O'Donel High School

Mount Pearl, Newfoundland and Labrador, Canada

OD-4D STAFF

NO.	NAME	POSITION	ROLES
1	Connor Whalen	**Chief Executive Officer**	**Management Fabrication**
2	Kristen Marks	**Chief Financial Officer**	**Deck Management**
3	Erin Matthews	**V.P. Communications**	**Corporate Media Relations**
4	Lauren Hayes	Manager	Human Resources
5	Ashley Hunter	Technician	Tool Design & Fabrication
6	Victoria Hynes	Technical Writer	Technical Report Coordination
7	Jonathan Pike	Technician	Tool Design & Fabrication
8	Christian Samson	Manager	Media Outreach
9	Alexia Spencer	Software Manager	Software Design & Testing
10	Chris Stacey	CAD Technician	Design and Modeling
11	Quinn Whalen	Technician	Tool Design & Fabrication
12	Sarah White	Safety Officer	Training & Monitoring

COMPANY DIRECTORS: Jim Hickman, Joseph Santos

Not In Photo: Chris Stacey

ABSTRACT

OD-4D is a subsidiary of O'Donel High School, Mount Pearl, Newfoundland, Canada. OD-4D undertakes technology development and fabrication in the underwater environment. This Technical Report documents the design and testing of our most recent project in aquatic robotics, the work class Remotely Operated Vehicle (ROV) ***ICE***.

ROV ***ICE*** is purpose-built for the deployment and maintenance of equipment required for the operation of Ocean Observatories. ***ICE***, can perform the four (4) major Mission Tasks, involving twenty-three (23) separate activities, within a 15-minute mission on an Ocean Observatory, as follows:

TASK 1. Activate a Backbone Interface Assembly for an Ocean Observatory.

TASK 2. Acquire a time-series of temperature data from a subsea hydrothermal vent.

TASK 3. Replace an Acoustic Doppler Current Profiler (ADCP) on a mid-water mooring platform.

TASK 4. Remove bio-fouling organisms from an array of five instrument packages associated with the Ocean Observatory.

Figure 1: ROV ***ICE***

ICE has:

i. a novel, 2-section, high density polyethylene (HDPE) frame, (a flying frame section and a detachable tool skid);
ii. moveable and expandable buoyancy for trim adjustment with payloads of different weights;
iii. six Seabotix™ BD-150 brushed thrusters (vectored at 20^{o} from the forward axis);
iv. topside electronics for variable speed and precision maneuverability in 3 axes;
v. multiple video-cameras providing tool and navigation views;
vi. novel, mission-specific, pneumatic tools with demonstrated effectiveness.

In practice trials, ***ICE*** has completed all mission tasks in a time of 11 minutes 15 seconds. We look forward to demonstrating the capabilities of ***ICE*** at the upcoming trials in Washington, USA.

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1.0 FINANCIAL DATA FOR PROJECT

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 (6)	3390.00		3390.00
Pneumatic pistons, valves, fittings and tube	463.00		463.00
Lexan™ buoyancy tubes (5”) & end caps	89.00		89.00
High Density Polyethylene (4’x8’x0.5”)	220.00		220.00
SS Aquacam™ video-camera (2)	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.	399.00	399.00	
SeaCon Brantner “*WetMate*™” connectors	1600.00		1600.00
TRAVEL			
Group airfare (13 people x $1000.00) *est.*	13000.00		13000.00
Accommodations (13 people)	4860.00		4860.00
Van Rental and Fuel (6 days)	638.00		638.00
Meals: (13p x 6d x $35) *est.*	2730.00		2730.00
TOTAL	$31,315.00	$3,439.00	*$27,876.00

*The ROV components were purchased over a 2-year period. Travel is for 2013 only

Table 2: Contributions to OD-4D

CONTRIBUTORS	VALUE ($US)
Private & Gov’t of Newfoundland and Labrador (NL) (Materials)	$ 750.00
Private & Gov’t of NL via Marine Institute, MUN (Regional Winner)	$ 17,500.00
Funds earned by team members	$ 4,200.00
Individual contributions (13 people @ $500.00 each)	$ 5,500.00
TOTAL Contributions	$27,950.00
TOTAL Expenses	$27,876.00
Balance (for materials and components for 2013 competitions)	$ 74.00

2.0 DESIGN RATIONALE

The design process for ROV ***ICE*** follows the classic procedure illustrated in Figure 2. This process always starts with gaining a complete understanding of the mission tasks provided by the client in January 2013. It included having company staff research the mission tasks and constraints, analyzing the mission requirements, and building the mission props. From this experience, a set of precise design specifications was developed. These are later used as the “gold standard” by which to measure the effectiveness of all ROV systems and payload tools.

