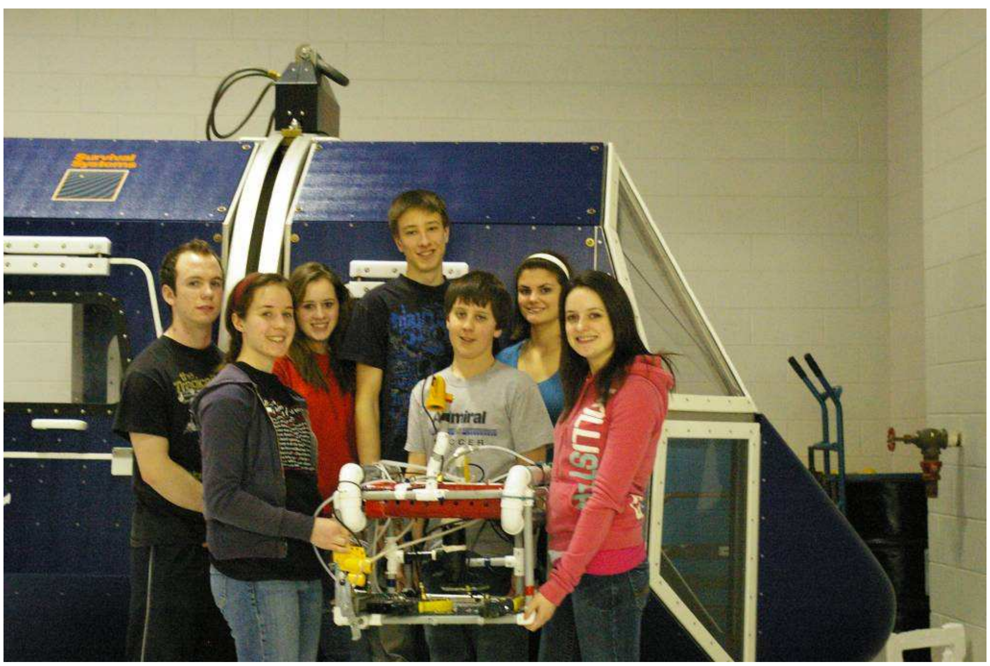
Dalbrae Aquatic Robotic Team

Technical Report

Dalbrae Academy, Mabou, Cape Breton, Nova Scotia, Canada



Team Members: Richard Gillis, Bridget Wilson, Elizabeth Chisholm, Keane MacLean, Alex MacDonald, Tess Campbell, Mallory MacDonald and the Silver Dart IV.

Team Mentors: Ed Dunphy and Tom Malloy

Table of Contents

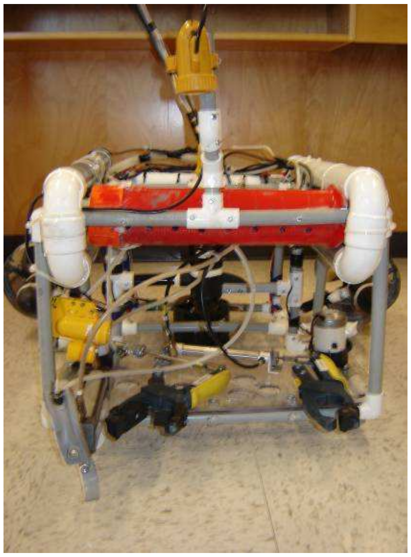


Figure 1: Our finished ROV

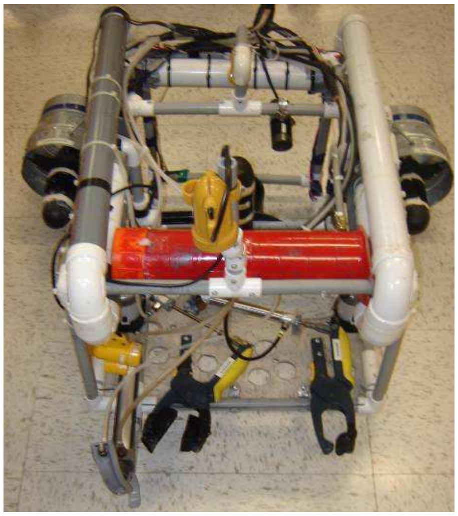


Figure 2: Our finished ROV, top view

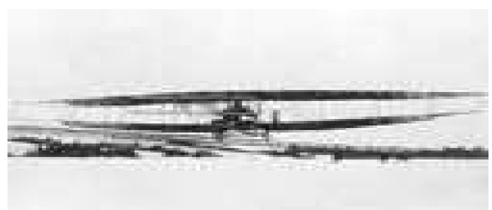
Abstract

The 2009 Dalbrae Aquatic Robotic Team consists of seven first time members. Our Remote Operated Vehicle, the Silver Dart IV, was built on four basic principles: speed, redundancy, safety and teamwork. All are qualities essential to finishing the job.

This year, M.A.T.E. assigned four challenging tasks involving submarine rescues. They include: surveying the submarine for damage, delivering pods to an escape tower, providing ventilation, and mating a transfer skirt to a submarine. To fulfill these tasks, our R.O.V. is equipped with a left, right, and vertical motor for moving around the pool as well as two lateral thrusters. A ballast tank and two main pontoons control our buoyancy. There are four underwater cameras installed for clear vision from all angles in the pool.

For the missions, we have designed tools capable of multiple uses to complete the assigned tasks. A ram attached to the end of a pneumatic piston is used for lifting and opening. Two pneumatic grippers are used for picking up pods, transporting the air line, and opening doors. Our transfer skirt is designed and attached for easy mating. The robot is controlled by a pilot and co-pilot operating pneumatic and electrical systems.

This project required many hours of hard work and learning and we can proudly say that the Silver Dart IV has come in on budget and is capable of accomplishing all of the assigned tasks within the assigned time limit.



The Silver Dart

Our ROV is called the Silver Dart IV to honour the 100th anniversary of flight in the British Empire in Baddeck, NS, Canada. Given that our team name is the Dalbrae Aquatic Robotic Team (DART), it seemed fitting that we should adopt this name. We wanted to honour the spirit of McCurdy, Bell, and the rest, to show that the tradition of experimentation and ingenuity lives on in Cape Breton. This event, and the hard work and inventiveness behind it, are part of our heritage in Cape Breton and served as our inspiration. We had originally set up an opportunity to meet the builders of the Silver Dart III this February during the re-enactment flight on February 23. Sadly, winter storms meant that we were unable to travel on that day or on a second arranged date.

