O'Donel High School

Design, Develop, Demonstrate, Deploy

Mount Pearl, Newfoundland and Labrador, Canada

OD-4D STAFF

NO.	NAME	POSITION	ROLES
1	Christian Samson	**Chief Executive Officer**	**Management Fabrication**
2	Victoria Hynes	**Chief Financial Officer**	**Deck Management**
3	Sarah White	**V.P. Communications**	**Corporate Media Relations**
4	Elizabeth Tuck	Technical Writer	Human Resources & Research
5	Stephen Chislett	Technician	Tool Design & Research
6	Emily Wiseman	Graphic Designer	Lead Graphic & Visual Design
7	Jonathan Pike	Technician	Tool Fabrication & Testing
8	Kaitlin Genge	Fabrication Technician	Tool Fabrication & Testing
9	Rafael Sánchez Bravo	Fabrication Manager	Lead Tool Design & Fabrication
10	Chris Stacey	CAD Technician	Design & Modeling
11	Quinn Whalen	Tether Manager	Tether Management
12	Michael Howse	Safety Officer	Training & Monitoring
13	Riley Fancey	Technician	Tool Design & Fabrication

EXTERNAL ADVISORS: James Hickman, Joseph Santos, Laura Matchim

Figure 1: OD-4D

Not In Photo:
Sarah White

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 scientific and archeological research and conservation requirements of the Thunder Bay National Marine Sanctuary (TBNMS). ***ICE*** performs three major Mission Tasks, involving seventeen separate activities, within a 15-minute time- frame on an Ocean Observatory, as follows:

Task #1: SHIPWRECKS
Explore, document, and identify an unknown shipwreck recently discovered in sanctuary waters.

Task #2: SCIENCE
Collect microbial samples, measure the conductivity of the groundwater emerging from a sinkhole, replace a sensor array and estimate the population of zebra mussels found on the shipwreck.

Task #3: CONSERVATION
Remove trash and debris from the shipwreck and surrounding area.

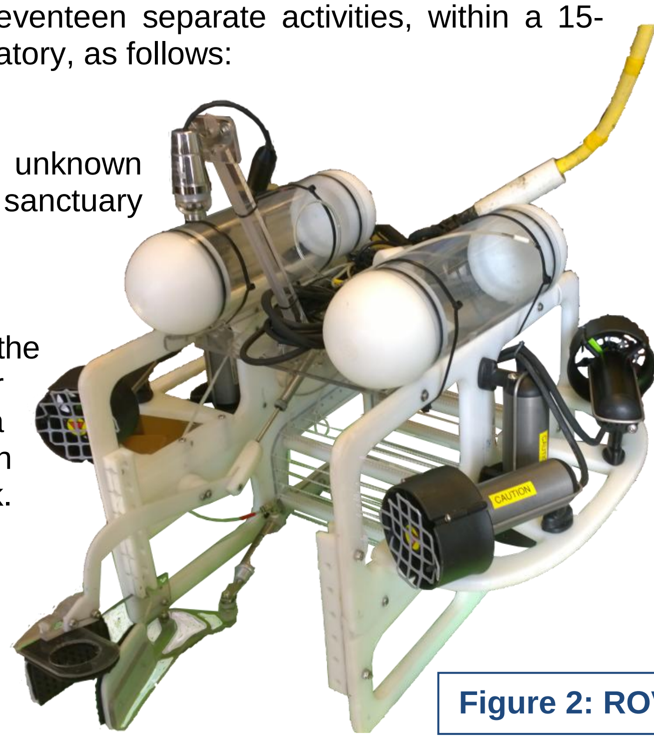

Figure 2: ROV ICE

ICE has the following features:
i. Two-section, high density polyethylene (HDPE) frame featuring a detachable tool skid, protective thruster brackets
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. Video-cameras providing tool and navigation views;
vi. Mission-specific, highly effective pneumatic and mechanical tools.

In practice trials, ***ICE*** has completed all mission tasks efficiently. We look forward to demonstrating the capabilities of ***ICE*** at imminent trials in Alpena, Michigan, June 26-28, 2014.

