Interim Technical Report

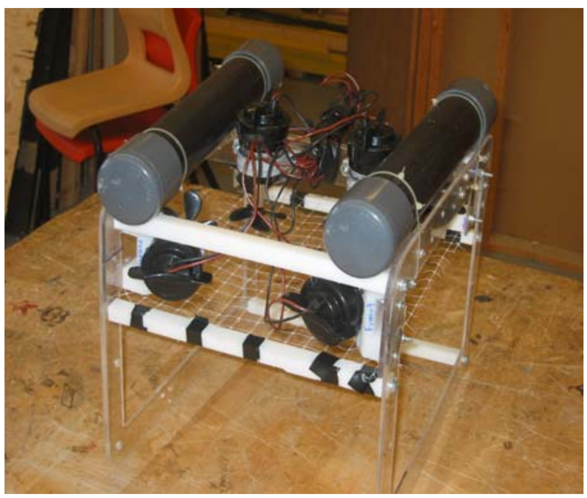
WolfHenn 157 ROV

Submitted by the

Avalon East School District Robotics Team

June 11, 2004

Submitted to the Marine Advanced Technology Education Center



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Abstract

This Interim technical report describes the Remotely Operated Vehicle **WolfHenn 157 ROV**, built by the Avalon East School District Robotics Team, St. John's and area, Newfoundland and Labrador, Canada.

This ROV was created to compete in the 2004 MATE (Marine Advanced Technology Education) Center/ MTS ROV competition hosted by MATE. The mission of the **WolfHenn 157 ROV** is to explore and conduct research on a previously unknown tropical reef in a 25-minute time frame. It is a multi-purpose unit; designed to search, identify, tag, and sample – all desirable capabilities of a functional ROV. There are seven different tasks for which **WolfHenn 157 ROV** has been designed. Some of the unique features of this unit include:

i. a clear, low drag structural frame which affords excellent visibility;
ii. a redundant thruster array with flexible positioning for high maneuverability and reliability;
iii. a sampling vacuum which doubles as an extra thruster;
iv. a dual-purpose tagging and ichthyologic sampling system;
v. a twin-camera, switchable-view optics system with integrated artificial lighting;
vi. proportional control system for al motors which provides extremely fine positioning capabilities;
vii. a remote control is system designed to operate two different cameras as well as switch power between devices for specific tasks to conserve energy.

This report also includes a description of the design rationale, troubleshooting techniques, and future refinements. For more detailed images of our project, please consult http://avalonrobotics.dyns.cx

Acknowledgements

The Avalon East School District Robotics Team would like to thank the many contributors who made this project possible. We would especially like to thank the following:

The Marine Institute, St. John's, NL
Johnson Pumps ITT Canada, Toronto, ON
IPEX Canada, Mt. Pearl, NL
O'Donel High School (venue & resources), Mt. Pearl, NL
Pro-Dive Oceaneering, Mt. Pearl, NL
Scuba Schools International, Mt. Pearl, NL
Thomas Glass (Plastics- Lexan), St. John's, NL
CECON Ltd., St. John's, NL
AIMS Ltd., Mt. Pearl, NL
Canadian Technology Network, St. John's, NL
Inuktun, Nanaimo, BC
Newfoundland Power, St. John's NL
DF Barnes Ltd., St. John's NL

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Team Introduction

The Avalon East School District Robotics Team is made up of high school and post secondary students from St. John's, Mt. Pearl, Paradise and Conception Bay South. The team consists of 21 boys and 3 girls, from O'Donel High School, Gonzaga High School, Holy Spirit High School, Prince of Wales Collegiate and Holy Heart of Mary High School, who meet every Saturday to design, create and test tools created for the 2004 MATE ROV competition. See Appendix B for a complete list of team members.