Finally, in keeping with Mr. Bell's tradition of working for the community at large, we are very excited by a project our ROV team will be embarking on in July. We have been asked to use our ROV to help Parks Canada do testing in Freshwater Lake in the Cape Breton Highlands National park. The lake has been invaded by a fresh water mussel that is not native to the area. We will be attaching a GPS and a depth gauge to our ROV. We will record these reading as well as the visuals from our cameras on a lap top computer for the scientists to analyze. It is also expected that our grippers will gather samples. We are looking forward to using our ROV in this practical manner and doing some "real" life science.

Safety

“Safety first, safety last, safety always.” Right from the start of our project, safety has been a primary objective and this was the mantra passed on to us by our mentors. Safety goggles were a must when drilling, cutting, or soldering. Gloves and masks were used when using adhesives. Our pool deck was continuously kept as clean and dry as possible, and life jackets were mandatory when working on pool deck. In the shop, our workspace was kept swept and tidy. A clean work space is a safe work space. When learning how to use any new tool, we were given a step by step instruction by our mentors on all features of the tool and on how to safely operate that tool. Any time we were using any major tool, such as a band saw, or reciprocating saw, we were supervised by one of our mentors.

Following a military system, we initiated a command and repeat system. When checking motors or grippers, the team member on deck gives the command and the pilot or co-pilot repeats the command and executes the command. This system greatly reduces any chance of miscommunication.

Eventually, safety became second nature to our team members. Team members looked out for themselves and their teammates and would remind each other if goggles were forgotten. We always thought well ahead before starting anything that could be dangerous, and took the necessary precautions. Many safety features are added to the control box as well, including an E-stop, fuse and ready light. These systems are discussed in more detail in the electrical section. We are proud to say that there were no injuries during the construction of our ROV.

Figure 3: Working on the pneumatic control box

Design Rationale

“**Before anything else, preparation is the key to success**.” -Alexander Graham Bell

Once our team was assembled, our first task was to familiarize ourselves with the assigned missions. Groups of two students were assigned one of the mission tasks to become experts in and to present the task to the group. Next, all the mission props were built allowing us to get used to measuring, cutting and working safely with tools and PVC. The missions props were always nearby to help us focus on our objective and to test ideas. Then it was time to research and design an ROV that would accomplish these missions as quickly and accurately as possible within our projected budget of about $2000 in new expenditures.

Anticipating that things can and will go wrong, whenever possible we built redundant systems. If the vertical thruster struggles, our ballast tank is capable of raising our ROV. Two grippers, each capable of many functions, and multiple cameras allow us to accomplish the tasks. We have two sets or pilots and co-pilots in case someone is sick or having an off day.

The frame was built with salvaged ½" PVC conduit from the electrical program at the Nova Scotia Community College (NSCC) and a collection of tees, elbows and connectors.

The three cameras in front are each on a different plane so we have a 3-dimensional view of our tools and our environment. A fourth camera faces the rear to view the skirt and any obstacles behind us. Neutral buoyancy is maintained by the use of some permanent floatation and a ballast tank that allows for variable buoyancy.

Our payload tools are all powered by pneumatics and all serve multiple purposes. A ram is positioned on the right side of the ROV to open and lock the hatch in task three, and open and close the air vent. Two grippers are used to gather the pods, open the door, carry and insert the airline into the inlet valve. The challenging task of opening and closing the air inlet valve with the minimal amount of movement and time was accomplished by including an air line on the end of the ram pointing upwards. Once positioned, the air will drive the valve upwards and close or open the valve with the help of the ROV.

There are 3 motors on our ROV. There are 2 horizontal motors positioned in the back to enable the ROV to turn easily and allow the ROV to move forward and backwards. The horizontal motors are brought in at the rear of the ROV to keep them safe from damage and out of the way. There is a vertical motor placed at the centre of gravity and provides the ROV the ability to move upwards and downwards and keeps the ROV balanced. Two bilge pumps provide lateral movement. The end result of our work is a functioning ROV that came in on budget and can perform all required tasks. All systems and features of the Silver Dart IV are discussed in further detail in the following technical report.

Frame

Our robot's frame is made of ½" inch PVC conduit that was salvaged from NSCC's electrical program. We used plastic connectors and screwed the robot together with self-tapping screws to make sure it was held together securely but was still easy to repair or modify. A piece of clear Polycarbonate sheet is used as the platform for the grippers and ram. Holes and large sections are cut out of the platform to allow water to flow through it, giving the ROV easy movement up and down in the water. The entire frame is perforated by drilling holes into the PVC piping at the top and bottom. The idea is to fill the frame with water so there are no air bubbles that would cause it to be unbalanced.

Width in the front:	50.5 cm
Width in the back:	38 cm
Length:	58.5 cm
Height:	33.5 cm

Figure 4: Prototype with pontoons and motors attached

The dimensions of the ROV changed during the construction. The ROV is narrower at the rear by 14.5 cm to bring in the horizontal motors. The vertical thruster is placed at the center of gravity inside the ROV about 9 cm from the bottom so the propeller will be protected. The ROV was made 33.5cm high to make room under, and to enclose the vertical motor.

Cameras

The Silver Dart IV has 4 cameras. The three front cameras each point along a different plane that provides a 3-dimensional view of our tools and surroundings. The side camera is to inspect the submarine for damage in task one. When inserting the air line during task three, this camera is rotated 90 degrees to offer a better view of the ram. The front camera is to see the grippers and piston/ram. The middle camera is used to see where the ROV is going and to see our front tools and the props while we're completing the missions. The back camera allows the pilot to see the skirt and to avoid obstacles behind the ROV. Three of the cameras were salvaged from previous years to cut down on costs. All cameras run through the electrical control box for power.

Lessons Learned

There were so many lessons learned from this project. Some of the many lessons we have learned throughout this project are: safety, teamwork, hands-on skills, and the ability to bring text book learning to life. Safety played a huge role throughout the duration of the ROV project. While building the Silver Dart IV, we were conscious of potential safety hazards at all times. It was comforting to know that we were safe and we all gained a greater comfort level around tools and machinery.

Cooperation is an essential aspect of all great teams. Everyone had to work together in order to have a stress free work environment. We took all ideas into perspective and discussed each one individually. We made decisions as a team. Whenever a major decision was to be made, each individual member had to address the topic. A debate usually began and then a consensus was reached. We found by thinking things through and gathering everyone's ideas the decision was close to or best decision. Through this method all members felt valued and we learned that sometimes your own idea is not always best and even if your idea is not chosen you should support the team.