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1.0 FINANCIAL DATA

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

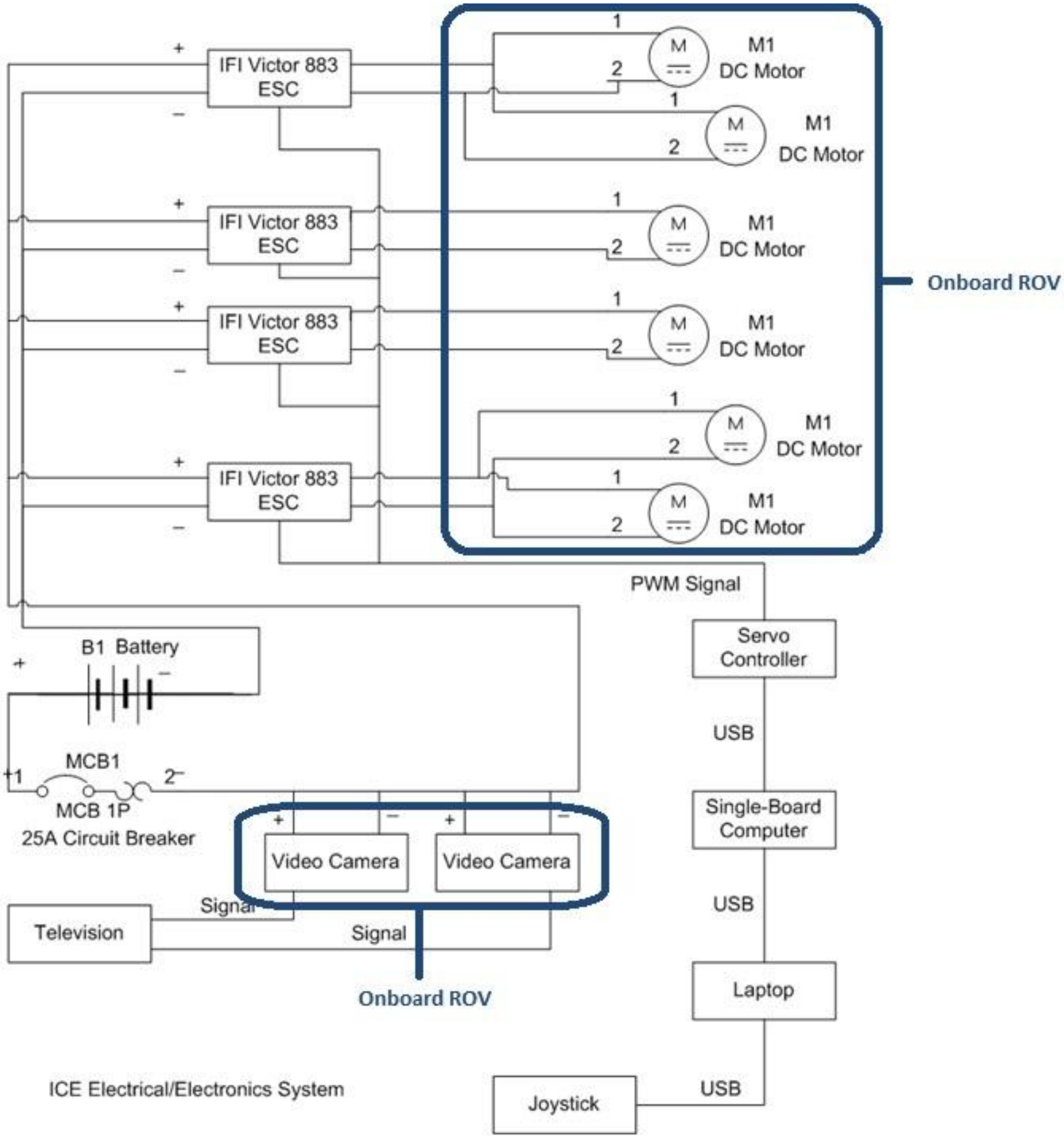
ITEM	BUDGET ($US)	DONATION ($US)	EXPENSES ($US)
MATERIALS and COMPONENTS			
Topside electronics: ESCs, servo controls	1350.00	1350.00	
Inuktun™ Inc. video-camera	1200.00	1200.00	
Tether - Leoni Elocab Inc.	250.00		250.00
Seabotix™ BTD-150 brushed thrusters (six)	3390.00		3390.00
Pneumatic pistons, valves, fittings and tube	463.00		463.00
Lexan™ buoyancy tubes (5”) & end caps	129.00		129.00
High Density Polyethylene (4’x8’x0.5”)	220.00		220.00
SS Aquacam™ composite video-camera (two)	980.00	490.00	490.00
Joystick (USB)	76.00		76.00
Fasteners, drill & CNC bits, glues.	70.00		70.00
Mentor PC Netbook PC used as PLC.	699.00	699.00	0.00
SeaCon Brantner “*WetMate*™” connectors	1600.00		1600.00
TRAVEL			
Group airfare (15 people x $837) *est.*	12812.00		12812.00
Accommodations (15 people X five nights)	3357.36		3357.36
Van Rental and Fuel (six days)	1350.00		1350.00
Meals: (15p x 6d x $30) *est.*	2730.00		2730.00
TOTAL EXPENSES	**$30,676.36**	**$3,739.00**	***$26,937.36**