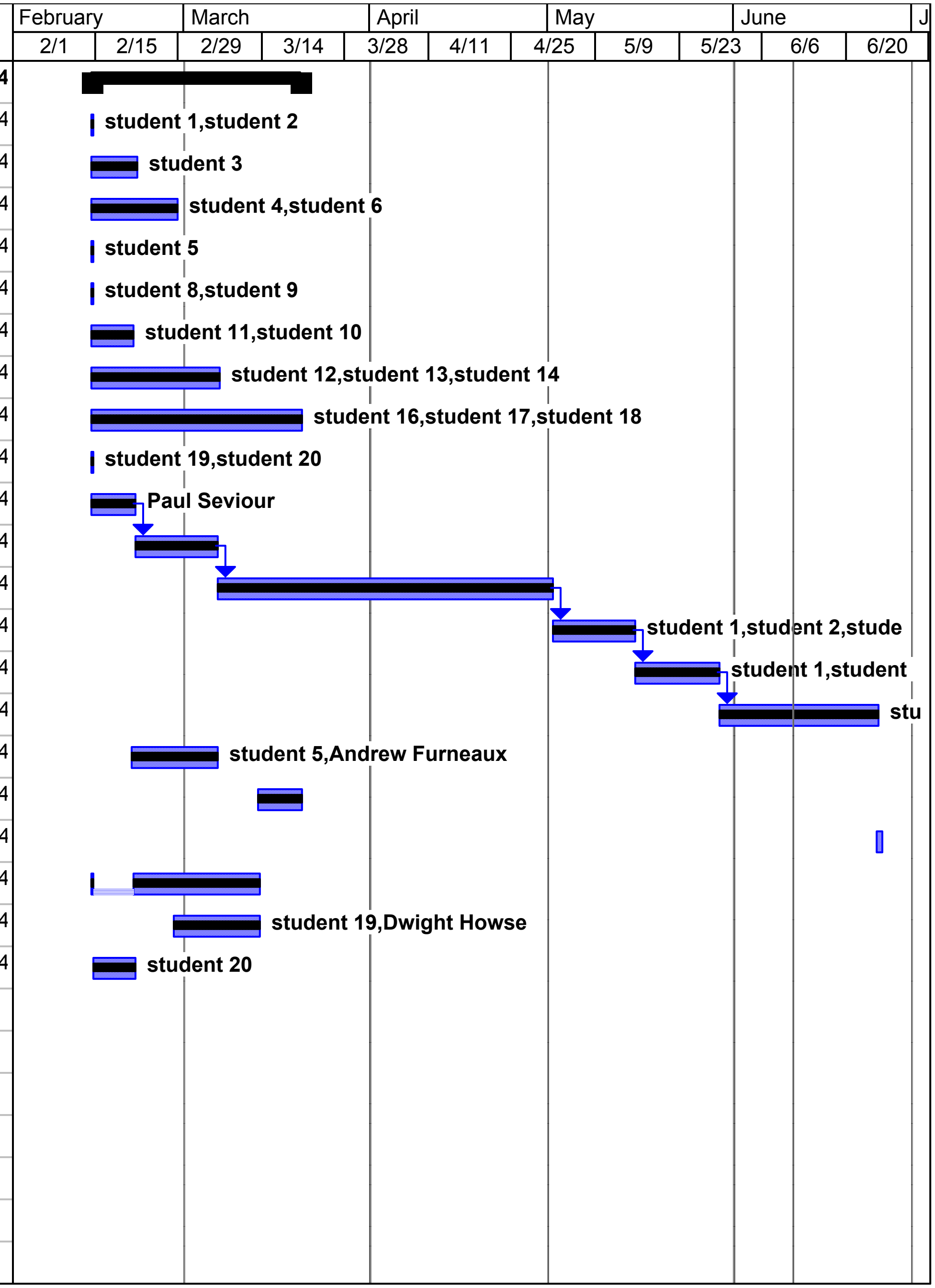
Project Management

During our initial meetings, it was important that we utilize our time appropriately. Using Microsoft Project, a time management program, we designed a schedule of expected dates of completion for each stage of the ROV, and used the program to designate tasks and duties to each person on the team. This cut down on time which would have been wasted at the start of each meeting trying to delegate tasks to everyone and deciding which task to complete. It was considerably easier for us to complete each stage of production, as we knew which tasks we needed to complete and the time frame in which we had to do so. Because of our schedule, operations ran smoothly and we remained on track in the months prior to the competition.

The Gantt chart that we designed was vital to each meeting because as soon as we began each meeting, we knew where to start. We have included a sample of our Gantt chart, as seen below.

We also assigned administrative roles to three of the team members, and this simplified things even more. While the rest of the team was designing the ROV, building models and testing equipment, the administrative team was observing, asking questions and taking notes. When it came time to create our technical report, most of the needed information was already collected.