The majority of the building process took place at the Nova Scotia Community College Campus in Port Hawkesbury. We were able to learn and practice essential hands-on skills from designated professionals, which was not only helpful skill-wise, but also in terms of safety. Everyone seemed to have a different method of soldering and we took all the advice and developed a technique that suited us best.

In today's school systems we are often taught through a lecture style of learning. In doing this project we were able to truly understand the concepts of forces such as thrust, weight, and buoyancy. We wanted and needed to extend our knowledge into new areas and enjoyed the process.

Pneumatics

When designing our payload tools we looked at the required tasks and at any restrictions. The restrictions of cost and amperage lead us to choose pneumatics. Commercially available electrical grippers were over $1000 and outside our budget. When all motors are operating under load and all cameras operating, the system draws close to 18 amps. This was close to the limit of 25 amps so the decision not to use electrical tools was made. Hydraulics was also an option but we knew that the chance of a loose fitting connector or a hose leaking during our initial experiments was high. We would not want to pollute the pool. A leaking pneumatic part would simply release air bubbles so, from an environmental perspective, air was the obvious and green choice.

Our ROV uses pneumatics to operate two grippers, one ram and our ballast tank. All components are connected by ¼" pneumatic hoses along the tether to a pneumatic control box which is operated by the co-pilot. The three pistons are double acting pistons with one air line required to extend the shaft and one to close it.

Figure 5: Top of pneumatic panel

One air line runs to the ballast tank and is attached to the valve of an inner tube inside a cylinder allowing us to have variable buoyancy. Finally we have our last hose, which is on the ram, not controlling it, connected to the top. The upper part of the ram is positioned under the valve and air is shot upwards to assist in opening or closing the valve.

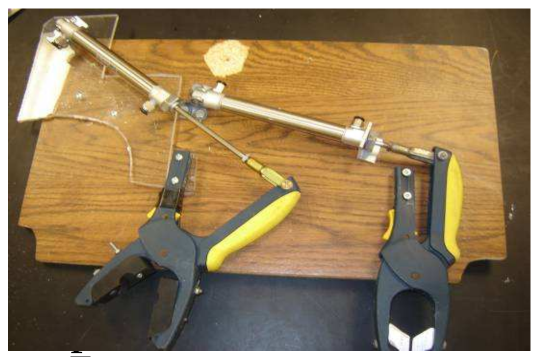


Figure 6: Gripper prototypes

The pneumatic control box is built with a wooden box and a plexi-glass top so any obvious disconnections can be spotted. The bottom of the box is hinged so that the inner workings can be easily accessed. At the back of the box is one input plug that is connected to a compressor. The compressor is set to output 40 PSI or 273 kPa. The input plug branches off to go to three separate control valves and one regulator. The control valves operate the two grippers and the ram while the regulator operates the ballast tank. A pressure gauge is connected to the regulator to monitor the amount of air in the ballast tank. All components are connected by ¼" hose with a variety of tees and elbows except the line to the air hose on the ram, which is a larger diameter to allow more air flow. At the back of the panel are 8 friction lock connectors where the hoses are inserted to connect to the tether. All connectors and hoses are color coded for accurate and easy connections. Extra pieces of hose and a couple connectors are kept in the control box if repairs are needed. These tools are very affordable and have proven to be easy to use, durable and are not damaged if water enters the piston.

Tools of the Remote Operated Vehicle

On our Remote Operated Vehicle, we have three main tools. We have two grippers, and one ram. All of our tools on our ROV are custom designed and built by us. All three tools are pneumatic operated. No sensors beyond the cameras were required to complete the missions.

Our two grippers are modified Mastercraft vice grip tools. The grippers are open and closed by one double acting pneumatic piston each. We decided to use the rubber from hockey pucks to custom make the pinchers on our grippers because hockey puck rubber is easy to work with, very available, easy to shape and won't let objects slip like aluminum and other metals would. The rear of the piston is fixed to the poly carbon sheet. The front is able to pivot slightly to avoid any twisting or stress on the gripper handle. When we ordered our pneumatic pistons, we measured the shaft length required to have full motion. We had to experiment to find the right angle to set the piston at in order to open our grippers without adding any stress to the handle.

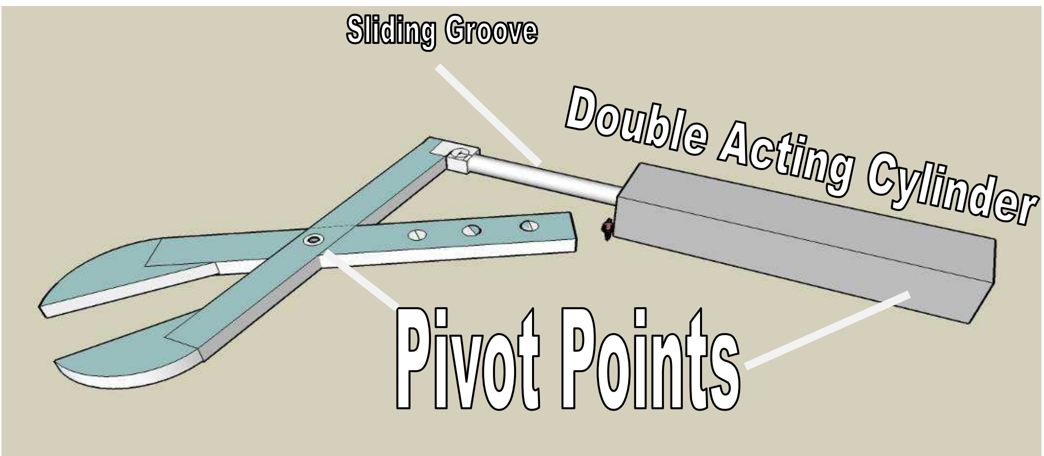


Figure 7: Mechanical drawing of gripper

The Ram is constructed using another pneumatic piston that we were able to salvage. The piston was older and rusty at first so it was dismantled. All seals were checked and all moving parts were lubricated. The throw length seemed to be smaller than expected. A small bushing was found inside the cylinder that must have been used to limit the throw length. This was removed and the throw length was increased by 3 cm.