*The ROV components were purchased over a 3-year period. Travel is for 2014 only

Table 2: Contributions to OD-4D

CONTRIBUTORS	VALUE ($US)
Private & Gov’t of Newfoundland and Labrador (NL) sources. (Materials)	$ 750.00
Private & Gov’t of NL via Marine Institute, MUN (Regional Winner)	$ 15,000.00
Funds earned by team members	$ 6,000.00
Individual contributions (13 people @ $400.00 each)	$ 5,200.00
TOTAL Contributions	$ 26,950.00
TOTAL Expenses	$ 26,937.36
BALANCE (for materials and components for 2014 competitions)	**$ 12.64**

2.0 SYSTEM INTEGRATION DIAGRAM



3.0 DESIGN RATIONAL

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. From this experience, a set of precise design specifications are developed. These are later used as the “gold standard” by which to measure the effectiveness of all ROV systems and payload tools.

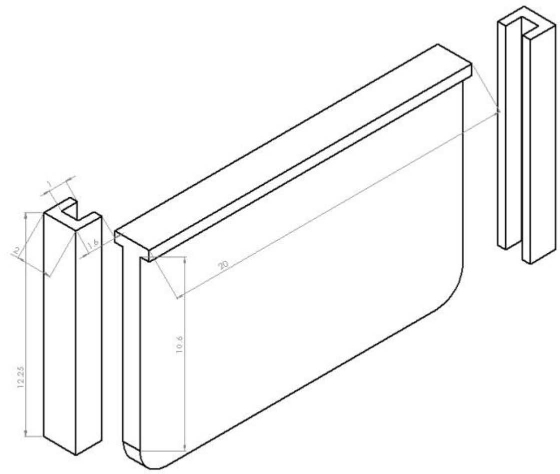


Figure 3: The *“Guillotine”* Solidworks^{TM} mechanical drawing

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.

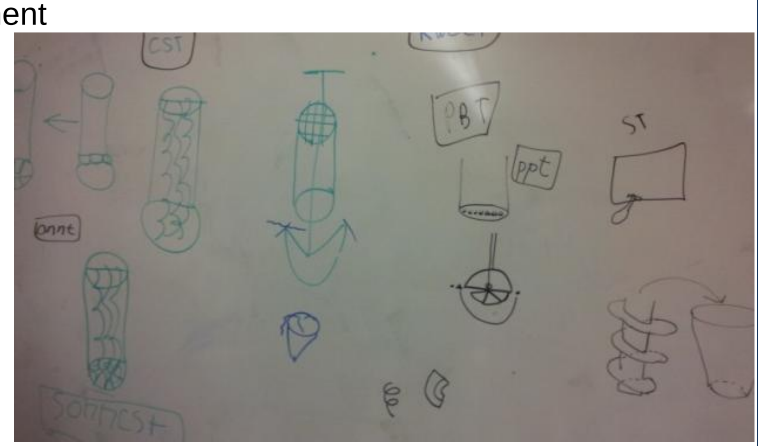


Figure 4: Drawing board concepts

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.

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) for a 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 L x 33cm W, x 32 cm H.

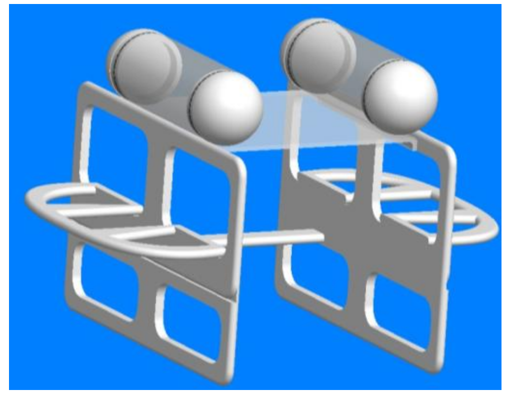


Figure 5: *ICE*'s frame and buoyancy

ROV Frame Specifications:

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

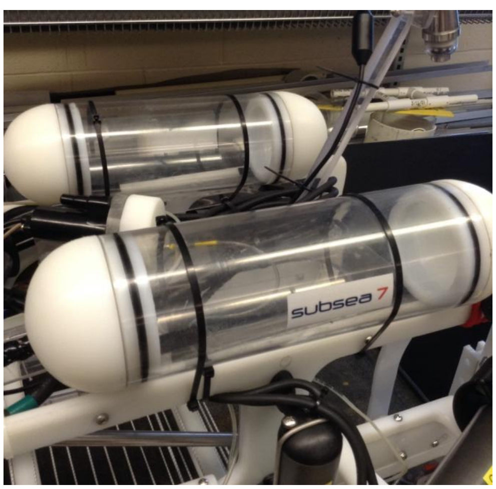


Figure 6: *ICE*'s *3" Lexan™* tube buoyancy chambers.

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. The different lengths accommodate and balance tool mass on each side of the ROV

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 in line with the forward axis of the ROV and do not contain any electronics, however they have this potential in future designs. These sealed tubes have been pressure-tested at 2 ATM (202.65 kilopascals) for one hour without detectable leaking.

3.2 Propulsion

ROV ***ICE*** is propelled by six *Seabotix™* BTD-150 thrusters. This is the second year OD-4D has used these; last year being the first time 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.

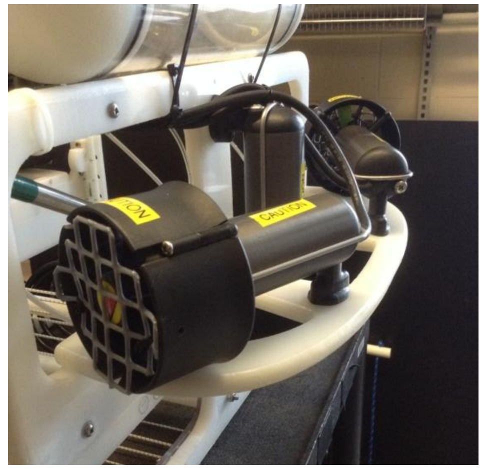


Figure 7: BTD150 Thrusters

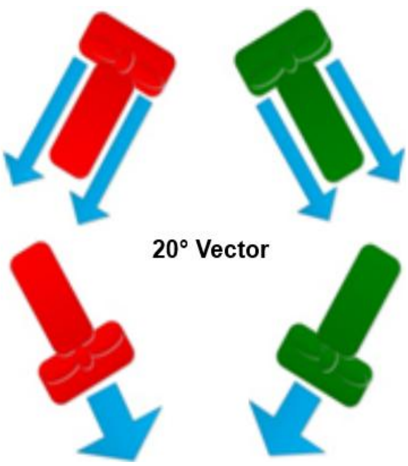


Figure 8: Thruster action in Surge motion

The propeller is a twin blade, 70mm in diameter. The motors are configured as 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 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

All manually-operated controls on ***ICE*** are pneumatically actuated. Our earlier efforts at electrical actuation met with disaster. Fluid power was chosen as the safest and most reliable and efficient option, since is uses a 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.

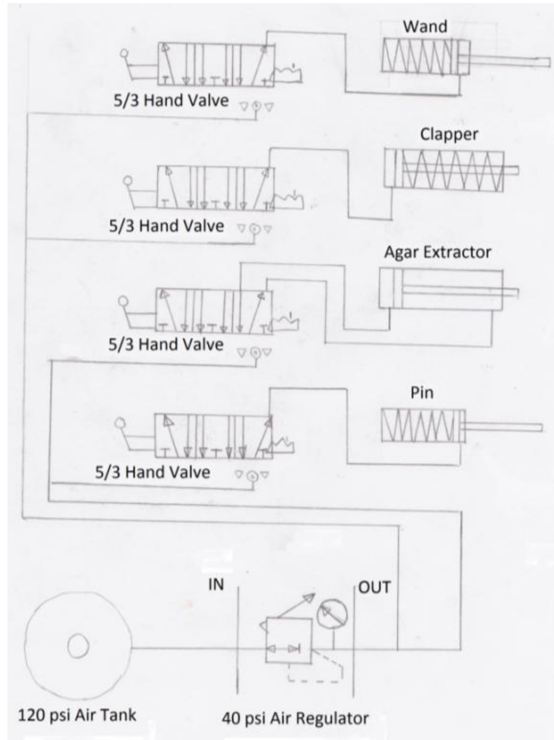


Figure 9: Pneumatic Schematic

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 *"Agar Extractor"*

ii. one, single-action, spring-loaded pneumatic cylinder which acts as a pin to latch the science tool array in position on the ROV

iii. one, single-action, spring-actuated cylinder to close a vertical palm gripper.

iv. one, single-action, spring-actuated cylinder to actuate the *"Wand"* for securing the dinner plate relic during retrieval.

