O'Donel High School

Design, Develop, Demonstrate, Deploy

Mount Pearl, Newfoundland and Labrador, Canada

OD-4D STAFF

Staff Member	Responsibility / Role	New/ Return	Grade	Career Goal
Kaitlin Genge	President & CEO	R	11	Aerospace Medicine
Michael Howse	Manager, Safety Officer	R	11	Ocean Engineer
Jonathan Pike	Manager, Fabrication Technician/Testing	R	12	Electrician
Quinn Whalen	Manager, ROV Operations - Pilot	R	12	Software Engineering
Emily Wiseman	Manager, Software Designer	R	11	Electrical Engineer
Kathryn Brophy	Graphic Designer / Marketing	N	12	Graphic Designer
Harrison Latham	ROV Operations - Pilot	N	11	Aviation Pilot
Joel Hatcher	Research, Software Designer	N	10	Computer Engineer
MacKenzie Morgan	Fabrication Technician	N	12	Production Engineer
Noah Williams	ROV Operations - Pilot	N	10	Mechanical Engineer
Robin Murphy	CAD Technician	N	10	Software Engineer
Patrick Breen	Tool Development, Public Relations	N	10	Aviation Pilot
Zachary Norman	Fabrication Technician, Testing	N	10	Computer Engineer
Clark Payne	Tool Development	N	10	Mechanical Engineer
Matthew Butt	Research & Development	N	10	Mechanical Engineer
Maxwell Parrell	Fabrication Technician, Testing	N	10	Automated Production

EXTERNAL ADVISORS: James Hickman, Joseph Santos

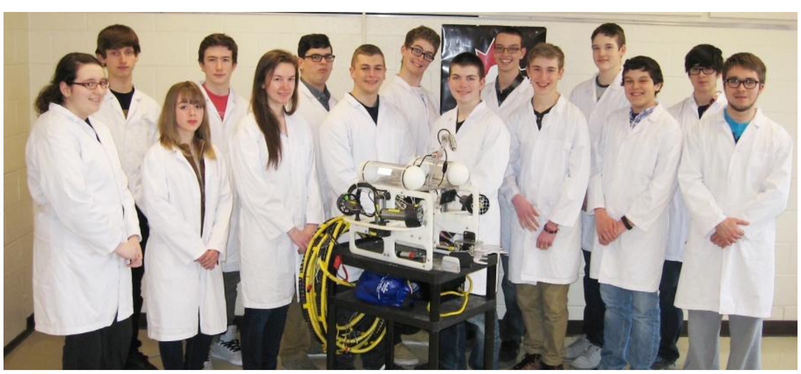

Figure 1: OD-4D

Not In Photo: Michael Howse, Quinn Whelan, MacKenzie Morgan

ABSTRACT

OD-4D is a wholly-owned subsidiary of O'Donel High School, Mount Pearl, Newfoundland and Labrador, Canada. OD-4D undertakes technological development and fabrication in the underwater environment. The work-class Remotely Operated Vehicle (ROV) ***ICE*** is our most recent project in aquatic robotics. ROV ***ICE*** is specifically configured to support the polar science ice community's needs for an ROV which is able of performing multiple underwater tasks in extreme arctic conditions. ***ICE*** performs three major Mission Tasks, within three 15-minute time-frames, as follows:

Task #1: SCIENCE UNDER THE ICE
Maneuver through a hole in the ice to collect samples, identify and count species, deploy a sensor, and survey and evaluate an iceberg to determine the threat level to area oil installations.

Task #2: SUBSEA PIPELINE INSPECTION AND REPAIR
Conduct a close visual inspection to locate a corroded section of pipeline, remove that section of pipeline and return it to the surface, prepare the remaining pipeline for a replacement section, and repair a wellhead.

Task #3: OFFSHORE OILFIELD PRODUCTION AND MAINTENANCE
Test the grounding of anodes on the leg of an oil platform, determine the angle that a wellhead emerges from the seafloor, and move fluid through a pipeline system.

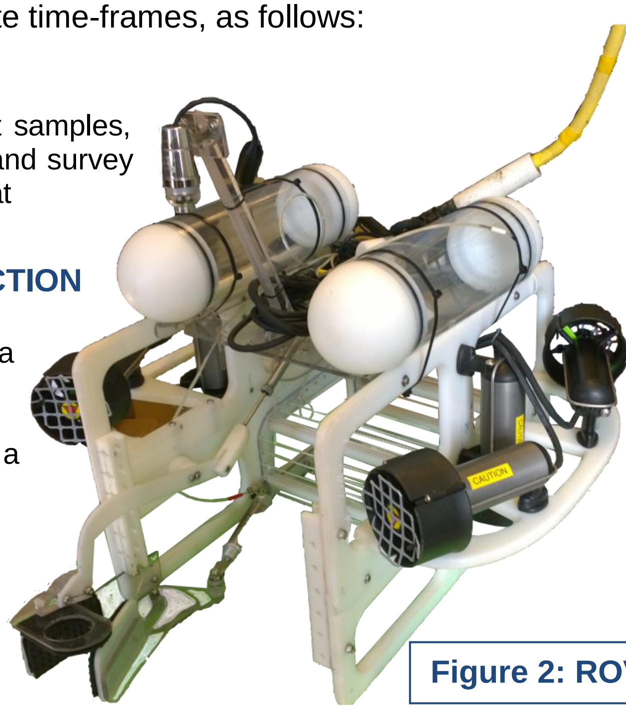

Figure 2: ROV ICE

ICE has the following features:

i. A two-section, rugged high density polyethylene (HDPE) frame featuring a detachable tool skid, protective thruster brackets, and lift rails.
ii. Two, clear Lexan™ (polycarbonate) adjustable position buoyancy tubes
iii. Six (6) *Seabotix*™ BD-150 brushed thrusters with protective nozzles
iv. Electronic controls provide variable speed and precision maneuverability in 5 axes
v. Rotating video-cameras (2) provide multiple angle tool views and a navigation view;
vi. Mission-specific, highly effective pneumatic and mechanical tools – 2 fixed, 9 gripped by fixed tools. Two tools appear to have Intellectual Property features, following patent searches.
vii. In practice trials, ***ICE*** has completed all mission tasks efficiently.

We look forward to demonstrating the capabilities of ***ICE*** at imminent demonstration trials in St. John's, Newfoundland, June 25-27, 2015.

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1.0 FINANCIAL DATA

Table 1: Total cost of materials and travel to MATE International ROV competition.