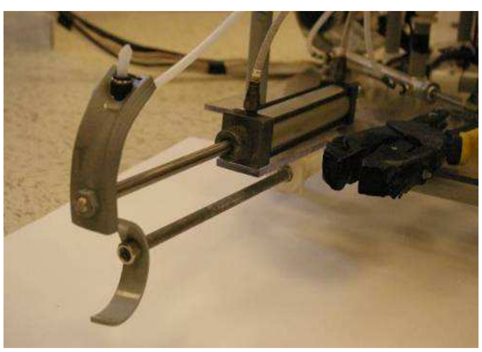


Figure 8: Extended Ram

Scrap PVC plastic was heated and bent to make two opening devices. The bottom hook is designed to open the hatch of the submarine and the top is designed to lift the air valve. An air line is attached to the top hook connecting to a 90 degree elbow. The top of the elbow has a piece of hose shaped to concentrate water upward. The air line is fitted under the air vent line and air is released to push the valve open or closed.

Challenges

"**Sometimes we stare so long at a door that is closing that we see too late the one that is open.**" ---
Alexander Graham Bell

Throughout this project we have faced many challenges. Living in a rural community called for a lot of travel. The only pool available to us required about 3 hours travel time. Time in general was a challenge as most team members attempted to juggle ROV meetings with sports, school work, part-time jobs and family commitments. As with most projects, financial issues also presented challenges so we had to spend a great deal of time raising money through soliciting sponsorship, working at bingos and raffles, and searching for used parts to salvage.

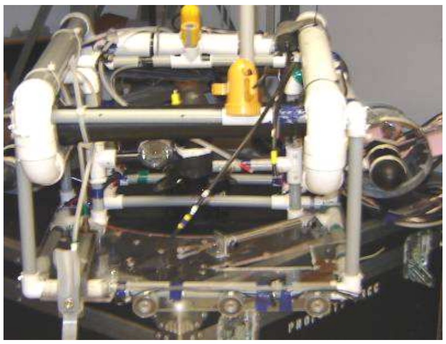


Figure 9: ROV with Electromagnets

The biggest challenge we faced this year was the use of the electromagnets. Once we were familiar with the missions, our team brainstormed ideas to accomplish the tasks as efficiently as possible. We decided to try using three electromagnets to pick up the pods by the U-Bolts.

We researched various products and were able to get a reduced cost from APW winding, a company out of New Jersey. The model we chose was rated to lift 30 kg. The magnets were 5 centimetres in diameter but only 1.9 centimetres of each was magnetized. Plan A was to position the magnets under the front of the ROV and position the ROV over the pods, energize the magnets by a switch at the control box, lift and fly the pods to the open hatch and drop them one at a time into the hatch. It would require two trips to transport all 5 pods.

Initial tests showed that the magnets could not reliably lift the pods in this position. We deduced that the magnets were not getting enough surface area of contact due to the rounded edges of the U-Bolt. We decided to position magnets so that the faces were vertical so they would attach to the side of the U-Bolt giving it a larger area of contact. Although this worked much better, with the jostling required as the pods are lifted out of the carousel and moved, we did not feel we could trust this method. Further brainstorming produced the idea to position two magnets side by side so that they would attach to the vertical area of the U-Bolt. This produced better results but we were still not convinced this was going to work.

An attempt was made to build a solenoid switch with a spring loaded plunger being pushed out to hook on to the U-Bolt. This attempt did not yield satisfactory results. With time and money running out, we spoke with the representative of APW Windings with the hope of using a magnet with diameter close to the diameter of the U-Bolt. Such a product was available but the cost and increased mass combined with the uncertainty of success caused us to reluctantly abandon the magnet approach.

It was a sad day when we had to "cut the cord" of the magnets and attempt another solution. Throughout trials in the pool we found that whenever we could not pick up the pods with the magnet, we used the pneumatic gripper to capture the pod. The choice was then made to go with this approach. The gripper was reliable but it was slower. In order to decrease the time to move all 5 pods, a second gripper was made and positioned at the front of the ROV in such a way to easily grab two pods at once. The grippers were also positioned to allow us to better complete Task #3 when we are supplying air to the submarine. These ideas are explained further in the Tools section.

Although the experience with the electromagnets was not successful, we do not feel that it was a total loss. Yes, a lot of time was spent on this idea, but many lessons were learned along the way. We learned about electromagnets, circuits and switches and how to measure voltage drops. We learned that sometimes we won't always know the answer to a problem right away. Only hard work and experimenting can show you if your solution is the right one. We learned to accept the highs and lows of experimental design as we worked through different stages, and finally, we learned that some times you just have to let go of an idea when it is eating up too much time. Looking back, this challenge did a lot to bring us together as a team.

Performance Results

Throughout the building and testing or the Silver Dart IV we performed basic tests of its performance. The tests would show if the ideas were working and if there were problems with any components. The final results are summarized below.

All motors Current Draw

	Forward and Up (Amps)	Reverse and up (Amps)	Forward and Down (Amps)	Reverse and Down (Amps)
All motors	13.5	12.5	13.0	12.5

Thrust and Speed Results

	THRUST (N)	Speed (m/s)
Forward	20	0.36
Reverse	10	0.30
Up	13	0.24
Down	9	0.18

Current Draw

	Forward (Amps)	Reverse (Amps)
Left motor	5.5	5.0
Right motor	5.3	4.9
Both Horizontal motors	9.2	9.0
Left Bilge Pump	2.5	
Right Bilge Pump	2.5	

Buoyancy

Archimedes Principle states that the buoyant force on a submerged object is equal to the weight of the fluid that is displaced by the object. Since most of the tasks required the ROV to be operating in mid-water, it was decided to make the ROV neutrally buoyant. When the motors are shut off the ROV should stay at that level. To achieve neutral buoyancy the mass and volume of all major components were calculated. The majority of the mass comes from the three Sevylar trolling motors, each with a mass of 2.2 kg and an approximate volume of 580 cm^3. Other major sources of mass come from the 3 pneumatic pistons. The grippers and cameras were very light as was frame with our ROV coming in with a total mass of 15.9 kg.

The majority of our buoyancy comes from the use of two pontoons. The pontoons are made of very light weight 2” PVC piping used with internal vacuum systems. Initial calculations indicated that the pontoons should provide an additional 6000 cm^3 of volume with minimal mass. Each pontoon consists of two 63 cm lengths of PVC connected by two 90 degree elbows at each end. Although the elbows and tubes are glued with 3m marine adhesive it was decided that they would be filled with dense foam so that if there was a leak the pontoons would not fill with water. Each pontoon has a total volume of 3483 cm^3 and a mass of 810 grams, giving us a net upward force. The pontoons were made slightly longer than the ROV so that they can be moved forward or back to make the Silver Dart IV sit level in the water. This feature has served us well as the ROV evolved in construction. The pontoons are incorporated into the frame and held secure by tie-wraps. Two other smaller cylinders full of foam were placed at the back and on one side of the ROV to balance it.