ID		Task Name	Duration	Start	Finish
1		**Build mock-ups**	**5 days**	**Sat 2/14/04**	**Sat 3/20/04**
2		build towfish	2 hrs	Sat 2/14/04	Sat 2/14/04
3		acquire a bell	15 hrs	Sat 2/14/04	Sat 2/21/04
4		build tubeworm cluster	21 hrs	Sat 2/14/04	Sat 2/28/04
5		build barrel and plug	1.5 hrs	Sat 2/14/04	Sat 2/14/04
6		build carbonate mockup	3 hrs	Sat 2/14/04	Sat 2/14/04
7		build fish	8.05 hrs	Sat 2/14/04	Sat 2/21/04
8		build submarine	30 hrs	Sat 2/14/04	Sat 3/6/04
9		build reef	40 hrs	Sat 2/14/04	Sat 3/20/04
10		build mussel cluster	3.5 hrs	Sat 2/14/04	Sat 2/14/04
11		Order materials	10 hrs	Sat 2/14/04	Sat 2/21/04
12		Await arrival of materials	14 hrs	Sat 2/21/04	Sat 3/6/04
13		Build first prototype	70 hrs	Sat 3/6/04	Sat 5/1/04
14		Test prototype	14 hrs	Sat 5/1/04	Sat 5/15/04
15		Refine prototype	14 hrs	Sat 5/15/04	Sat 5/29/04
16		Build final product	30 hrs	Sat 5/29/04	Fri 6/25/04
17		Develop web page	20 hrs	Sat 2/21/04	Sat 3/6/04
18		Arrange travel	14 hrs	Sat 3/13/04	Sat 3/20/04
19		Travel	1 day	Fri 6/25/04	Fri 6/25/04
20		Documentation	27.23 hrs	Sat 2/14/04	Sat 3/13/04
21		Fundraising/ sponsorship	20 hrs	Sat 2/28/04	Sat 3/13/04
22		accounting	10 hrs	Sat 2/14/04	Sat 2/21/04



Design Specifications

Main Structure Design

1. Structural frame

We used 0.32 cm thick Lexan® Plastic was used to construct our frame. Two 0.95 cm diameter stainless steel rods, treaded on both ends, were used as lateral structural support members for the frame.

2. Remote Control System

The controller system is from IFI robotics; it is an Isaac 16 system. This system is capable of driving 8 pulse width modulated (PWM) Victor 883 motor controllers and 4 spike (on/off) reverse polarity relays. It can also read 4 analog inputs and 8 switches. For our controller we require 3 pulse width modulated motor controllers and 1 spike relay. User interface is through 2 joysticks each of which has x-y motion, one wheel motion and 2 switches. The controller uses a stamp processor that is programmed through a windows-based utility application. The programming language is similar to BASIC.

3. Video Camera

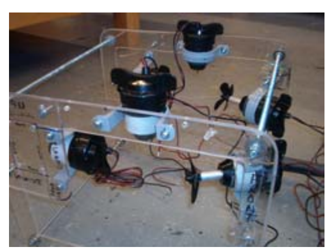
We used an *Inuktun*®'fireflEYE' camera. Inuktun is a Canadian hi-technology firm with products in the underwater services sector. The main camera looks forward, while the secondary camera looks downward, and is mainly used when the ROV is moving up and down, or while operating the tools. The camera can operate to a depth of 300m. It contains a 0.64 cm CCD chip with a 5 Lux minimum light level. It has an underwater field of view of 39^o (H). It also contains 10 8W LEDs distributed in a circle around the main camera lens, for a better underwater picture. The second (Vertical view) board camera is 1/3 CCD with a 42o field of view inside water proof housing which we obtained from Carillo Underwater Systems. We improved this unit by adding a ring of 8 white LEDs on a printed circuit board, around the lens, inside the case, for improved visibility in low light conditions.

4. Tether

Our tether consists of 7 wires plus a coax cable. There are seven 18-guage wires and one 75 ohm coax cable. The plastic coating of our tether is waterproof and neutrally buoyant.

5. Thrusters

We are using six ITT ®/Johnson sealed bilge pump motors as the mechanisms of our thrusters. They have a discharge capacity of 1000 GPH. These 12 volt motors have a maximum current draw of 4 amps with the propellers we selected from our Bollard Pull testing.