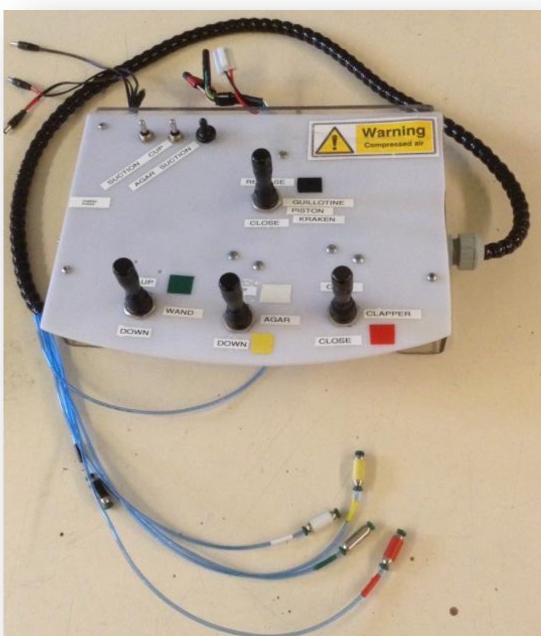


Figure 10: Pneumatic Control Panel

3.4 Sensors

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.

Figure 11: SS AquaCam™

- 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

3.4.1 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 *"Agar Extractor"* and *"Clapper"*. The Nav-Cam is accompanied with frame capture software to take photographs of the shipwreck. Through these photos we can efficiently measure the dimensions of the shipwreck.

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, It provides a photo used for shipwreck dimensioning and mussel population sampling in a 50cm ID quadrat. By integrating views from both cameras, pilots can simulate depth perceptions in 3-D space.

3.4.3 Salinity Sensor

The ICM water analyzer is a multi-meter which determines water temperature, pH, oxygen concentration and conductivity. The sensor probe for this instrument is attached to a detachable science tool plate mounted on the bow of the ROV called the "*Guillotine".* This instrument allows us to identify salt *and* fresh water. It measures the conductivity of water surrounding the sensor in micro (μ) and m (milli-) Siemens. This instrument is calibrated to be used with 15 m (50') of cable. Its range of conductivity is 0-999.9 uS/cm, with an accuracy of 3% FS.

Figure 12: ICM™ Water Analvzer

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.

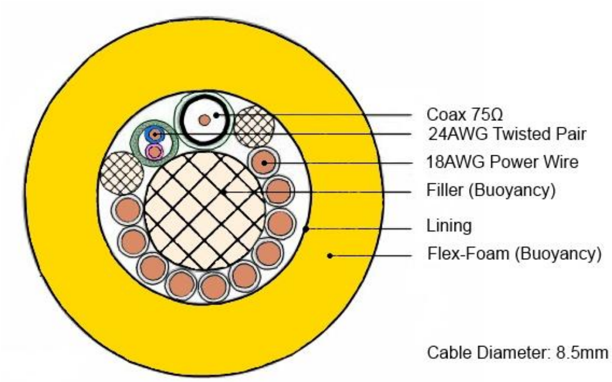


Figure 13: Primary Tether Components

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	Video signal: video camera to the surface

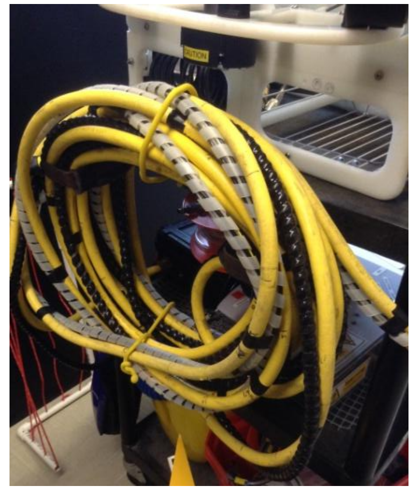


Figure 14: Tether (Primary yellow, Secondary white/black)

3.5.2 Secondary Tether

In the Secondary tether, there are:

- two small video camera cables
- one pair of electrical wires (not used this year)
- five (5) 2 mm ID, 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.