Fine-tuning our buoyancy using foam and pontoons, as we added and subtracted components, would be far too time consuming, so it was decided that we needed to incorporate a variable buoyancy system in the form of a home made ballast tank.

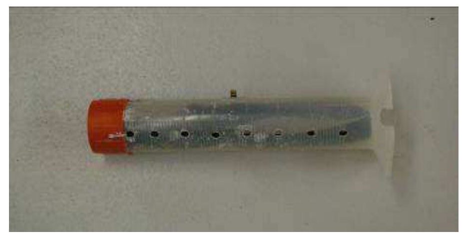


Figure 10: Ballast tank

The tank is made of a modified 1800 ml plastic graduated cylinder with a 9 cm end cap. Holes were drilled along the tank and a motorbike inner tube was inserted. The valve stem valve was removed and a pneumatic hose in attached. This hose is attached to our pneumatic control system to a regulator and pressure gauge. When we need more vertical force, we turn the regulator sending air to the inner tube that expands and displaces water from the tank. The co-pilot, in discussion with the pilot, adjusts the pressure as needed. This tank does a great job of helping achieve neutral buoyancy. It also provides extra lift when the grippers carry the pods. In keeping with our desire for multiple systems, the tank is able to lift the ROV to the surface if the vertical thruster malfunctioned.

Tether

Figure 11: Laying out the tether

Our tether is made up of eight ¼” pneumatic hoses, four camera wires, three lengths of 16 gauge speaker wires and a length of tuna fishing line. We calculated that we would need 20 meters of length. Right from the beginning we wanted to ensure that when transporting and operating the tether there would be no chance to damage the motors or cameras by pulling on the wires. This situation was avoided by incorporating two systems into the tether: a strong Tuna fishing line and a rubber tube. A heavy gauge tuna fishing line runs the length of the tether and is securely attached to the frame. We could lift a disabled ROV by the fishing line if needed. Where the tether attaches to the ROV a tension relief system is incorporated. All wires and hoses are bundled tightly and fed through a rubber tube that is attached to the frame. The tube is tightened around the bundle and then the tube is attached to the frame such that there is always slack on the wires and hoses. If the tether is pulled, the tube will stretch and no tension is placed on the wires. If the tether is pulled harder the tuna line will take the strain. If the ROV ever became disabled underwater, it could be pulled up by the tether, while the tuna line and tube system would ensure that no damage is done to any components. We carefully laid out all of the necessary wires and hoses in parallel lines, so that when they were brought together, they wouldn't twist around each other. Pieces of foam are added at strategic places along the tether to make it neutrally buoyant so that it will not interfere with the operation of the Silver Dart IV.

Electrical

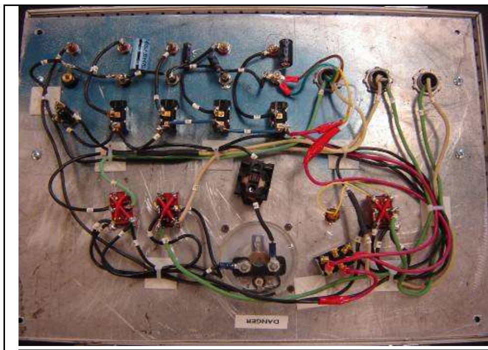


Figure 12: Control Panel Bottom

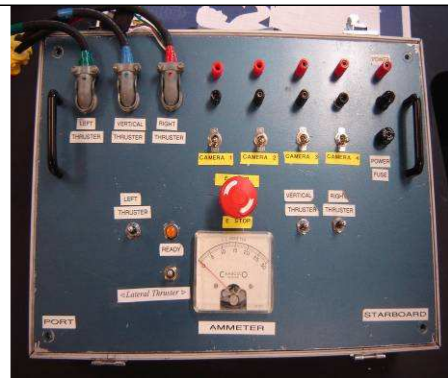


Figure 13: Control Panel Top

Figure 14: Alex and Tom working on the control box

The electrical features on the Silver Dart IV include the control panel, the tether, the cameras and the motors. When planning our control system we knew we needed a system that was affordable, that we could design, build and repair by ourselves, and not purchase off the shelf. No team members had much experience with circuits so we decided to go with a hardware approach as opposed to buying a control box or using a software approach that sometime end up being "magic boxes" that are not always understood. By designing and building our own system we have had a great learning experience and we have a system that we are able to adapt and repair when needed. We are very confident that we can trouble shoot and repair any problem with our control system.

Before starting our system, investigations into the basics of series and parallel circuits, switches, voltage and amperage, and multi-testers were performed. An aluminum tool box was salvaged to house the controls. It is solid and transportable. The next decision that the team had to make was whether to make our control panel permanently attached to the robot or to make it detachable. There are positive and negative effects to both choices. We choose detachable because of the extensive traveling that we had to go through to practice. If we had to transport the ROV, the tether and the control panel together, the bulk of this system would make it awkward and the chance of damage was too high. We all realized that it would be much easier to get set-up on the pool deck when everything is already attached but that did not offset the other concerns. We considered having the tether detach at the ROV end but decided that the difficulty in ensuring that all connectors were waterproof was too great to risk this approach.

So, the tether is permanently attached to the ROV and is attached and detached at the back of the electrical control box. The wires to the motors leave the control box and are attached using modified male and female extension cord plugs. Our ROV is stored in our physics lab at school and we were concerned about damage. We did not want to risk having someone plug the motors into a standard wall outlet with a male end and ruining all of our thrusters because of the 120V coming out of a power outlet, so the end of the tether has the female plug. The wire exiting the control box has the male plug. The only thing that would happen if this plug was inserted into the wall is the fuse would blow, which is cheap compared to the cost and work required to repair a motor. We have learned that commercial ROVs would have the female end of the plug at the control box because the danger of the metal ends of the male plug shorting out on a metal ship deck is too great a risk. The Silver Dart IV only requires 12 Volts and we are not on a metal deck so the risk of shorting out is not a problem.

The cameras are easily attached to the control box. The power adapter of each camera was cut and two banana plugs were soldered on to the wire. These plug into jack posts on the control box with switches to turn off cameras if they are not needed. The video jacks will plug directly into our monitors. Three monitors are permitted at the competition but we have access to four cameras, so one monitor receives the feed from two cameras and we can easily switch to the camera offering the optimum view for the task at hand. Sometimes when turning the motors off and on we noticed some flickering on the monitors. This occurred more often if the battery was getting weaker. Capacitors were inserted for each camera to try to reduce this flickering.

