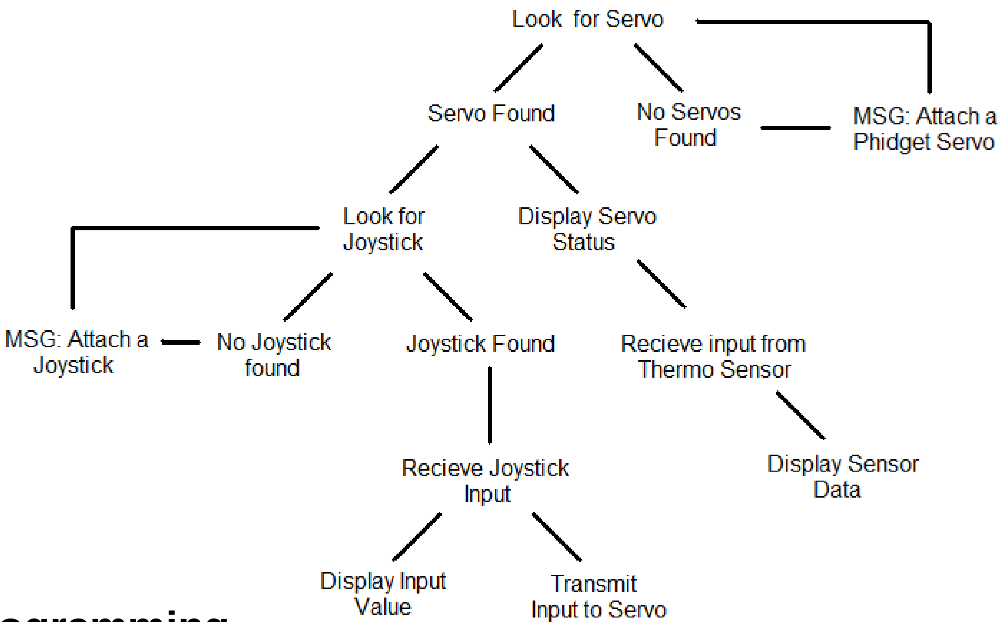
7. Ballard, R.D. 2000. The Eternal Darkness: A Personal History of Deep Sea Exploration. Princeton University Press, Will Hively. 388pp

Electrical Schematic

Compliments of Quilliq Energy Engineering Department (see appendix 3 for the original drawing done by team member Allan Heath).



Flow Chart of Software



Programming

This year we decided to control our ROV using a computer and joystick. In past competitions, we used a control box and momentary switches to move the ROV in the water. This method is very difficult because individual motors only have the ability to go either full forward, full reverse, or no movement at all. Programming gives us the ability to vary the power of the thrusters, thereby controlling the speed at which the individual thrusters move water. This gives the ROV increased precision and stability.

To complete our goal of programming our ROV, we began practicing simple programs on *Visual Basic* to have a better understanding of the programming language. Once we were comfortable with the language, we began to create our form of the program. We needed to create a form that was easy to understand but also had all the required information.

Within the form we added text boxes to view the joystick input values being sent to the electronic speed controllers. We also included progress bars to give a visual image of the amount of power that was being supplied to the thrusters. There are also a few text boxes that provide information on which buttons are engaged on the joystick and the temperature the thermal couple is measuring. There is also an area that shows which Phidgets devices are connected to the computer.

We were very successful this year with programming the ROV; thanks to our mentor Norbert Turpin who took time out of his daily plans to teach us the programming language.

Personal Reflections

Sarah Ali: My experience with the robotics team has been fabulous! I have learned about time management, team work and task management. I am interested in this area of science and thankful for this opportunity.

Eric Blair: Robotics has been a blast and has finally allowed me to apply the lessons taught in school to the real world. Finishing the robot was satisfying but the work leading up to it was even more fun.

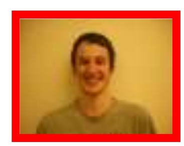
Ritchy Collin: This was my second year in robotics and I learned a lot. This experience gave me the chance to explore engineering and other fields of science concerning ROVs. I also got to travel, which I love.

Zachary Cousins: Robotics has shown me that doing a project takes a lot more work than it looks! This experience has taught me that if you work as a team and stay focused you can get a lot done.

Seane D'Argencourt: Being on Team NORTH has truly been an underwater robotics apprenticeship. I now have the skills, and opportunities, to work in a field below the sea should I choose to do so.

Chris Guo: All the things I've experienced at Robotics can't really be summed up in this space, so I'll say that I've learned a number of valuable lessons that will help me later in life.

Allan Heath: I have found robotics to be stimulating in many ways. It has been an experience I will never forget because it taught me many things I will be able to apply in my life.



George MacKay: I have learned many skills during my time on Team NORTH. My experiences on the team have broadened my knowledge in the field of ROV technology and inspired me to continue my education.

Lewis MacKay: During my experience with this robotics team I have learned many valuable skills. This fun and educational experience sparked my interest in the field of robotics.