Table 4: Secondary Tether Components

Type of conductor	Number of Wires	Size	Function
Power wires	2	AWG 18	Accessory Power to waterproof tool motors.
Pneumatic Hoses	5	2 mm ID 1723 kP	Fluid power to onboard actuators
Camera cables including shielded video & power cables	2	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 four 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, 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 such as DirectX. Stock MS.NET programming in C# for the USB joystick we used was a compiled program from MS DirectX. 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.

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.

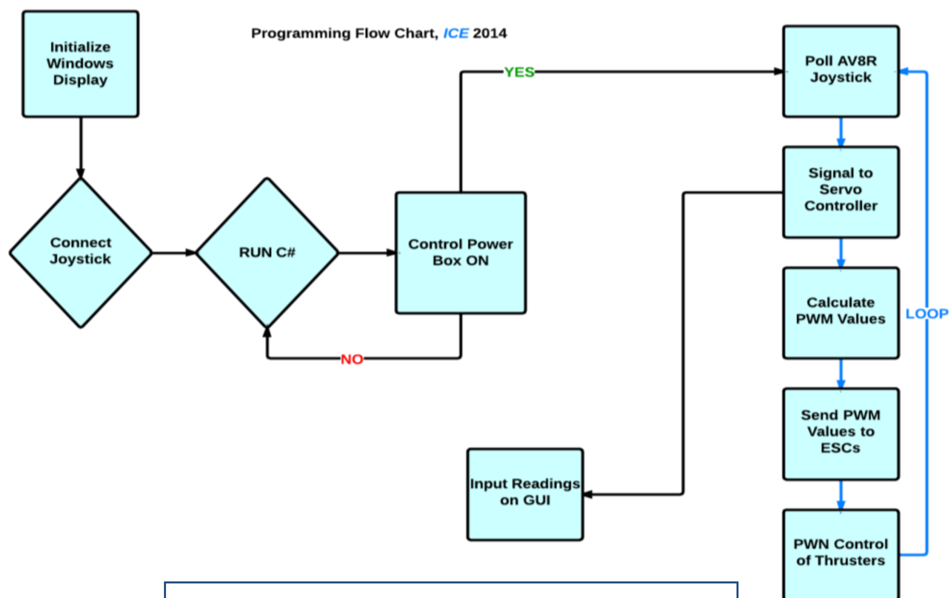


Figure 15: C# Program Flow Chart

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

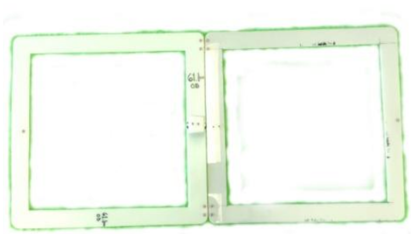
To avoid complications with electronics and for an increase in safety, our tools actuate using surface-supplied pneumatic air pressure.

Table 6: Payload Tools and Description

TOOL	Description
Agar Extractor 	A clear Lexan™ pipe is actuated via pneumatic piston to penetrate the microbial mat in a vertical motion. At the same time, a miniature, 12V bilge pump is activated from a surface switch. The combination of the rapid downward movement and suction penetrates and sucks the Lexan™ tube into the agar. The continued suction retains the ager after extraction and a plastic toothed fringe around the collar of the tool, retains it during transport to the surface. After this task and the conductivity sampling are complete, the Lexan™ panel on which both are mounted is released from the ROV and floats to the surface where it is retrieved and the contents extracted.
Colmillo 	An ICM water analyzer with a "*Colmillo*" (Spanish for "fang") made from PVC pipe is used to penetrate the cellophane plastic that covers the Solo™ cups. The water analyzer can accurately measure which cup holds salt water with its salinity sensor. The *"Colmillo"* is designed so that it cannot cut or damage human skin or pool walls.
Bungee Net 	A long, 1/8" diameter bungee cord is strung through small holes in an HDPE frame, located near the stern of the ROV. When the ROV lands on the debris bottles, the downward force pushes them into the net, where they remain until the ROV surfaces.