To control the motors we first experimented with a variable resistor to allow for different speeds and perhaps a smoother movement. A potentiometer was wired to a motor and the battery. When we tested it on the thrusters, it gave too much resistance to properly function as we had hoped. A potentiometer with a smaller resistance turned out to be hard to find and finally it was decided that by pulsing in with the thrusters, we could control the speed quite easily.

We control the thrusters by using double pole, double throw, momentary on/off switches. These switches mean that they are spring loaded so it will always return to an off position without the help of human hand. These switches are hooked to three separate tether connectors for which we used extension cords. They are all colour coded to match the vertical, right, and left thrusters to their corresponding switches. The extension cord then connects to the 20 m tether to our robot. We choose 16 gauge wires because it was large enough to not offer a lot of resistance but small enough to reduce weight and cost. The motors originally came with a high and low speed. However, tests showed very little difference in the operation of the motors at the different speeds. Combined with the fact that one of the horizontal thrusters low speed wire was damaged, it was decided to go with high speed only.

The two bilge pumps are controlled by one momentary on/off switch and are connected by a modified electrical plug originally designed for connecting trailer lights. This system allows for easy and accurate connection.

Experience has taught us that a motor will tend to draw more current when it is having difficulty or about to fail, so an ammeter was added to the control panel to monitor the total current running through our system. The ammeter allows us to continually check how the motors are working and to gauge if we are close to the 25 amp limit.

Safety played a huge role in this project, both for us and our ROV. Four main safety measures were incorporated into our control panel: an E-stop, a fuse, and an ammeter and a ready light. An E-stop allows us to shut all power going to the control panel in case of an emergency such as something caught in the propeller or someone working around the motors. The 25 amp fuse limits the amount of power used by the ROV. The ready light eliminates any uncertainty at to whether there is power to the system. As soon as the tether team gains control of the ROV at pool side, the command to kill all power is given, repeated, and the E-stop is activated, killing all power to the ROV.

We decided to stay organized by creating a wire scheduling chart which outlined what each numbered wire means. This helped with the initial wiring and made any changes easy when we added the ammeter, the extra camera, and the bilge pumps. All wires are clearly numbered and the wire schedule is attached inside the control panel for easy access, diagnosis and repairs.

Motors

This year we decided to salvage the motors from last year's ROV. The motors began their life as 12 volt trolling motors from Sevylar. These motors were made to power a small boat or dinghy, so using them for an ROV is no problem in terms of thrust. Talking to ROV alumni from previous years, it was learned that their biggest weakness was their tendency to leak. The chlorine was hard on the o-rings and seals. The pool we use is 4.0m deep which was much deeper than the motors were designed for. When attached to a small boat these motors would normally sit about 30 cm underwater.

To get the motors ready, a marine grade adhesive was place around the o-rings and a high pressure seal was attached around the propeller shaft. The motors originally came with a 1.0m metal shaft. This was cut to about 13 cm. During this task it was found that there was a small coil of wire inside this shaft that was damaged when the shaft was cut. This turned out to be a small length of wire that worked as a resistor to offer a low speed. It was decided this year to go with high speed only since tests showed a minimal difference in performance between high and low speeds. The motor end of the shaft was stuffed with cotton balls to prevent any sealant from entering the motors, a piece of ½" PVC was inserted at the other end of the shaft and then the shaft was filled with 3M Marine Adhesive Sealant 1500.

Figure 16: Horizontal motor with shroud

Figure 17: The left motor , Rear View

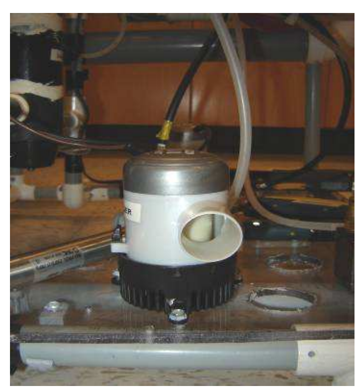


Figure 18: Bilge pump

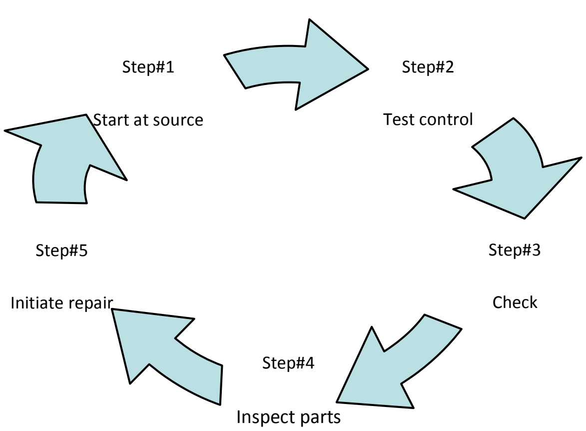
This product was recommended by one of the instructors at Nova Scotia Community College (NSCC). Although we spent the vast majority of our time working on our own, when we needed assistance or expert advice, our mentor would arrange for someone to work with us. Often this was an instructor at NSCC. This gave us a chance to meet people in different fields who would share their expertise and talk about their program and job experiences.

The horizontal thrusters were attached to the frame using 40mm of PVC piping inserted into the motor's shaft. The PVC piece is then attached to a tee on the frame. In order to ensure the motor was secured properly, the steel shaft on the motor was riveted to the PVC pipe. The placement of the horizontal motors was a source of some discussion. They were placed at the back to balance out the weight of our payload tools placed on the front of our ROV. Placing the motors inside the frame may have protected them better, but by placing them outside they offered more torque and greater manoeuvrability by shorting the turning radius. To ensure that the motors did not extend too far out and to keep our ROV compact, the rear of the frame was made about 10 cm narrower to draw in the motors while keeping the pathway for the water unobstructed. To protect the propellers from the tether or other obstacles they were enclosed in a shroud made of a 7" to 6" duct work reducer. These were solid, light weight and easy to attach. A threaded rod runs from the shroud to the frame to add further support to the motor. The shrouds had an additional benefit by funnelling the water and improving our forward motion.

Two SEASENSE 1100gph bilge were added to the ROV near the outer edges of to provide lateral movement. The pumps use less than 3.0 amps yet they allow the ROV to move sideways giving the pilot more precision when aiming for door handles or pods.

The vertical thruster is another modified trolling motor. It is fitted inside a larger diameter tee with a reducer to fit the frame. The fin from the motor was used to secure the vertical motor in place. The fin fits in a slot in a piece of conduit and then was bolted in place. We decided to place it at the center or gravity of the ROV so that when we go up, or down, our ROV would stay as level as possible. It is also placed so that the propeller is about 9 cm above the bottom so it will not come in contact with material when we land on the submarine or the pool bottom.