Separate Tasks and Tools

1. **Task 1- Towfish**

We are using a Lexan and acrylic plastic claw with an elastic closing mechanism to snap over the shaft of the towfish and pick it up. It operates by spreading open upon contact with the towfish shaft. We chose this method and not an attachment mechanism for the towfish ring, as it required less precision in piloting. The detachable claw is attached to the ROV using a PVC pipe arm which is recessed after delivery of the claw mechanism, to prevent being snagged on other reef features. A light-weight bungee cord, located between the fingers of the claw prevents it from opening and the towfish from escaping the ROV, once attached.

2. **Task 2- Read captain's bell**

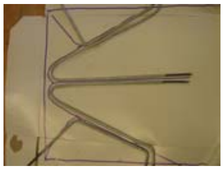
We will use our main camera to read the inscription on the Captain's bell. Our secondary camera is attached to view objects out of the field of view of the primary camera. It is our fail-safe design mechanism to ensure the bell will NOT be out of sight. If we need to move around the bell to be able to read it, our ROV is fully maneuverable.

3. **Task 3- Patch hole in leaking barrel**

We will insert the shaft of the patch into a pipe that is mounted onto our ROV. We will then approach the leaking barrel so that the Velcro on the patch sticks to the barrel, and then we slowly move the ROV away, leaving the patch on the barrel.

4. **Task 4- Fish collection**

Our fish collector consists of a frame of metal rods which form a series of pathways for the fish to follow. When the fish hit them, they will be guided towards the back of the ROV.



5. **Task 5- Find source of methane and tag tubeworms**

To tag the tubeworms, we use the center portion of our Fish Collector. Weights will be attached to the Tags using carabiners and the tags are preloaded in the Fish Collector. To release the tag, the ROV must move down to place the weight on the target and then reverse. We are going to weight the tag so that it is heavy enough to sink onto the tubeworms and stay there.

6. **Task 6- Find and tag mussel bed**

We will use our camera to locate the mussel bed and then use the same mechanism as for the tubeworm tagging to deposit our tag (see above).

7. **Task 7- Carbonate collection**

We are using a vacuum designed to collect the carbonate rocks. We have a tube which has a Johnson bilge pump motor attached to one end. The motor creates a vacuum inside the tube, sucking the rocks from the bottom and expelling the water from the top. A hinge prevents the rocks from falling out.

Design Rationale

While designing our ROV, we were constrained by many elements. Before we could begin designing or constructing our ROV, it was necessary to find sponsors and obtain the required materials and funds. Our primary objective was to complete the required tasks, while conforming to the 2004 Competition Rules.

Main Structure Design

1. **Frame**

Lexan® was used because it is strong and virtually indestructible, light density and yet lightweight and easily conformed with heat. Because it is clear and almost invisible in water, it also provides an unobstructed view all around the ROV. It cuts, shapes, and bends with heat easily so it is easily formed to our design needs.

2. **Control System**

Our control system is the standard that is used in many Robotic competitions. We are using this particular system because it can be programmed to do different tasks and we already had access to it.

3. **Video Cameras**

There are many benefits of using the ***Inuktun*** 'fireflEYE' camera. It is lightweight and can be secured to virtually any surface. It is versatile and can fit through small openings. The camera itself can be connected to video recorders, monitors, and televisions. The camera met our budgetary constraints because it was donated to us. Our other camera was one that we already own, and therefore fit our budget as well.

4. **Tether**

We chose this particular tether because it met all the necessary wiring specifications, its very small diameter and the highly flexible and visible coating floats in water, making it an excellent choice for our ROV.

5. **Thrusters**

ITT/Johnson donated the thruster motors that we are using. We are using them because our experimentation with Bollard Pull testing indicated that they are the most powerful motors in their size class and they fit our limited budget.

Separate Tasks and Tools

1. **Task 1- Towfish**

We needed to be able to pick up the towfish with something that was strong enough to hold it, but was capable of releasing it as well. Our current design does exactly this: the arm remains attached to our ROV, while the claw itself gets released, with the towfish held inside.

2. **Task 2- Read captain's bell**

The simplest way to read the bell is using our main camera, as it is the most capable. It has a horizontal field of view, allowing it to read the bell without much maneuvering. We also have a secondary camera with an alternate viewing perspective for wider scanning and detection.