Conor Mallory: Being on Team NORTH has given me many opportunities to both learn and gain exposure in things that I would not have otherwise. Being part of the ROV competitions has undoubtedly influenced my decision to pursue engineering as a career.

Jessamyn Mallory: Being a part of the robotics team has introduced me to a new group of friends and a new way of thinking. I have developed a great set of skills thanks to the experiences and time spent with the team.

Budget

TEAM NORTH
Budget Sheet
September 2007 – June 2008

Expenses	
Return airfare from Iqaluit to Ottawa	$9,330.00
Return airfare from Ottawa to San Diego	$8,875.00
Accommodations in Ottawa	$540.00
Accommodations in San Diego	$5,910.00
Ground Transport	$2,300.00
Materials for the ROV (including new laptop, monitor, servos, ESCs, tools (drills) etc)	$6,500.00
MATE t-shirts	$300.00
Meals	$5,000.00
Activities in San Diego	$2,500.00
Shirts, hats, jackets	$2,250.00
TOTAL EXPENSES	**$43,505.00**

Revenue	
MATE travel stipend	$1,000.00
High School canteen / Hot dogs	$1,640.00
Raffle Tickets (Dec.)	$6,690.00
Legion	$2,000.00
Department of Education	$5,000.00
QIA (Qikiqtani Inuit Association)	$2,250.00
Raffle Tickets (May)	$8,900.00
BRCC(Baffin Regional Chamber of Commerce)	$4,000.00
Brighter Futures	$4,500.00
BRCC (for shirts, hats, jackets)	$2,250.00
Iqaluit Men’s Hockey League	$750.00
Skills Canada	$1,500.00
Melanie Abbott	$2,700.00
Student Contribution	$1,100.00
TOTAL REVENUE	$44,280.00

Acknowledgements

Throughout our endeavor into the world of robotics, Team NORTH has been given help from many people and corporations. Team NORTH could not have made it to San Diego without their help. We would like to extend a gigantic thanks to:

First Air
Baffin Regional Chamber of Commerce
Nunavut Department of Education
Brighter Futures
MATE
The Royal Canadian Legion
Skills Canada
Northern Lights Café
Qikiqtani Inuit Association
Iqaluit Swimming Pool
Iqaluit Men's Hockey
Inuksuk High School
Outcrop (Melanie Abbott)

Appendix 1

Brochure created by Team NORTH to increase publicity.

WE NEED YOUR HELP!

This project requires a lot of effort from students, parents, teachers and the community. We need your help in all areas, from designing, constructing, testing and fundraising. The estimated cost of building materials and travel expenses to the International Competition in San Diego this year is $40,000. If your organization can help support this wonderful opportunity, your donation would be greatly appreciated.

Please feel free to contact us to find out more about Team NORTH. We sincerely appreciate your support and interest in this project.

CONTACT INFORMATION

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We would like to thank our sponsors for all of their donations.

Nunavut Department of Education

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SUPPORT NUNAVUT'S TEAM NORTH AT MATE'S INTERNATIONAL ROV COMPETITION

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TEAM NORTH

In 2005, a group of students at Inuksuk High School made their first underwater ROV (Remotely Operated Vehicle). Every year a new ROV (robot) is built and our team competes at MATE's International ROV Competition, which is held at different locations all over North America. Competition missions simulate real-life oceanographic scenarios, and usually feature a theme (hydrothermal vents, polar environments, underwater observation, etc.). Visit www.marinetech.org for more details.

Team NORTH competes against students from all over the world. The competition involves a technical report, a poster display, an oral engineering evaluation and completion of missions by the robot.

TEAM HISTORY

At the first competition in Houston, Texas, Team NORTH placed 14th out of 25 teams, which is a very good performance for a rookie team. Last year's competition took place at the Marine Institute in St. John's, NL. Our team finished 10th overall and took home first place for the Technical Report portion of that competition. Team NORTH also caught the eye of many different organizations including the Discovery Channel, who featured an interview with the team on an episode of the *Daily Planet*.

Team NORTH showcasing their first place award for technical report at last year's competition.

FUTURE PLANS

This year's competition will be hosted in San Diego, California in June. With the experience and confidence we have gained in the past two years, we are certain that our results will improve once again.

Science and engineering are two of the fastest growing fields in today's world. Team NORTH will show the world that Nunavut's youth can compete and succeed in these fields.

We are proud to say that three of our past team members have moved on to post-secondary schools in areas relating to engineering. One of our past team members has also joined an underwater robotics team at the university level. Underwater robotics provides students with a unique hands-on approach in exploring the world of science and engineering.