Suction Cup 	The *"Suction Cup"* is located underneath the *"Clapper"*. The *"Suction Cup"* has a small hole drilled though it's top which holds a small pneumatic tube. The tube feeds into a second miniature, 12V bilge pump, which creates significant suction. This tool is a back-up tool for collecting the ceramic plate.
Clapper 	The *"Clapper"* is our primary gripping tool. It 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 second, single-action normally-closed, pneumatic cylinder. The inside faces are covered with studded rubber pads to increase gripping friction. The *"Clapper'*s" first task is to place the *"Carabineer"* onto the mast debris; then used to place the *"Quadrat"* on the shipwreck. It also allows us to open and close the cargo container, recover the old sensor string and position the new one with ease and pick up any debris bottles in the event the *"Bungee Net"* malfunctions.
Wand 	The *"Wand"* is a white Lexan™ arm attached to the inner starboard side of the ROV. It is actuated by a single action pneumatic cylinder which permits vertical movement. At the end of the Lexan™ arm there is a flat piece of Lexan™ coved with a studded rubber pad. When the *"Wand"* is lowered onto the top edge of the *"Clapper"* the downward pressure and rubber grip allow the retrieval of the ceramic plate.

3.8 Attachments

Great Crate 	The "*Great Crate*" is a weighted basket which is used to transport the "*Quadrat"* and the new Sensor array to the bottom and bring the two debris bottles, ceramic plate and the old sensor array, to surface so it can be retrieved by the deck crew. The "*Great Crate*" is made of polyethylene. A HDPE bracket, designed to transport the "*Quadrat"* to the bottom, is attached on one side. This unit surfaces under control of the ROV, assisted by inflating a lift bag.
Carabineer 	The "*Carabineer*" is used for removing the mast debris blocking the ship's entrance as the first task of the mission. This tool was modified to enable the ROV's modest thrust force to attach it to the mast debris. This was achieved by replacing the stock spring which closes the "*Carabineer*" with a weaker one. Finally, a Lexan™ bracket was designed so that the "*Carabineer*" could be carried down by the *"Clapper".* The *"Carabineer"* is attached by a rope to the *"Great Crate"* so that when the *"Great Crate"* returns to the surface, the mast debris is brought with it.
Guillotine 	The "*Guillotine*" is a clear Lexan™ plate which slides into two channels on either side of the ROV at its bow. It acts as a detachable science tool plate with the *"Agar Extractor"* and the Salinity Sensor attached. The "*Guillotine*" is locked into place by a pneumatic cylinder shaft which, when withdrawn, releases the unit from the ROV. It can then surface and be retrieved by the connecting power cable and pneumatic supply, clearing the ROV for to perform subsequent tasks. The *"Guillotine"* was designed to be slightly buoyant in freshwater.
Quadrat 	Our "*Quadrat"* is also a multi-purpose attachment. Its enclosed open square area is precisely 50 cm x 50 cm (0.25 m^2) and is used to visually sample the zebra mussel population. Its external dimensions are 61.1 cm on all sides, which is used as a known standard to permit photogrammetric measurements of the shipwreck. . The *"Quadrat"* is made up of two materials: floating HDPE and sinking Lexan™. To ensure its correct orientation when in use we use bismuth weights as ballast.

4.0 SAFETY

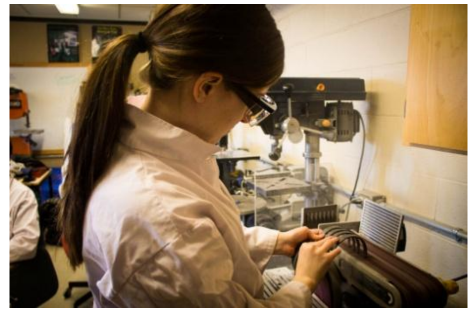


Figure 16: Team member following safety protocols

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. 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 not allowed to use tools for a week and had to memorize our safety checklist. (Apendix B)

During tool development 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

4.1 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, filling in when needed.

4.2 Technical

Guillotine: Our early testing revealed that the Guillotine was quite heavy and unbalanced the ROV. Foam buoyancy was added to make it neutrally buoyant, which stabilized the whole unit.

Agar: The "*Agar Extractor"* went through several prototypes and modifications before it achieved its current efficiency. The unit initially could not penetrate thick agar, so a saw-tooth edge was cut into the perimeter of the collection tube. Weeks of experiments finally revealed that simply turning on the suction pump before penetrating the agar sucked the whole unit to the bottom of the agar cup. It was a "*Eureka*" moment. We now routinely collect 170-225 ml per mission.