3. **Task 3- Patch hole in leaking barrel**

We found by experimenting that inserting the shaft of the patch into a tube on our ROV, approaching the leaking barrel, horizontally and pressing the patch onto the leak, it, we were to attach the patch consistently with minimal time required for the task completion. Furthermore, this was the simplest solution we developed.

4. **Task 4- Fish Collection**

A simple metal rod frame or "rake" was determined to be the most efficient way for our ROV to collect fish. This horizontal frame has three channels running aft on the inside of the ROV. It effectively collects any fish we approach, at any depth or length of fastening line. We attempted to secure the fish after entry into the rake with small brush bristles pointing aft, but they tended to restrict the entry of the specimens and precluded the option of discharging them into the collection basket. Instead, we upturned the forward end of the frame which limits neither.

5. **Task 5- Find source of methane and tag tubeworms**

We will use our primary Inuktun camera to find the methane bubbles. Tactically we will scan the reef horizontally by using this camera and look vertically and obliquely downwards as we descend, This is the best way to complete this task, because it can be done quickly. To tag the tubeworms, we will use the double-function fish collector which reduces our tool requirement and allows for quick and accurate release of the tags.

6. **Task 6- Find and tag mussel bed**

To tag the mussel bed, we will also use the fish collector in reverse. We attach a small anchor to each tag with a different length of string, placing the tags on this unit before commencing our exploration of "Mystery Reef" and delivering them to the source by simply the reduces our tool requirement and allows for quick and accurate release of the tags.

8. **Task 7- Carbonate collection**

The rock vacuum we designed out of acrylic pipe has the ability to both elevate the carbonate rocks when the motor is on and to hold the lava rocks inside the pipe without use of the motor. The rocks are then returned to the pool deck inside the tube.

Troubleshooting Techniques

We had problems with all of our initial designs, and it was necessary to test them multiple times to ensure that we had the best designs possible. Most of the trouble that we encountered was with the equipment that we were using for different tasks, like collecting fish and lava rocks.

Our towfish catcher underwent countless revisions and redesigns. Many of our designs were exemplary, but would not work in underwater conditions, making them a liability. Our current design works well because it does not require a lot of pressure to close over the towfish, but closes with enough force to carry the towfish weight.

In order to determine the best combination of motor and prop a series of tests were performed. Three repetitions of each motor determined an average. The tables below show the results.

Bollard Pull Test Results:

Motor	Propeller	Volts	Amps	Force/Newtons
Johnson/ITT 1000gph	4-blade 70mm dia.	12	4.0	39N
Johnson/ITT 1000gph	3-blade 60mm dia.	12	3.2	36N
Johnson/ITT 1000gph	3-blade 70mm dia.	12	3.8	38N

We expected a possible voltage drop over the length of our 12m tether and consequently also tested the props and motors using the voltage measured at full load on the tether.

Motor	Propeller	Volts	Amps	Force/Newtons
Johnson/ITT 1000gph	4-blade 70mm dia.	8.5	2.9	26N
Johnson/ITT 1000gph	3-blade 60mm dia.	8.5	1.8	22N
Johnson/ITT 1000gph	3-blade 70mm dia.	8.5	2.4	19N

Equipment used for the Bollard Pull Test: Regulated power supply for voltage, digital Fluke ammeter for amps. A spring scale was used for the Bollard Pull force.

Challenges

One of the major problems that we faced when preparing for the competition was finding a venue that was suitable for designing and building our robot. We had originally thought that we would use O'Donel High School, which has the workshop we needed to build the different tools for each task. Unfortunately a public sector strike prevented us from using the building for a period of time. We needed a venue that had the tools that were necessary as well as computers for completing other parts of the competition and enough space to hold all the members of the team. The Marine Institute was gracious enough to let us use their facilities every Saturday, even though they also had employees who were on strike. Even then, everything could not be run as efficiently as predicted. It was difficult to become adjusted to the building's tools and the tank we used for minor testing was still at the high school, (the one that belongs to the Marine Institute is very difficult to book.) We used a large mobile plastic tank filled with water to do most of our testing. Any technical or documentary items were created between two laptops, which did not always have the programs we needed, limiting usage again. When the strike ended we returned to our previous location at the high school. We were behind in our tasks but made deadlines when required to do so. This challenge was one that had to be overcome by all members of our team, and we can see that in the end it worked out.