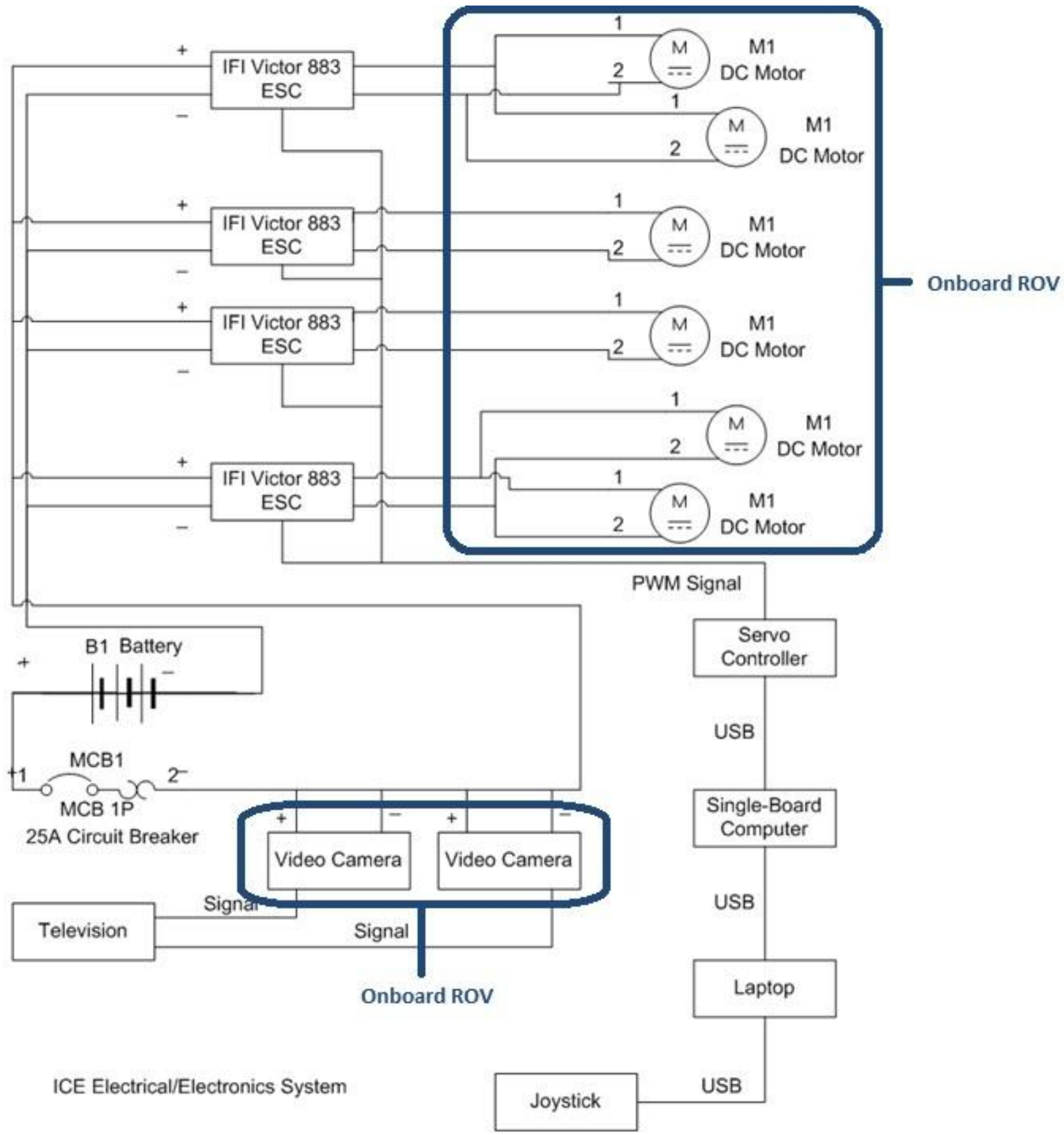
ITEM	BUDGET ($US)	DONATION ($US)	EXPENSES ($US)
MATERIALS and COMPONENTS			
Topside electronics: ESCs, servo controls	1350.00	1350.00	
SS Aquacam™ colour video cameras (3)	1430.00		1430.00
Tether - Leoni Elocab ™Inc.	250.00		250.00
Seabotix™ BTD-150 brushed thrusters (six)	3390.00		3390.00
Pneumatic pistons, valves, fittings and tube	463.00		463.00
Lexan™ buoyancy tubes (5”) & end caps	129.00		129.00
High Density Polyethylene (HDPE) (4’x8’x0.5”)	220.00		220.00
Joystick (USB)	76.00		76.00
Fasteners, drill & CNC bits, glues.	70.00		70.00
SeaCon Brantner “*WetMate*™” connectors	2350.00		2350.00
TOTAL EXPENSES	**$9,728.00**	**$2,700.00**	***$8,378.00**

*These components were purchased over a 4-year period. Average annual expenses =$2,094.50

Table 2: Financial Contributions / Earnings towards development of *ICE* by OD-4D

CONTRIBUTORS (over a 4 year period)	VALUE ($US)
Gov’t of Newfoundland and Labrador (NL) sources. ($750/yr)	**$ 3000.00**
Funds earned by team members (community recycling program)	**$ 5,378.00**
TOTAL Contributions	**$ 8,378.00**
TOTAL Expenses	**$ 8,378.00**
BALANCE (for materials and components for 2015 competitions)	**$ 0.00**

2.0 SYSTEM INTEGRATION DIAGRAM



3.0 DESIGN RATIONALE

The design process for ROV ***ICE*** always starts with gaining a complete understanding of the mission tasks provided by the client in January of the competition year. This is achieved through researching the mission tasks, analyzing the requirements, and building the mission props. These mission requirements inspired a set of precise design specifications. These are later used as the "gold standard" by which to evaluate the effectiveness of all ROV systems and payload tools.

This analysis produced the following list of Design Specifications:

i. small size (width and height <60 cm)
ii. adequate carrying capacity for tools and materials
iii. capable of multi-axis movement and maneuverability
iv. capable of low-speed, precision movement
v. a variety of specialized tools, ideally multi-purpose
vi. multiple video-camera views
vii. tools provide redundancy in task completion
viii. adequate thruster force for movement and lifting.
ix. simple, intuitive control of ROV and payload tools.

The stepwise design process for the ROV structure, capabilities and payload tools included:

i. individual brainstorming sessions
ii. idea evaluation by small groups of two to four staff
iii. most promising ideas evaluation by whole staff.
iv. top designs prototyped and tested.

The design process is cyclical. As new information emerges from testing and research, refinements in design are made. Sometimes, radical shifts in design or technology are adopted to improve the ROV or the payload tools it carries. Some of tool designs required for more complex, multi-step mission tasks required up to eight (8) design cycle modifications.

3.1 Frame and Buoyancy

ICE's frame is a masterpiece of design. It has been inspired by our core value of excellence and engineered to rigorous design specifications. The frame is an open-bottomed box with perforated sides. It is fabricated from six pieces of 1/2" thick HDPE (high density polyethylene) and a bent-edge piece of clear 1/4" thick *Lexan*™ (polycarbonate) which forms the roof. This modular frame permits quick adjustments in height and width in accordance with mission requirements and is also easily transported when disassembled. Current frame size is 48 cm Long x 65 cm Wide x 32cm High. Total mass in air is 12.3 kg.

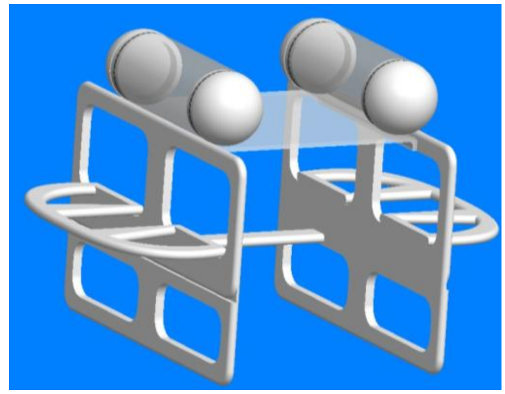


Figure 5: *ICE*'s frame and buoyancy

ROV Frame Specifications:

i. the roof is transparent and permits vertical camera vision and ambient lighting;
ii. the frame provides attachment sites for thrusters, cameras and payload tools;
iii. rounded edges and small profiles reduce drag in forward and vertical movements;
iv. it floats (density (ρ = 0.95g/cm^3) thereby reducing the drag of additional buoyancy;
v. the detachable tool skid can be altered as mission tasks and tools change over time.