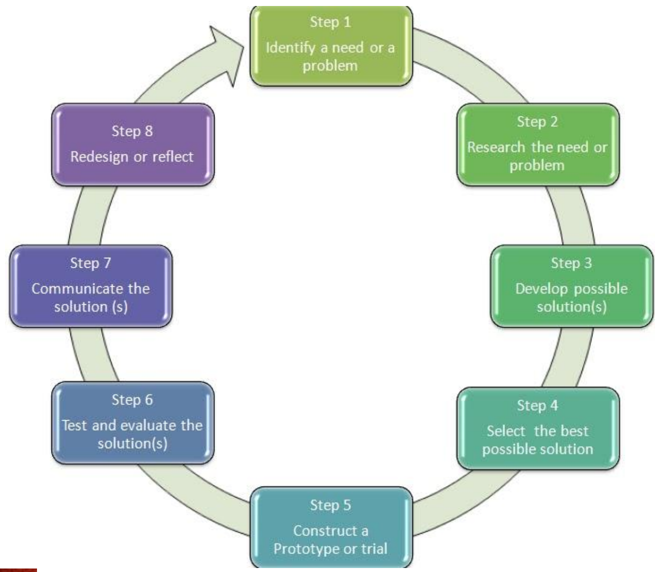
Shipwreck dimensions: We also found that the accuracy of photogrammetry in measuring the shipwrecks was highly variable. This technique involves frame capture from our composite video cameras, measuring pixel length of ship dimensions against a known length and simple ratio calculations. Extensive experimentation indicated that the most important factor causing the variation was the angle at which the photographs were taken. We concluded that photographs must be taken at as close to 90^{o} to the surface as possible for high accuracy estimates. Pilot practicing and coordination with our Science Officer refined this technique to the point where accuracy is less than 2 cm using these methods. A number of other ROV and tool design refinements resulted from extensive testing and practicing the mission task performances.

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



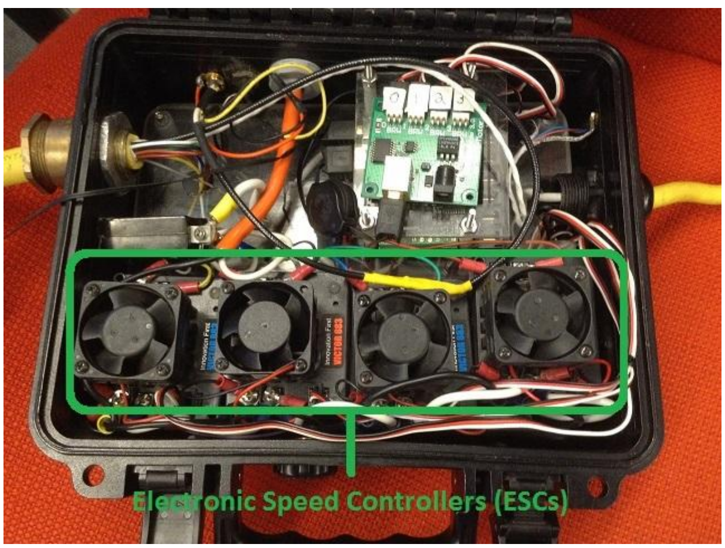


Figure 18: Electronics Control box

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 60 cm minimum opening in the shipwreck. 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 *"Clapper"*, *"Guillotine"*, *"Agar Extractor"* and the *"Colmillo"* 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 purpose 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. Two extra Lexan™ brackets were added on both starboard and port sides near the bow of the ROV, in order to mount the *"Guillotine".* The stern of the ROV was re-engineered to incorporate the *"bungee net".*

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 tool we are reusing this year is the *"Clapper"*; however we have modified it with new attachments. This is because we found that we needed a reliable multi tool, and the "Clapper" has proven to be just that. 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………"

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.

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 a 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 fourth 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 during a group 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.

10.1 Financial Contributors and Donations in Kind

Table 7: 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 (2013-2014)

Tasks	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Meet new members	■								
Meetings every Wednesday	■	■	■	■	■	■	■	■	■
Teach new members the 4Ds	■	■	■						
Discuss scope		■	■	■	■				
Build props		■	■						
Re-design ROV			■						
Tool research and development			■	■	■	■	■	■	
Team bonding			■	■	■	■	■	■	■
Build ROV				■	■	■	■		
Design poster					■	■			
Create poster information					■	■	■		
Engineering panel preparations					■				
Practice with ROV					■	■	■	■	■
Meetings every Friday						■	■	■	■
Tool refinement						■	■	■	■
Practice engineering panel						■	■	■	■
Assemble poster							■		
Saturday meetings for specialized tasks							■	■	■
Improve poster								■	■

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"***