Future Refinements

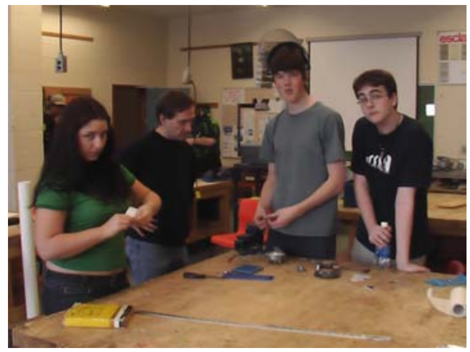
Our ROV is currently complete. All its secondary equipment, used to complete the mission tasks, is finished and assembled, but whether it will work in the underwater environment has yet to be tested. If we had more time to work on our ROV, we would work on our tag dropping mechanism. It is finished and works well, yet we think that we could have done a better job with it, had we more time to brainstorm, build prototypes and test it out. We will have additional time prior to the competition to make it more esthetically attractive. It currently uses some tape, wires and other such necessities which detract from the aesthetic look and contributes a little to drag in operation. It does, however, complete all mission tasks. Our final version will be more esthetically refined.

Lessons Learned

We as individuals have gained skills, knowledge and personal benefits well beyond what we would have thought possible, especially those of us who came onto the team with little or no knowledge of robotics. As a team, we have learned that we have individual strengths that can be refined and developed, but we should let ourselves diversify and experience every aspect of the ROV. We found that, when coming to the final phases of construction, we as a group had set limits on what each member of the team would do. For example, instead of everyone taking turns working on the different pieces of equipment, people would end up working on the same equipment every week. It worked well this way because we could show up every week and know exactly what had to be completed. Unfortunately, we are now finding that most of the team is highly knowledgeable on certain parts of our ROV, and ignorant about others. It is wasteful of our limited amount of time to have to explain what simple mechanisms do, but for people who did not design or work on them, it is very necessary. Next year, we will be sure to rotate the team so that everyone works on every aspect of the ROV at least once. It may be less efficient at the beginning, but will be well worth it in the end.

Justin working on Prototype 1 in our test tank.

Gina, Mr. Howse, Mark B. and Mark S.
working on mockups.



Jonathan and Dave working on a towfish hook.

Stephen, Matthew and Michal working
on Prototype 2 in the workshop.

ROVs and Marine Sanctuaries-Research Essay

The ocean remains one of the biggest mysteries known to mankind. No one can be quite sure what secrets lie deep beneath the pristine surface. We have yet to discover all forms of aquatic life that swim our waters, yet with the recent use of underwater ROVs in exploring our marine sanctuaries we have reached a much deeper level of understanding of how these ecosystems work and have come to truly value the wonders that are our oceans.

The *Tiburon* is just one example of how ROVs are being used to explore sanctuaries Designed by scientists at the Monterey Bay Aquarium Research Institute, the *Tiburon* was designed to explore Monterey Bay, an extremely deep underwater canyon. Since its first launch in 1997, it has made over 400 dives. It has played a major role in helping scientists make numerous geological, biological, and oceanographic discoveries. ("Way Down Deep," National Geographic June 2004, www.mbari.org)

Due to its reliance on electrical thrusters and manipulators, the *Tiburon* has the ability to move quietly through the water, with minimal disturbance of its surroundings; there by protecting the ecosystem and its inhabitants. This ability is enhanced by the use of a "variable buoyancy system", designed to reduce the use of thrusters by letting the ROV float motionless in the water.

As it has a maximum operating depth of 4000 meters, the *Tiburon* is the perfect vessel for exploring the depths of the Monterey Bay Canyon and has quickly become one of the most informative sources we have on deep-sea information.

Since the Titanic sank in 1912, many explorers have tried to discover it's exact location, but only one was successful. Using ROVs and related technology, Robert Ballard found the Titanic in 1985, but took few pictures and left it undisturbed. Now, almost 20 years later, the *Hercules*, *Argus* and *Little Herc* ROVs are being used to explore the wreck of the Titanic. Robert Ballard has coordinated a return to the wreck using these ROVs. Aside from exploring the ship, the ROVs use sensors to measure salinity, temperature and pressure, and provide lighting for the explorers. They have manipulators like water jets and moveable arms that will help with the excavation and exploration of the wreck. They also have high definition cameras, which will aid the main goal of the explorers: mapping the decay and deterioration of the Titanic. They will take pictures of the ship, which will be compared with pictures taken at the time of the ship's initial discovery in 1985.(www.titanic.com/dory/163/Robert_Ballard, www.edhelper.com/ReadingComprehension_33_16.html)

There are various types of ROVs, each with different uses. MBARI's usage of ROVs to explore unknown marine environments is a unique approach, using modern technology to explore unknown worlds. Robert Ballard's ROVs, which are being used to explore the wreck of the Titanic, are preserving the past, giving us a glimpse of the grandeur that sank with the Titanic. Though both ROVs have different vocations, it is apparent that both can be used for everyday applications.