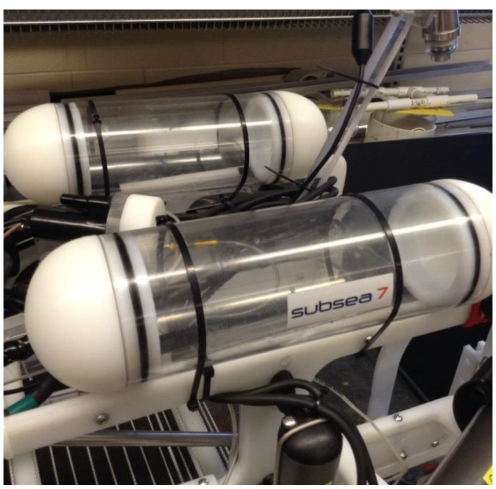


Figure 6: *ICE*'s *3" Lexan*™ tube buoyancy chambers.

This frame was designed in SolidWorks™ 3-D CAD and converted to NC-code in Master CAM, for cutting on our Red Cam™ CNC Router. Our frame accommodates the four, vectored horizontal thrusters and has an abundance of space for all tools.

Buoyancy is achieved through the use of two hydrodynamic torpedo shaped Lexan™ air chambers (15 cm outside diameter x 22 cm length and 28 cm Length), each enclosing about 1.35 to 1.5 liters of air. Neutral buoyancy and trim is adjusted as required by different tools by simply modifying the length of Lexan tubes…a 30-minute long task.
The 4 HDPE end plugs were CNC lathed. The plugs have O-ring groves which seal the cylindrical end of the plug and the inside wall of the Lexan™ (polycarbonate) pipe. At this time, the buoyancy tubes are aligned with the forward horizontal axis of the ROV and do not contain any electronics, however they have this potential in future designs. They have been pressure tested to 2 ATM (202.65 kilopascals) for three hours, without detectable leaking.

3.2 Propulsion

ROV ***ICE*** is propelled by six *Seabotix*™ BTD-150 thrusters. This is the third year OD-4D has used these units; 2013 being the first year in a decade using commercial thrusters rather than fabricating them. These thrusters are equipped with Kort nozzles, which are designed to be wider on the back than the front. This allows for maximum efficiency of thrust. The thrusters use brushed motors, creating an additional 40% thrust than our original, in-house fabricated motors.

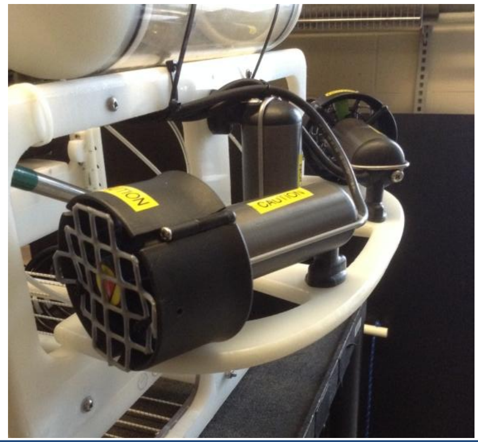


Figure 7: BTD150 Thrusters

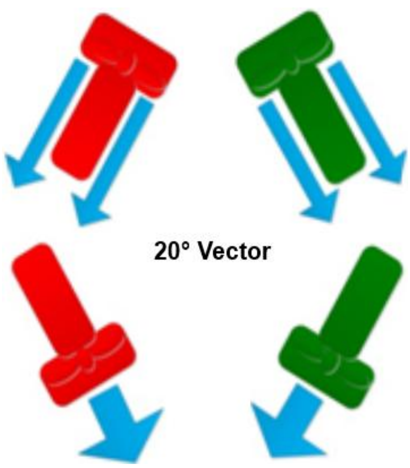


Figure 8: Thruster action in Surge motion

The thrusters have twin blade, 70mm diameter propellers. The horizontal thrust motors are configured as illustrated and below (Table 3). They are mounted in two horizontal pairs vectored 20º from the forward axis. This configuration allows for maximum maneuverability with minimal reduction in forward speed. In addition, there are two individually powered vertical thrusters which are mounted in opposing orientations, mid-ship on both port and starboard sides. This configuration ensures balanced and equal thrust in forward and reverse directions, which also facilitates greater precision of movement.

Our Bollard Pull tests revealed that each thruster produces 9N of thrust when powered with 13.5 Volts DC. They draw maximum amperage of 5.8A for a 30 second duration; however, the draw increases with continued usage to 4.25A. The optimal operational voltage for these motors suggested by Seabotix, Inc. is 19 VDC.

Each thruster weighs 350g in freshwater and 705g in air. They have a specified depth rating of 150m. Peak start up Bollard thrust was tested at 0.91 kg-m with 12V DC (nominal) voltage; continual Bollard thrust was recorded at 0.69 kg-m.

Table 2: Location of thrusters on *ICE*.

Port Side	Starboard Side
Two Horizontal Thrusters, fore and aft	Two Horizontal Thrusters, fore and aft
One Vertical Thruster, mid-ship	One Vertical Thruster, mid-ship

3.3 Pneumatics

Most manually-operated controls on ***ICE*** are pneumatically actuated. Fluid power was chosen as the safest and most reliable and efficient option, since it uses a safe and environmentally friendly power source which does not compete for electrical power.

Our air pressure source is a 150 psi rated air tank that is filled prior to launch. This 20 liter volume is adequate for 4 hours of operation of the ROV under current mission demands. A regulator limits air output pressure to 40 psi to comply with MATE's prescribed safety standards. This output pressure feeds the co-pilot's console (See figure 8) in which manual, Two-way valves divert the pneumatic power to ***ICE***'s onboard tools through individual 1/8" OD flexible polyethylene tubes.

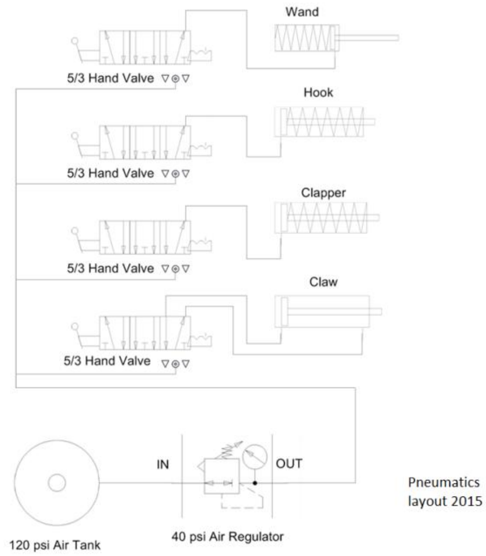


Figure 9: Pneumatic Schematic

4 pneumatic valves are installed in the co-pilot's console, which correspond ergonomically to the tool's positions on ***ICE***. Each pneumatic valve admits pressurized air into tiny 1/16" ID tubes, pressure rated to 250 psi. The mission tasks this year require:

i. one, double-acting pneumatic cylinder that is powered by a pair of pneumatic tubes to operate the "*Claw"*

ii. one, double- acting pneumatic cylinder which operates the "*Clapper*"

iii. one double- acting pneumatic cylinder to operate the *"Wand"*

iv. Two double acting pneumatic cylinders to actuate two separate "*Pipe cappers."*