<u>Trouble Shooting</u>



When a problem occurs, we found it easiest to start from the source of power (i.e. battery or compressor). The next step was to check the controls and make sure all lines were connected. If the problem was still occurring, we follow our tether to the robot, inspecting cables and hoses. We then check the actual part on the ROV. Once we find the source of the problem, we attempt a fix and then test before we re-enter the pool to assure there are no further problems. This technique has served us well and with each challenge that we overcame we feel more confident. Some teammates even look forward to minor problem to try test us.

Future Improvements

If we got the chance to do this project again, there would definitely be a few changes. Now that we are much more comfortable with electrical systems, we would experiment with joysticks instead of toggle switches. By researching the construction of a joy stick, we would be able to attach the wires to the motors. There could be many advantages to using joysticks. For our generation, one that is growing up in a video-game world, joysticks are a natural fit. Our drivers might be able to manoeuvre the ROV much more efficiently due to this advantage. The possibility of moving at variable speeds would also make our job easier.

Submarine Rescue Systems

The McCann-Momsen rescue chamber was used in what is referred to as "the greatest submarine rescue in history" (Maas, Peter). In 1939, U.S. submarine, the Squalus, sank 243 feet when a ventilation valve was left open. Thirty-three men sat helplessly, trapped inside the submarine; 26 crew members were killed due to flooding. Commander Charles Momsen made the crucial decision to use his new invention- the McCann-Momsen Rescue chamber, a diving bell. The U.S. Navy had previously disapproved of Momsen's invention. Disregarding their wishes, Momsen ordered for the diving bell to be sent down.

Figure 18: The McCann- Momsen Diving Bell

The diving bell is a large steel bell-shaped chamber that is lowered by cables into the ocean to land on the escape hatch of a sunken submarine. The bell forms a water-tight seal on the escape hatch. A rubber gasket is placed around the diving bell's bottom to   minimize the air pressure inside the bell. Once attached, the trapped crew members can escape into the dry interior of the bell. During the Squalus Rescue, the diving bell made four trips to the submarine. It was able to recover all 33 surviving crew members. Unfortunately, the rescue of the Squalus, was the only successful submarine rescue to date; despite the fact that Momsen's diving bell does not use the technology we have today.   This invention is similar to the transfer skirt on our R.O.V.

During our research of Submarine rescue systems we found newer, more advanced systems employing ROV's such as the REMORA. The REMORA is 16.5 tonne ROV built around a diving bell with room for seven people. It is capable of operation up to depths of 500 m and can mate with a sub even at angles of 60 degrees. Like our own ROV team, the vehicle uses a three person system made of a Pilot, Navigator and Dive Supervisor. Unfortunately, upon further study, we discovered that this system had a major problem during trials in December, 2007.

Figure 19: REMORA

A winch failure left two men trapped in the ROV on the ocean floor for 12 hours. This failure led the Australian government to "mothball" the project.

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Acknowledgements

"It takes a village to raise a child" African proverb

We couldn't possibly take all the credit for the completion of our project. We send out thanks to our many supporters who have helped us along the way.

First of all, we would like to thank NSCC for their donation of pool time and use of the workshops. We would also like to thank them for putting their time and effort into the regional competition as well as their financial support towards us. Thank you to the Marine Advanced Education Center (MATE) Team who put the project together, allowing us to learn and experience the process of building an ROV. This gave us the chance to learn skills that we wouldn't otherwise learn. Also, a thank you goes out to the judges for giving up your time.

We would like to thank our families and the Dalbrae community for the endless support with fund raising. We would like to thank Tom Malloy, who helped us with the electrical control box and help turn our hand drawn schematic diagrams into professional looking schematics. We would like to thank our mentor Mr. Dunphy, because without him this project would not exist at our school. We appreciate the amount of time he has devoted to the team, and all the things he's taught us along the way. His dedication is an inspiration to us. Finally we would like to take this opportunity to thank those businesses and agencies that supported us financially. We have made it a point to acknowledge our sponsors throughout the construction of the ROV. Any time media followed our story we acknowledged our sponsors. We held a media/sponsor night in May where sponsors and media were invited to the pool to observe our presentation and see the ROV in action. We had our advertising board and poster display on hand and we very pleased to be able to publicly thank our sponsors and give them a chance to see what their support helped accomplish.

Sponsors:

Nova Scotia Community College ***Lake Mabou Farms*** ***VanZutphen Construction***
Nustar Energy ***Pauls Auto Glass*** ***Whycocomagh Lions Club*** ***Ross Screenprint***
Matheson Building Supplies ***East Coast Credit Union*** ***B & N Distributors*** ***New Page***

Home Hardware ***Haverstock Funeral Home*** ***APW windings*** ***Scotsburn Dairy***

Inverness Municipal Council ***Dominion Diving*** ***Hilltop Electrical and Plumbing***
Nova Scotia Department of Education ***Canadian Federal Department of Fisheries and Oceans***

Reflections

Elizabeth Chisholm: Before this project, I didn't know anything about soldering, buoyancy or pneumatics. Now I understand them and could explain each. Because this is such a hands-on project, everyone who joins comes out having learned something. I would definitely recommend this to anyone, because it is such a great learning experience and it's a lot of fun.

Alex MacDonald: At a glance, the ROV project seemed like an impossibility to complete all the work at hand. Our amazing mentors gave us the opportunity to learn about; electrical, pneumatic, troubleshooting, time management, hydro-engineering, and commitment. I will have the skills I have learned in this project for life, including my future career choice as an engineer.

Mallory MacDonald: The MATE ROV competition was a great learning experience. I am learning to master circuits. This project helped me build confidence in myself as well as teaching me various hands-on skills. This was one of the greatest experiences I've ever had.