Budget and Financial Statement

EXPENSES:

ITEM	COST ($CDN)
AIRFARE (Return St. John's to Los Angeles)	
21 students @ $810 (tax-in) [number of travelers estimated]	17010
5 mentors @ $810 (tax in)	4050
ACCOMODATIONS	
21 persons/ 4 nights + meals UCSB Residence @ $185 US/ person = $3885 US	5050.5
9 rooms/ 3 nights @ $110 US/night = $2970	3861
GROUND TRANSPORT	
Van rentals + gas & Insurance (3) 7 days @ $85 US/day = $1785 US	2320.5
MEALS	
26 persons x 4 days @ $25 US/day = $2600 US	3380
AIR FREIGHT – ROBOT	
Return air freight St. John's – Los Angeles	450
MATERIALS & FABRICATION COSTS (est.)	
Parts, motors, propellers, wiring, metal stock, plastic stock, Electronics	1900
Promotional items (banners, t-shirts, plaques for sponsors, etc)	1200
TOTAL Projected Budget	**$39,672.00**

REVENUES:

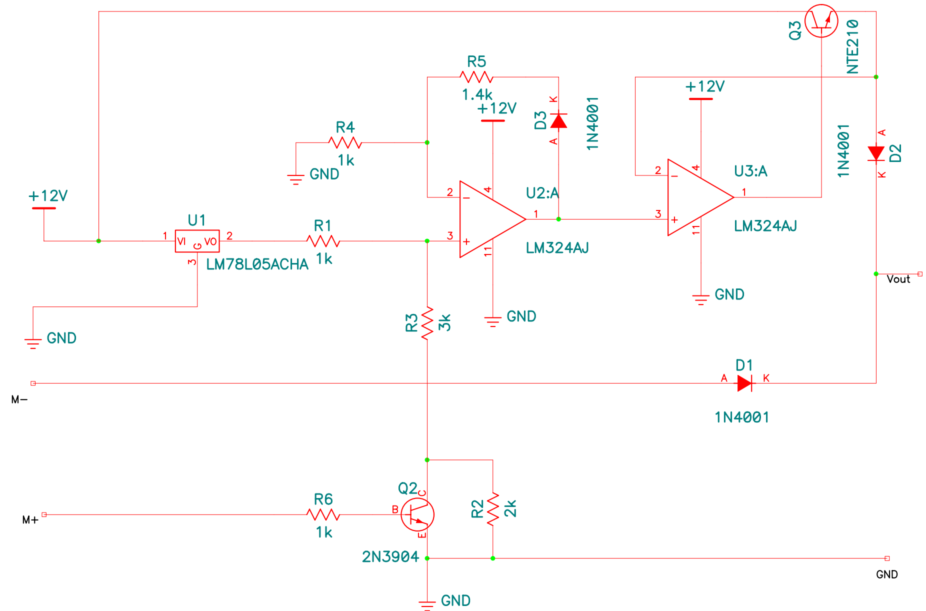
ITEM	FUNDS ($CDN)
PRIVATE SECTOR CONTRIBUTIONS	
Estimated (from previous years)	7000
SCHOOL BOARD CONTRIBUTIONS	
Estimated (from previous years)	0
PUBLIC SECTOR CONTRIBUTIONS	
Estimated (from previous years)	0
Projected contributions- student participant $1555.81 x 21 students	**$32,672.00**
TOTAL Projected Revenues	**$39,672.00**