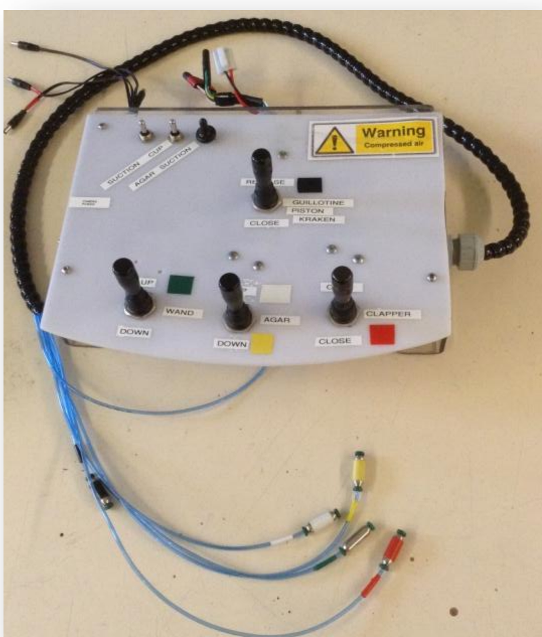


Figure 10: Pneumatic Control Panel

3.4 Sensors

Figure 11: SS AquaCam™

Vision is essential to complete this year's mission tasks. With multiple challenging tasks and different tools, the ROV requires different cameras for specific viewing angles. ROV ***ICE*** has two commercial waterproof SS-AquaCam™ video-cameras. They are mounted securely onto ***ICE*** with Lexan™ brackets. The company invested in these underwater cameras this year due to their extremely crisp, clear imagery and robust construction.

3.4.1 Nav-Cam

One SS-AquaCam™ underwater camera is located on the inside of the ROV's HDPE frame. This position is essential for navigation as well as viewing payload tools positioned in front of the ROV, such as the *"Claw"* and *"Clapper"*. It is also used to view vertical measurements taken by the measuring tape.

- Sony 1/3" Super HAD CCD
- 540 TV Lines Resolution
- 3.6mm Lens
- 8 White LEDs
- 92° field of view in air, 75° in water

3.4.2 Tool-Cam

This second SS-AquaCam™ is mounted on a 28cm long Lexan™ bracket angled over the front of the ROV, above the tools. This video camera affords full vertical view of all tool operations and approaching items on the pool floor. Similar to the Nav-Cam, this camera is used to view horizontal measurements taken by the measuring tape. By integrating views from both cameras, pilots can simulate depth perceptions in 3-D space.

3.4.3 Side-Cam

The third SS-AquaCam™ can be attached part way down the tool-cam's bracket. This video camera provides clear side view when rapidly surveying the corroded pipeline. It is also moveable to the top of the ROV to provide an upward view when completing over-head mission tasks (e.g. algae collection from under the ice)

3.4.4 Voltage Meter

Our underwater voltage meter is a sensory tool. It uses an 8 cm wide ring of stainless steel mesh attached to the inside of a 10 cm long section of clear 15 cm diameter Lexan™ pipe. This mesh is attached to the positive of two wires in a cable which is attached to a voltage meter on the surface. The second wire in the cable is the ground wire which attaches to a magnet imbedded in a plastic tab. It is designed for very rapid use in any conditions, but it holds the entire ROV onto the wellhead in moving water.

3.5 Tether

Our tether is securely attached to the ROV by a number of Seacon-Brantner™ wet-mateable, in-line connectors for the thrusters. Nylon strain couplings secure the tether to the ROV. It is quite easy to coil, prepare for dives, transport, use and handle.

Our tether management protocol has three phases:

i. **Transport**: storage and coiling using a '*flaking*' process of coiling which prevents twisting.
ii. **Deck side management**: uncoiling and straightening the tether before the mission, to prevent kinks or twists which would reduce movement of the ROV.
iii. **Mission Management:** Management of the paying out and retrieving of the tether during the mission, to minimize the amount of tether which the ROV has to pull.

The deck crew has been trained in the efficient deployment of the tether, as it is a critical aspect of the ROV's operations. We have two tether elements combined into a single unit with waterproof tape along its length.

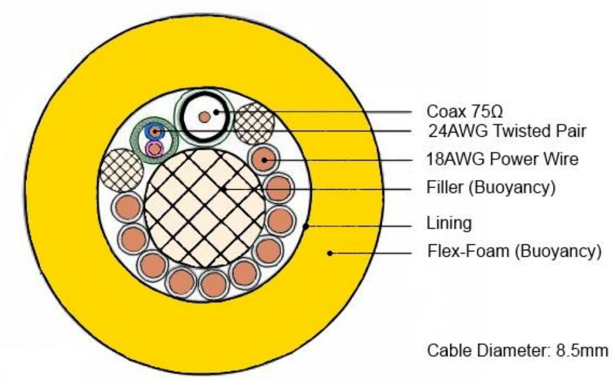


Figure 13: Primary Tether Components

3.5.1 Primary Tether

In the Primary Tether, the component wires are bundled within and protected by a buoyant foam layer with a slick surface coating. This neutrally buoyant tether minimizes drag and instability of the ROV. Two wires power the horizontal thrusters on the Port side and two wires power the Starboard side thrusters. A third pair of wires power the Port side vertical thruster and a fourth pair the Starboard side vertical thruster. Independent power to the vertical thrusters permits the ROV to roll and sway laterally; both features facilitate maneuvering and tool use.

Table 3: Primary Tether components

Type of conductor	Number of wires	Size	Function
Power wires	8 (4 pairs)	AWG 18	Power to three thruster pairs
Power wires	2 (1 pair)	AWG 18	**(UNUSED)** Initially power to onboard can
Shielded pair	2 (1 pair)	AWG 22	**(UNUSED)** Serial signals to onboard can
Coax cable (shielded)	1	75 Ω	**(UNUSED)** Video signal: video camera to the surface

3.5.2 Secondary Tether

In the Secondary tether, there are:

- three small video camera cables
- one pair of electrical wires (not used this year)
- one pair of electrical wires used to power bilge pump
- seven (7) 1/8” OD, 250 psi capacity air lines for actuating tools.

The components within the secondary tether are bundled and protected within a spiral cable wrap along its whole length. The combination of wires and air tubes also makes the secondary tether neutrally buoyant.

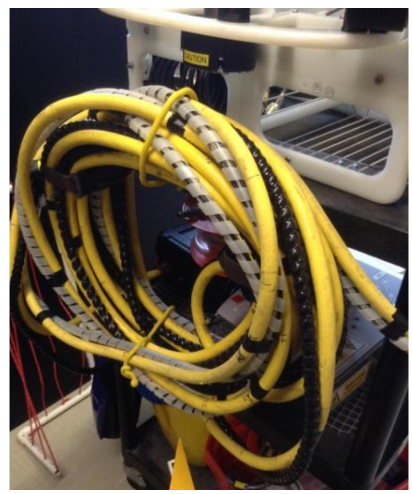


Figure 14: Tether (Primary yellow, Secondary white/black)

Table 4: Secondary Tether Components

Type of conductor	No. of	Size	Function
Power wires	4	AWG 18	Two redundant, and two to power the bilge pump
Pneumatic Hoses	7	2 mm ID 1723 kP	Fluid power to onboard actuators
Camera cables including shielded video & power cables	3	75 Ω	Video signal from onboard video-cameras

3.6 Electronics

3.6.1 Topside Control Electronics

We use a multi-function joystick as a human-machine interface to control ***ICE*** and its devices. The signals from the joystick are sent to the computer via USB where C# software interprets them.