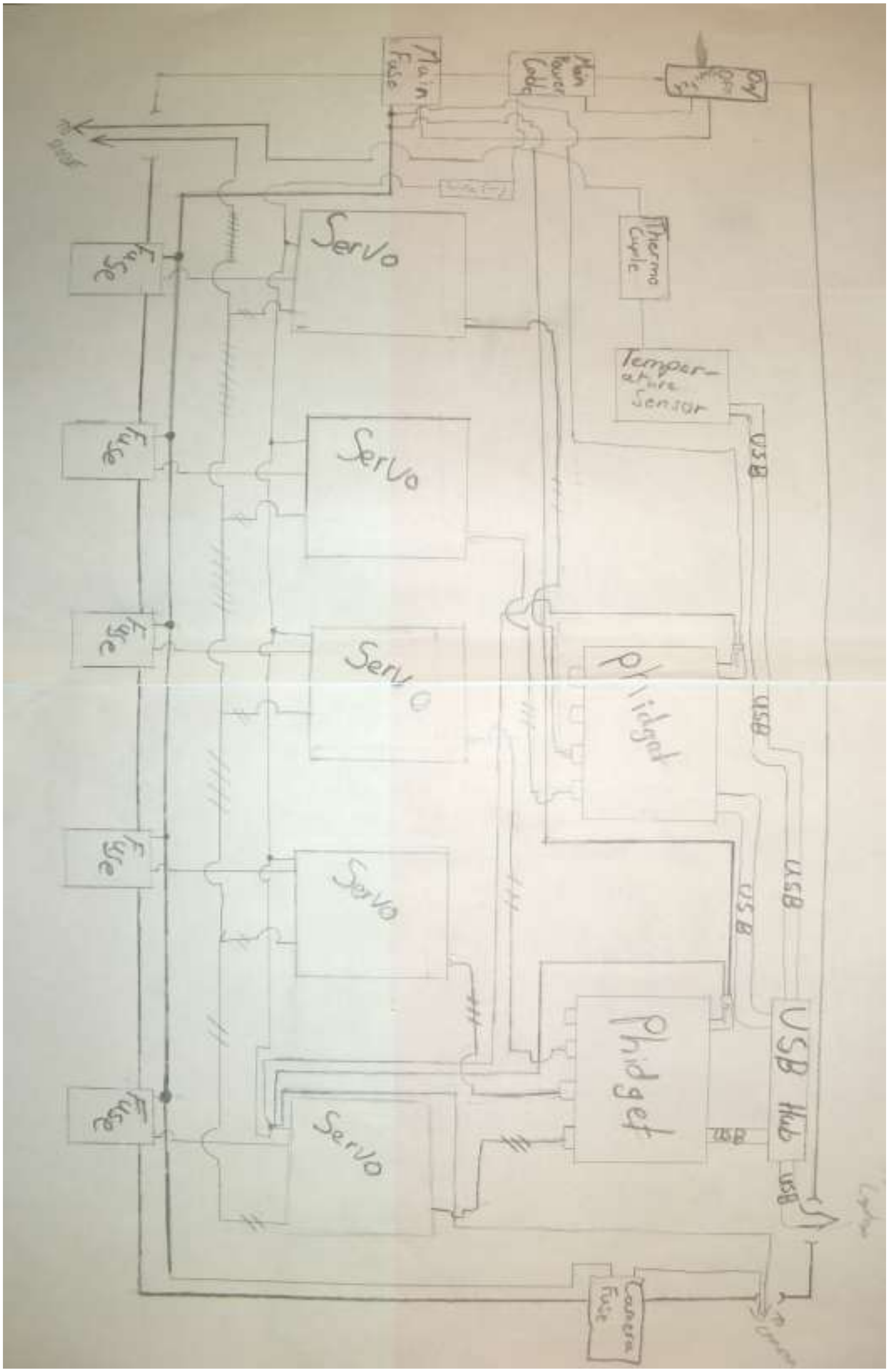
TEAM NORTH

Appendix 2

Poster created by Team NORTH to raise awareness in Iqaluit.

Appendix 3

Original electrical schematic drawing

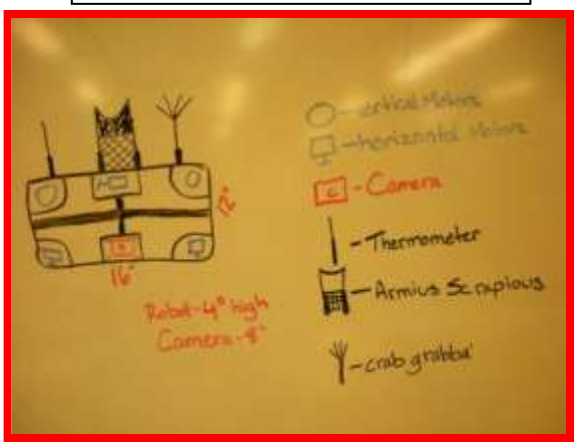


Appendix 4

Photos of Team NORTH in 2007-2008.

Team members soldering the tether connectors.

Tectonitron lining up the temperature sensor.



Brainstorming tool and motor positioning

Team Member Ralph filling his head with ideas.

Working hard or hardly working?

Brainstorming team doing what they do best

Chris testing the control system

Tectonitron at the pool during practice.

Team members preparing last year's ROV for a pool test

Team member Seane working on the technical report

Team members adjusting the camera and motor placements

Tectonitron at the Nunavut Tradeshow display booth.