MATERIALS DONATED AND ESTIMATED VALUES

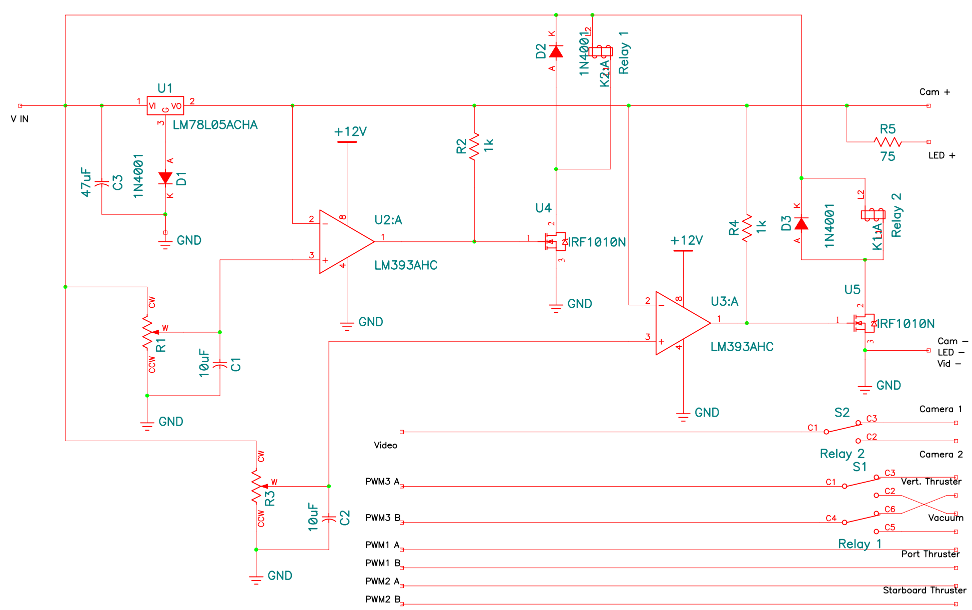
Inuktun Inc., Vancouver, B.C. – underwater camera	$1100.00
ITT/Johnson Inc., – 20 bilge pump motors	$240.00
Thomas Glass Ltd., St. John's, NL – Lexan pieces	$80.00
C&W Welding, Bay Bulls, NL - HDPE materials	$60.00
TOTAL Materials Donated	$1480.00

Appendix A: Schematics

Switchable power supply



Relay Driver



Appendix B: Team Members

Mark Brazil-	Mark is a 16-year old level 2 student who attends O'Donel High
Beau Callahan-	Beau is a 16-year old level 2 student who attends O'Donel High
Kyle Callahan-	Kyle is an 18-year old university student who attends Memorial University.
Darryl Chafe-	Darryl is an 18-year old university student who attends Memorial University.
Stephen Crewe-	Stephen is a 16-year old level 2 student who attends Gonzaga High
Gina Doyle-	Gina is a 17-year old level 3 student who attends O'Donel High
Scott Follett-	Scott is an 18-year old level 3 student who attends O'Donel High
Jason Forbes-	Jason is a 16-year old level 2 student who attends O'Donel High
Andrew Furneaux-	Andrew is an 18-year old level 3 student who attends Gonzaga High
Justin Higdon-	Justin is a 16-year old level 2 student who attends Prince of Wales Collegiate
Renée Hodder-	Renée is a 17-year old level 3 student who attends O'Donel High
Jonathan Howse-	Jonathan is a 15-year old level 1 student who attends Mount Pearl Senior High
Sarah Howse-	Sarah is a 17-year old level 3 student who attends O'Donel High
Brian James-	Brian is a 17-year old level 3 student who attends Holy Spirit High
Matthew Jenkins-	Matthew is a 17-year old level 2 student who attends Gonzaga High
Michal J. Kubiak-	Michal is a 15-year old level 1 student who attends Holy Heart of Mary High
Michael Lethbridge-	Michael is an 18-year old level 3 student who attends O'Donel High
Gary Paddick-	Gary is a 16-year old level 2 student who attends Gonzaga High
Stephen Mouland-	Stephen is a 18-year old level 3 student who attends O'Donel High
Darren Neary-	Darren is an 18-year old level 3 student who attends O'Donel High
Tim Ramsay-	Tim is a 18-year old level 3 student who attends O'Donel High
Michael Rees-	Michael is a 17-year old level 3 student who attends Holy Spirit High
Mark Snow-	Mark is a 17-year old level 2 student who attends O'Donel High
David St. George-	David is a 17-year old level 3 student who attends O'Donel High