The topside output of this software is a USB signal, input to our Phidgets™ 4-port servo controller. This controller produces a pulse-width modulation (PWM) signal that activates four electronic speed controllers (ESCs). These four ESCs act as proportional control switches, each one regulating the power to the three groups of thrusters.

Table 5: Topside Proportional control process

Joystick Control	Signal	Processor	Function
Joystick Y axis (SURGE)	Analog, Proportional	*Phidgets™* 4-servo controller	Hor. thrusters forward and reverse
Joystick X- axis diagonal (mixes X & Y axes)	Analog Proportional	*Phidgets™* 4-servo controller	Hor. Thrusters move ROV Stbd. or Port
Joystick Rotation (ROTATE - YAW)	Analog Proportional	*Phidgets™* 4-servo controller	Hor. Thrusters in opposite directions
Joystick Full X (SWAY)	Analog w/ dead band.	*Phidgets™* 4-servo controller	Vert. Thrusters Roll and Sway ROV
Throttle toggle (HEAVE)	Analog Proportional	*Phidgets™* 4-servo controller	Vert. Thrusters up/ down

3.6.2 Software

Our control design uses a PC laptop as a Programmable Logic Controller (PLC) for the operation of the electronic components described above. We have used C# programming to operate these electronics.

C# programming was chosen as:

i. it is a more widely used language in industry and research than Visual Basic, which is more commonly used in our schools.
ii. it was free from Microsoft which helped to keep our costs down
iii. C# has enormous support from electronics suppliers and is widely used as an interface program for electronics components
iv. it is part of the family of programs based on .NET technology

Nevertheless, since C# is not taught in high schools in our region, staff had to take responsibility to learn on their own. Printed manuals such as C# in easy steps written by Tim Anderson acted as guides and gave us the basic information required. The code in C# was designed by students, with some guidance from mentor advisors. The code was segregated in functional libraries to permit the ease of selecting code for the use of different tools and the ease of troubleshooting.

Given that we were novice programmers, we looked for simple solutions. We integrated stock API's from electronic component suppliers and MS.NET libraries. Stock MS.NET programming in C# for the USB joystick we used was a compiled program. The *Phidgets*™ 4-servo motor controller has a C# API available from the manufacturer.

Our programming is broken into three sections:

i. Input operations
ii. Processing operations
iii. Output operations

Input Operations:

The only input operations on ***ICE*** are those derived from the joystick. The signal range in all axes is between -1000 and +1000 and a ± 100 dead band was set to eliminate over sensitive joystick movements.

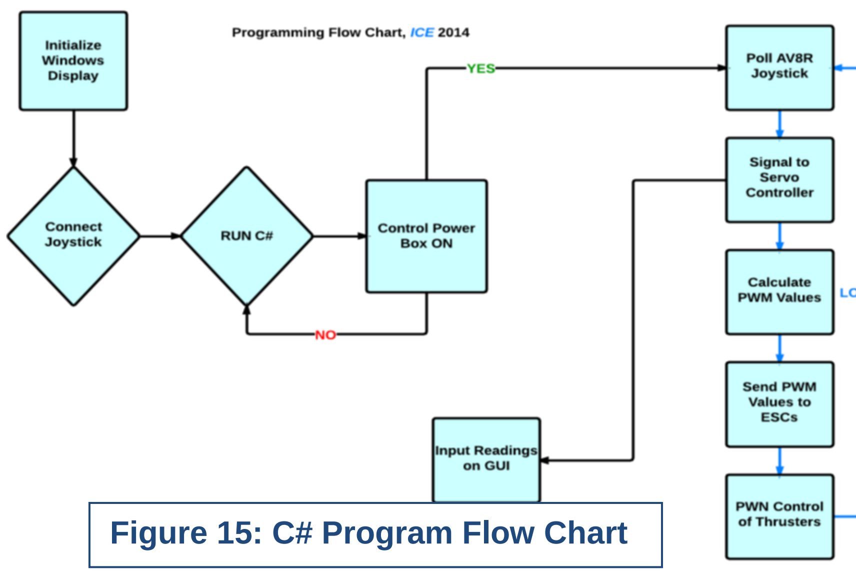


Figure 15: C# Program Flow Chart

Operations:

Forward and reverse thruster operations involve the same values of signal throughout the full range (100-1000) in both Starboard and Port horizontal thrusters.

Mixing the ranges of horizontal thrusters (ex. +500 in the Port and +200 in the Starboard thruster) results in the different speed of the thrusters on either side of the ROV moving in a horizontal forward arc.

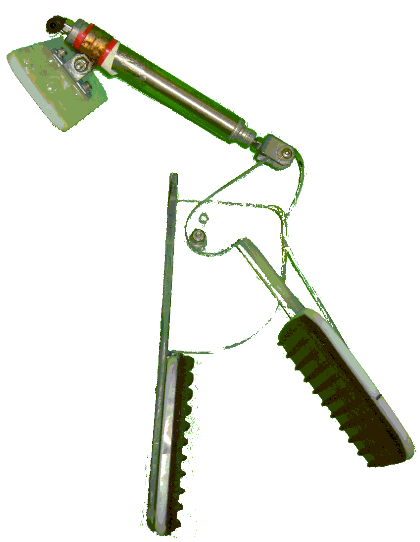
The signal values of -500 in the Port thruster and +500 in the Starboard thruster (from rotating the joystick, results in a rotation of the ROV to Port, within the ROV footprint. Using reverse directions of thrust for the vertical thrusters on either side of the ROV, results in a sway movement, permitting sideways movement in either Port or Starboard direction. This function can be turned off when not required,

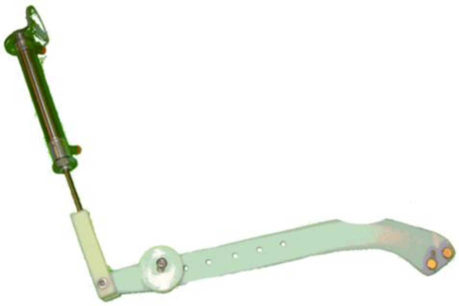
3.7 Payload Tools

To avoid complications with signal distortion from EMF in electronics components and for an increase in safety, our tools actuate using surface-supplied pneumatic air pressure.