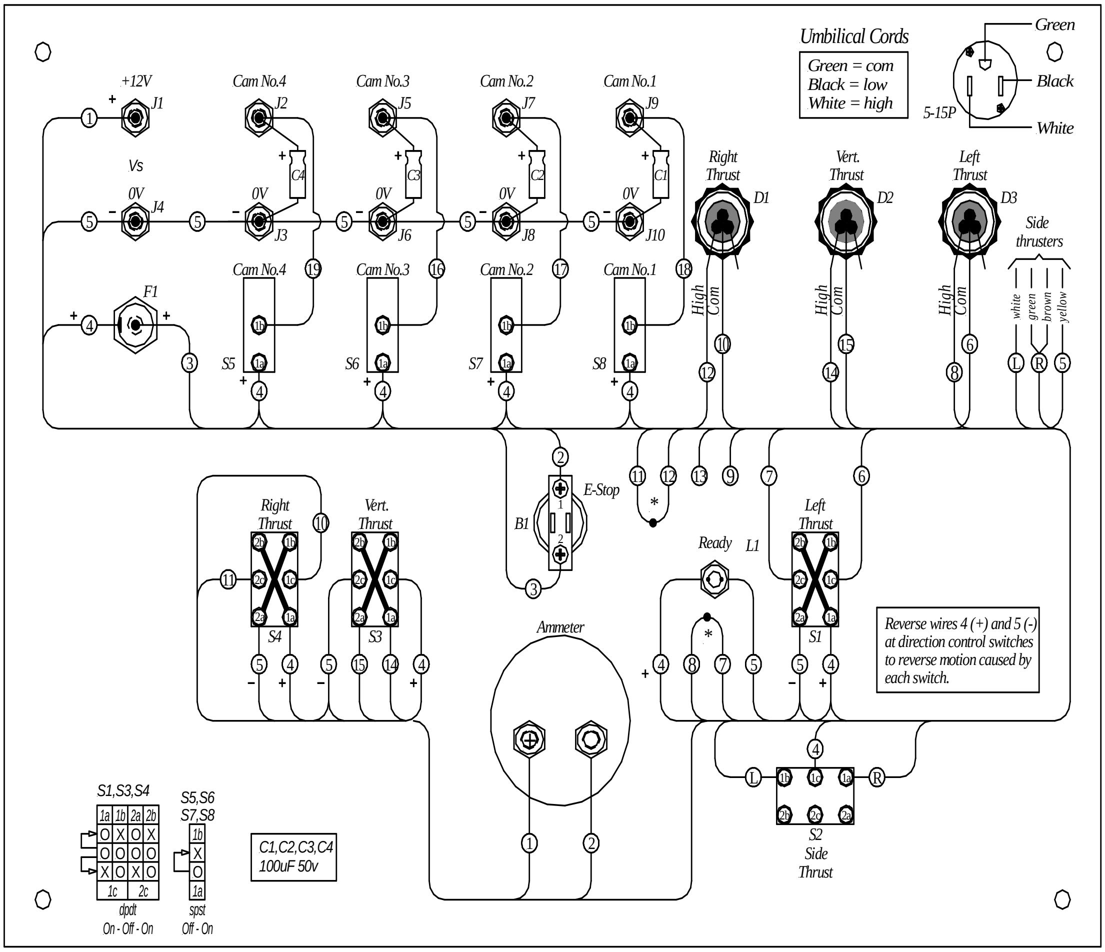
Tess "Squeege" Campbell: Before this competition I knew nothing about electricity or soldering or even what a drill bit was. Now I know how to wire minor electrical devices, how to solder, and my vocabulary has really expanded. I joined this project in hopes of learning new things, and that is exactly what happened.

Richard Gillis: One thing that stood out to me in my experience is that you can have as many ideas as you want, but not all of them are going to work. This project requires more teamwork than anything I have been involved in. We all had to learn to listen to each other, respect each other, and to trust each other.

Keane MacLean: I really like the teamwork aspect of this project. Everyone had their role to play. Pneumatics first caught my eye in this project and it all looked like a maze to me, but I stuck to it, and before I knew it I was the "airhead".

Bridget Wilson: I tried out for the R.O.V. team with hopes of broadening my horizons. Before joining the team, I had much exposure to trades or concepts like electricity and buoyancy. By the end of the project I could solder a wire, hook up a pneumatics system, and design tools, along with many other hands on skills. It has really given me a clearer picture of what I want to do in the future.

Electrical Control System Schematic



Control Panel Wiring (Rear View)

Drawn:	Date:	Scale:	Revision:		Drawing:	Sheet:
T.M.	May 13, 2009		05	Control Panel Wiring Diagram	ROV-2009	006

BUDGET

ROV Expenses

New Expenditures	COST
Mission Prop Expenses	65.38
2 Pneumatic pistons	116.3
pneumatic hose	42.5
nuts and bolts	55.5
pnuematic connectors	30.34
shrink tube	13.99
switches for motors	85.25
Speaker wire for motors	175.2
Tiburon underwater camera	155.38
glues	11.27
connectors/tubes for bouyancy	38.6
report covers and binders	38.33
marine silicone	22.59
silicone	13.5
Printing of Poster	75
Potentiometer	38
self tapping screws	26
inner tube for ballast tank	9.9
Friction lock pnuematic connectors	35.97
tie wraps and tape	78
Shipping for electromagnets	52.2
Wire for magnets and motors	156
bilge pumps	75.38
Total Expenses	**1410.6**

Donated/Salvage Items	Donated/Salvaged	Estimate $
Underwater cameras	s	240
3 Syvylar motors	s	451
60 m of Pneumatic hose	s	20
elbows and tees	d	35
180 ft of speaker wire	d	45
pnuematic piston	s	70
Switches	d	50
pnuematic controller	s	55
1/2" PVC conduit	d	46
ballast tank cylinder	d	15
aluminum suit case for controller	s	30
Ammeter	s	30
Lexon Sheet	d	70
Pressure gauge and regulator	s	90
Electromagnets	d	94
Jacks for Electrical Control Panel	s	50
Total Donate/salvaged		**1391**

Travel Expenses	
Meals for Regional Competition	240
Travel for Regional Competition	320
Accomadation for Regionals	459
Travel for Regional	7300
Meals for Internationals	700
Accomodation for Internationals	700
Total Travel Cost	9719
Total Expenditures	**11130**

DART Budget Revenue 2009

Name	Amount $	In Kind
Ideal Concrete	500	
New Page	500	
B&N Distributors		120
Home Hardware		60
Haverstocks Funeral Home	200	
Royal Bank	50	
NuStar Energy	200	
Pauls Auto Glass		70
Whycocmagh Lions Club	200	
Nova Scotia Community College	5000	
Matheson Building Supplies	75	
Dominion Diving	500	
Fisheries and Oceans Canada	500	
Lake Mabou Farms	100	
NS Department of Education	2000	
Hillside Electrical and Plumbing	100	
Inverness Municipal Council	700	
Total	10625	250

	Money Earned
Flea Market	350
Jan. Bingo	90
Feb Bingo	228
Raffles	922
Teas	340
Track Canteen	1500
Lion Club clean up	200
Total money earned	3630
Total Money In	**14255**