Table 6: Payload Tools and Description

Claw 	The "Claw" is a gripper made out of clear and non-transparent Lexan™ claws. Its open and close motion is actuated by a dual action spring loaded pneumatic piston. This tool's fingered grip permits removal of "U-bolts", and a number of required tasks. The claw fingers are cut at a slant to permit holding "hot stabs" at a 45^o angle for ease of insertion.	**Task 1** • Deploy the passive acoustic sensor **Task 2** • Remove the "U-bolts" • Install the well head • Install the hot stab

Bilge Pump  	Our bilge pump is a rule 1100gph bilge pump motor. Its high flow rate serves to effectively complete two tasks. It is powered from the surface using waterproofed cable.	**Task 1** • Collecting the algae sample from under the ice sheet **Task 3** • Pushing water through the pipeline
Clapper 	The 'Clapper' has two flat palms, oriented vertically. One palm is fixed; the other rotates horizontally on a pivot point, closing on the fixed palm. This multi-purpose unit is also fabricated from Lexan™, and is actuated by a third, double- action pneumatic cylinder. The inside faces are covered with studded rubber pads to increase gripping friction.	**Task 1** • Deploying the passive acoustic sensor in the designated area **Task 2** • Installing the gasket in the well head • Capping the Wellhead • Holding the carabineer tool **Task 3** • Holding the valve spinner

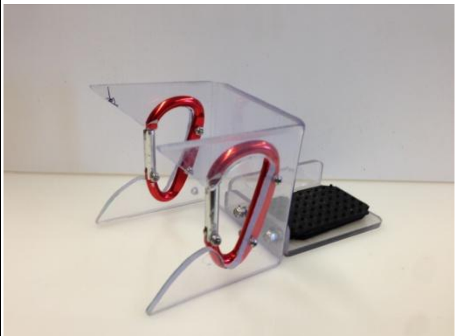
Wand 	The "wand" is an arm made out of Lexan and HDPE. Its 90^{0} vertical arc is actuated by a dual action pneumatic piston. At the end of its arm there is a Lexan™ plate with a piece of Velcro which can be used to carry tools. This offers a strong grip along with quick and easy attachment and detachment.	**Task 1** • Carrying the measuring tape for measuring the iceberg **Task 2** • Carrying the measuring tape for measuring the pipeline

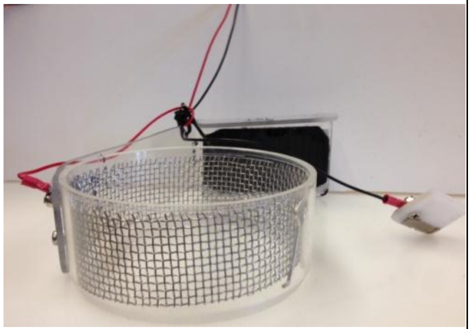
3.8 Attachments

ICE has several attachments, held by our clapper in multiple missions tasks.

Table 7: Attachments and Description

Pipe capper X2 	Our "Pipe Capper" uses a pneumatic piston, located on the inside of a PVC pipe. To push an interior HDPE circular plug which is attached to a circular ring outside PVC ring. The ring in turn pushes the pipe cap onto the open pipe. A spring mechanism keeps the Velcro-coated plug in place during that operation. The next step attaches the Velcro plug to the pipe.	**Task 2** • Installing the two Flange adaptors and bolts on the pipeline

Carabiner tool 	Twin carabineers mounted on a Lexan™ guide to hook onto the identified piece of corroded pipe that is to be removed from the pipeline. The carabineers are modified by replacing the stock springs with weaker ones, so they will operate with the thrust of the ROV. The Carabineer clamp is attached by a line to the surface, which is used to lift the corroded pipe section.	**Task 2** • Attaching the lift line to the section of corroded pipe • Lifting the corroded pipeline section to the surface.
Valve spinner 	This tool uses a waterproof bilge pump motor, attached to a well-lubricated gear-head salvaged from a power screwdriver. The motor is attached to a piece of precision cut and thermoformed Lexan which grips all spokes of the valves, in either direction, and centres the ROV over the valve. Time required for a complete turn is 15 seconds.	**Task 2** • Turning the valve to stop the flow of oil through the corroded pipeline. **Task 3** • Turning the valves to control water flow to the designated pipe.

Voltage meter 	Our voltage meter is a 5 cm length of 15 cm diameter clear Lexan™ tube, which we have lined with a small mesh stainless steel band. Between the mesh and the Lexan tube is a galvanized steel washer. A two-wire cable stretches between the ring and the surface of the water. The positive wire is attached to the stainless steel mesh. The second black wire is attached to a rare earth magnet which is on the outside of the ring and attracted to the steel washer. A handle on the Lexan ring is used to hold it in the gripper.	**Task 3** • Testing the grounding of anodes on well head

4.0 SAFETY

Figure 16: Team member following safety protocols

Safety is always the company's top priority. As we like to say, **"Prepare and prevent, don't repair and repent."** We know that if we do not take precautions, we will have to face the repercussions of our actions. Safety incidences are common among people new to the shop environment. To prevent any accidents from happening, we developed extensive safety protocols for all company activities. Unfortunately, these protocols may be forgotten if people are not familiar with them. One of these unfortunate incidences happened this year. A new member was using the band saw without safety glasses. Fortunately we saw what that member was doing and we stopped him. Although it was only a moment of forgetfulness we had to take it very seriously due to the importance of safety in the shop. That member was required to review and pass the shop safety test, (Appendix B)

During technical sessions, we follow strict safety procedures. These include:

- Prioritizing safety during discussions, displays, and actions
- No loose clothing
- Long hair tied up
- Closed toe footwear
- Safety glasses at all times when in the shop
- Appropriate behavior: no running/horsing around
- Safe materials handling: heavy stock is moved by two or more people
- Instruction and apprenticing for all shop equipment usage

ICE has numerous safety features which assure the safety of the deck crew as well as ***ICE*** itself. These features include thruster cowlings, grates on the thrusters, and curved edges on the ROV frame. Proportional control of the thrusters means that they're not always on full thrust, decreasing the risk of injury. Our use of low-pressure pneumatics is a safe and reliable alternative to electric tools. An air regulator set to 40psi limits pressure in all of the pneumatic components. All of the electrical materials are enclosed within the tether, epoxy potted sub cables, and wet-mateable bulkhead connectors.

When our 12VDC power supply enters the topside electronic box, the first thing it encounters is a 25A circuit breaker switch on the positive cable. This acts as a kill switch for all power to ***ICE*** as well as a fuse to protect the electrical system.

We also have rules of "NO HANDS" when power is on, and "NO POWER" when hands are on. This is strongly emphasized for anyone handling and operating the vehicle. We have a pre-dive checklist that we use before leaving the pit area and before every dive.

5.0 CHALLENGES

5.1 Organizational

OD-4D is fortunate to have such a diverse group of very passionate and devoted members. Having such a dedicated and highly-motivated team produces a strong commitment to the company and to excellence in our products and projects. Many of our staff members are quite talented in other areas: from fine arts to sport. Many others have community- based affiliations such as churches, scouting/guiding, and often to employment. These diverse interests are wonderful pursuits but frequently limited our team member's attendance during critical design and fabrication phases. We collaborated to determine the optimal days for meetings and developed a long-term schedule to which the whole team was committed. As a result, our group members appreciate the importance of teamwork, helping and accommodating the needs of other team members when required, and striving for excellence.

5.2 Technical Issues:

ROV Size: One issue in Mission one is designing our ROV to fit through the 75 cm square hole in the ice. We reduced the frame size of our ROV in order to be able to complete this mission. We also used the opportunity to further streamline our design and reduce drag, which is especially necessary since one task will be performed in a tank with a current.

Water pump: Our bilge pump is used for two tasks, pumping water through a pipeline, and retrieving a sample of algae from the underside of the ice sheet. Our pump did not function properly at the regional competition, which we believed was a result of electronic issues. Further testing identified the issues as an air lock. This issue has been fixed, and the pump will function quite efficiently at the international competition.

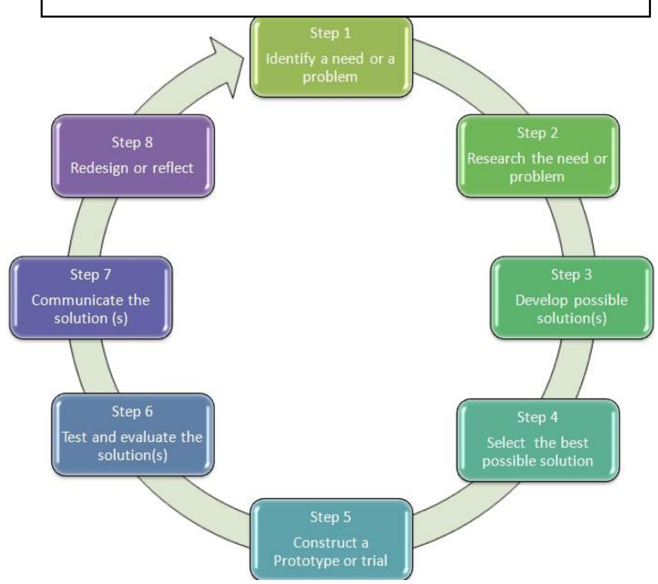
The Tool Crate: Our tool crate required many prototypes, going from a flat tray to a milk crate, to a box made from acrylic. Our crate was intended to be lowered to the bottom with necessary tools and props inside (such as our pipe capper and the hot stab) in order to reduce unnecessary trips to the surface. It was rather top heavy, and unbalanced, making it difficult to retrieve tools and props. Our third re-design produced a weighted platform which holds all needed tools for missions which are easily retrieved by our grippers.

6.0 TROUBLESHOOTING TECHNIQUES

To make troubleshooting go quickly and smoothly we follow the "Circle the Wagons" method. We look at each of our main systems, such as our electronics control box, computer, and co-pilot's console and draw an imaginary box around each. We then examine each input, output, and power conductor, which passes the imaginary boundary, for malfunction.

For example, we have our Electronic Speed Controllers (ESCs) arranged in a logical sequence consistent with the position of the thrusters, so that we can easily trace problems in a single thruster malfunction to a specific ESC.

Figure 17: Troubleshooting process



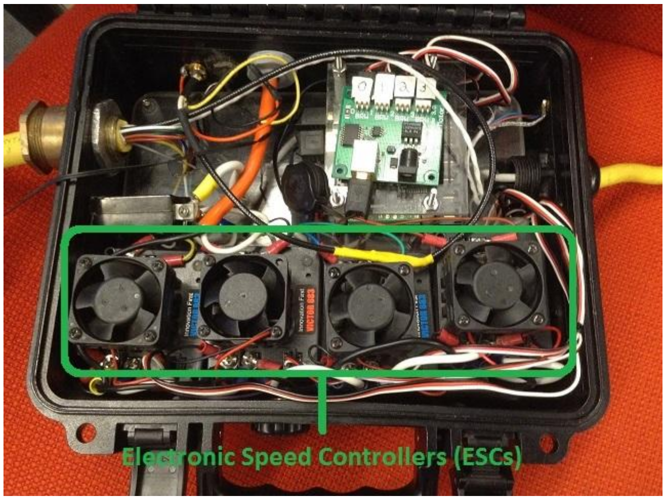


Figure 18: Electronics Control box

In addition to the electronic troubleshooting, the buoyancy of ***ICE*** is continuously changing due to the refinements in tool design; this prompts us to alter the amounts of buoyancy foam and bismuth weights on the ROV, as well as their placements. Our sealed buoyancy tubes have had many design refinements and testing on their own.

Over this year we have developed a series of predictive observations which our deck crew uses for early detection of problems. For example, cloudy video feeds indicate video camera leaks. A non- or poorly responsive thruster suggests blockage or entanglement. Odd noises from pneumatic controls forecast loose connections or valve problems. Fortunately, our experienced deck team has encountered most of the potential difficulties we may face and know how to recognize and correct them.

7.0 VEHICLE SYSTEMS

The vast majority of our components have been designed and built in-house. The basic HDPE frame for ***ICE*** was originally designed using Solidworks™ to be very adaptable to different mission tasks and be easily altered and re-sized. This year, the frame was narrowed to fit the 75 cm square entrance in the ice. Cameras were adjusted for greater visibility and one was replaced due to leaking. Completely new tools were designed and built for this year's mission. Some of them use recycled pneumatic actuators; others required new cylinder actuators of unique bore or stroke length. New components include tools such as the *"Claw", "Pump", "Pipe capper", etc.* which accompany our modified conductivity sensor. Every component was designed, cut and fabricated ourselves. Each tool was modified – multiple times – as trials revealed deficiencies or suggested enhancements.

Other new components such as the electronic components were ordered online from Phidgets Inc. We also purchased our 6 thrusters from Seabotix, and our SS Aqua cams were bought from LCA. A new tether with more advanced capabilities was ordered from Leonic Elocab, Inc. ON, based on our own in-house design.

All tools this year have been purposely built or redesigned for this year's competition. ***ICE'***s frame was redesigned to house new attachments that are directly incorporated into the ROV rather than an extended tool. An extra Lexan™ bracket was added near the bow of the ROV, in order to mount the *"Claw."*

The company has decided to reuse some components from last year only because we found them reliable and best suited for our ROV. The only tools we are reusing this year are the *“Clapper” and “Wand”*; however we have modified them with new attachments. The “Clapper” has proven to be a reliable multitool and the “wand” allows us to use the measuring tape in both horizontal and vertical positions. We are also reusing our basic copilot’s console as the design has been adapted to this year’s mission task requirements.

Our ESC electronics are being reused this year, as they are reliable and expensive to replace. “If it ain’t broke………” However, their signal clarity was tested using an oscilloscope.

8.0 LESSONS LEARNED

The research required for planning this and next year’s ROV exposed the entire staff to a host of new skill sets and materials science. Perhaps the most useful technical skills were those required for the design of components of the ROV using CAD (Solidworks™) and the conversion of these visual products in Master CAM™ to the codes required to operate our CNC router. It is a very powerful tool. We have had visitors from other schools attending this competition come to our school to learn how to use this equipment and to fabricate some of their own ROVs.

However, the most important lessons learned were ***affective*** outcomes, those involving personal growth, which we will carry with us for the rest of our lives. Affective outcomes are those which affect our way of looking at the world; our way of learning or epistemology, and our way of organizing and managing. Examples are as follows:

i. We understand the world as a much larger place with greater diversity of abilities, beliefs and cultures. We have started to realize the enormous opportunities that lie beyond our island shores and also the unique lifestyle and career options within technical fields that are right here at home.

ii. We have learned that learning by the book is but one way, and that the problem solving approach to learning is an excellent preparation for dealing with the issues of an adult world.

iii. We have come to realize that the essential skills of planning and organizing require time and management. This comes into play in other aspects of life as well, specifically for those preparing for post-secondary and future careers.

9.0 FUTURE IMPROVEMENT

The ROV ***ICE*** will always be a work in progress, as the company believes there is always an opportunity for improvement. The OD-4D staff is currently planning several upgrades to the vehicle to enhance its performance. The company plans to integrate on-board electronics. Currently, we have our electronics topside; this means that the ROV loses a percent of the original power as it passes through the tether. However, onboard electronics can minimize this deduction of power. In tandem with the onboard electronics, there is a tentative plan to house a new camera, which will have the ability to tilt about the y-axis to achieve a wider range of vision. Staff members have begun work on a new tether which features Ethernet cables, allowing the company to transmit high definition video from ***ICE'****s* cameras.

10.0 REFLECTIONS

Our company has made many significant accomplishments over the past year. Some of these include our growth as individuals and as a team, the knowledge we have gained and the knowledge we will pass on to future robotics teams, the significant advancements we have made on our ROV, the standards we have met and exceeded, and most notably the opportunity to compete on an international level for the fifth year consecutively. Each of our team members has become more confident since joining our company and we have created a bond that cannot be broken. Our ROV has become quite innovative with our updated tools and with these additions; ROV ***ICE*** is ready to take on each and every task in its way.

11.0 TEAMWORK

During the design, building and testing process, the team met on Wednesday afternoons starting in October. We drafted a development schedule (Appendix A) so that we would stay on track. Extra meetings were scheduled when we found we were falling behind. Weekly group discussions took place to innovate new ideas for every aspect of the ROV: different mission tools, frame and buoyancy, propulsion, electronics, software, etc.

Figure 19: Team members: Technical discussion

We often dispersed into separate groups to achieve goals quickly and efficiently. Each team member was assigned a different role and focus area, which kept our design process and fabrication running smoothly.

Each member became fluent in their area of focus; therefore, tasks such as writing the technical report and effectively communicating during the engineering panel presentation were quite straightforward.

One section of the company focused on the payload tools and overall functionality of the ROV, while the other keyed in on electronics and software. While designing models for our tools and chassis, we used fabrication techniques such as Solidworks, MasterCam and a CNC router. Our software and electronics team, together, learned the 2010 C# program, along with becoming comfortable with our electrical schematics.

12.0 ACKNOWLEDGEMENTS

OD-4D's success would not have been made possible without the continuous support of numerous bodies. Firstly, we would like to thank our parents who proved just how much they truly love us with all their support. Secondly, our mentors deserve just as much thanks; they are always there for us when we need a helping hand. Lastly, we would not have been here today if it was not for the generous support and contributions from a number of companies and organizations, both locally and nationally.

We send thanks to the MATE center of Marine Advanced Technology Education for giving us, as well as many other schools and organizations, the opportunity to compete on an international playing field. The practical skills and knowledge we gained from this experience will stay with each one of us for the rest of our lives. If we do continue on into the fields of ocean science exploration and development, the MATE competition will be our launching platform into this fascinating career.

12.1 Financial Contributors and Donations in Kind

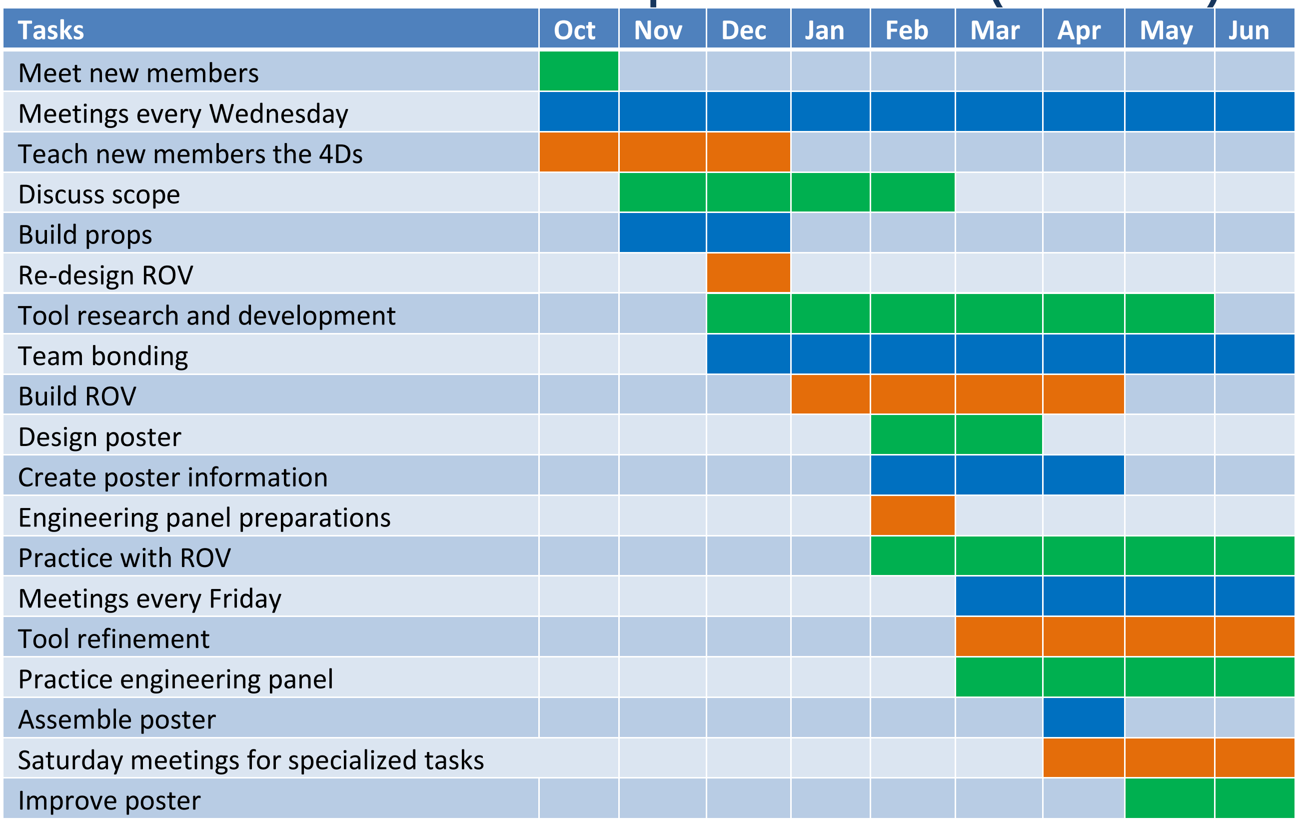
Table 8: Contributors and Supporters

Contributor	Type
Business, Innovation, Trade and Rural Development (NL)	**Financial**
Exxon Mobil	**Financial**
Statoil	**Financial**
Phidgets Inc. , Calgary, AB	**Donation (Electronics)**
SeaCon Branter, Santa Barbara, CA	**Donation (U/W Connectors)**
Thomas Glass, Mt. Pearl, NL	**Discount (Plastics)**
Eastern School District, St. John's, NL	**Facilities (School)**
Marine Institute, MUN, St. John's, NL	**Facilities (Test tank)**
Ocean Quest Adventures, CBS, NL	**Facilities (Test tank)**

13.0 REFERENCES

www.bimba.com
www.marinetech.org
www.seabotix.com
wolfcs.net/ssaquacam.php
Anderson, T. (2004). C# in Easy Steps. United Kingdom: Computer Step.

APPENDIX A: OD-4D Development Schedule (2014-2015)



APPENDIX B: ROV Operations Safety Check List

Pre-mission preparations:

- All fasteners are tested and tightened
- All pneumatic hoses are inserted in pistons
- Check for leaks
- Pneumatic tank is filled to specified limit
- Regulator is set to allowable limit
- Pneumatic connectors to tank match Control Panel
- Electrical power available for cameras
- All electrical cords available
- Charge computers fully
- All video cords available
- Safety Check sheet available
- Pre-dive check list available
- Mission Plan sheet available
- Timer available
- Safety equipment available:
  - safety glasses
  - *fluorescent* vests and life jackets
- Remove loose clothing.
- Tie up long hair.
- Check operations of all tools
- Check operations of all thrusters

ROV Team In-transit:

- Use a wheeled cart
- Secure equipment on wheeled cart
- Wear safety vests for visibility.
- Wear Safety Glasses at all times
- A team member is ***"Safety Point"***