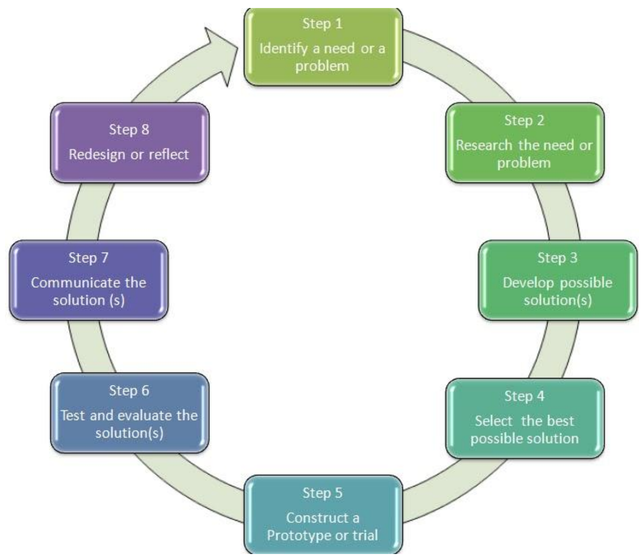


Figure 2: Design Process

This analysis produced the following list of Design Specifications:

i. Small size to maneuver around well-head structures;
ii. Adequate carrying capacity for Mission Task items onboard the ROV;
iii. Capable of multi-axis movement (5-axis: surge, roll, yaw, sway, heave);
iv. Capable of low-speed precision movement;
v. A variety of specialized tools for efficient task performance;
vi. Multiple video-camera views to see a number of tool operations;.
vii. Combining task completion in multi-function tools to save space;
viii. Adequate thruster force to lift Mission Task items
ix. Simple, intuitive control of the operations of ROV and payload tools.

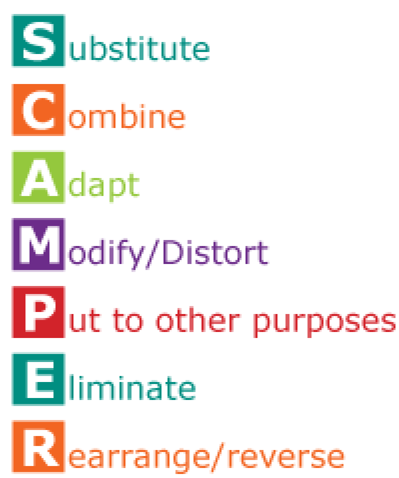


Figure 3: Scamper Process

During the subsequent meetings, we brainstormed multiple design solution ideas. SCAMPER (Fig. 3) methods were used to forge the early ideas into firm designs, which were sketched, scaled and later drawn in a Solidworks™ CAD design program.

These design specifications guided the whole rational process of OD-4D; **D**esign, **D**evelopment, **D**emonstration and mission task testing (**D**eployment).

The design process is cyclical. As new information emerges from testing, refinements in design are made. Sometimes, radical shifts in technology are adopted to improve the ROV or the payload tools it carries. One of the tools (the pneumatic claw c.f. pg. 11) has undergone 5 iterations, some minor, others significant.

2.1 Vehicle Systems

2.1.1 Frame and Buoyancy

ICE's frame has been engineered around our design specifications, having an open bottomed, box-shaped frame, fabricated from four pieces of 9.5 mm (1/2") HDPE (high density polyethylene) and a piece of 1.5mm (1/4") Lexan™. The modular frame permits adjustments in height in accordance with mission requirements and is also easily transported when disassembled. Frame size is 48 cm L x 33cm W, x 32 cm H. This durable, easily cut and heat bendable material affords:

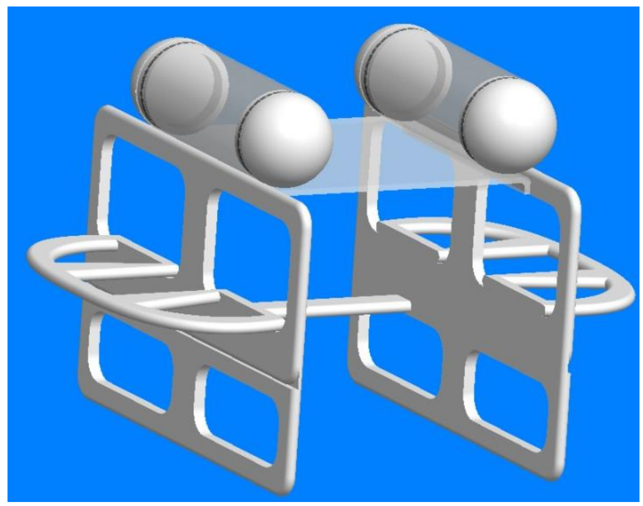


Figure 4: ***ICE***'s frame and buoyancy

i. The center is transparent and permits camera vision through it
ii. Access for ambient lighting within the frame
iii. A large area for attachment of thrusters, cameras and payload tools
iv. A small profile to reduce drag in forward and vertical movements
v. A low density ($\rho = 0.95 g/cm^3$)

The frame was designed in SolidWorks™ 3-D CAD and converted to G-code in Master CAM, for cutting on our Red Cam™ CNC Router. It accommodates the vectored thrusters and has an abundance of space for all tools. Buoyancy is achieved through the use of two hydrodynamic torpedo shaped Lexan™ air chambers (10 cm x 22 cm), each enclosing about 1.35 liters of air, are enclosed on each end by plugs CNC lathed from HDPE (high density polyethylene). The plugs have O-ring groves which seal the cylindrical end of the plug and the Lexan™ 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 for one hour without detectable leaking.

2.1.2 Propulsion

ROV ***ICE*** is propelled by six *Seabotix™* BTD150 thrusters. (http://www.seabotix.com) This is the first time in a decade we have purchased thrusters rather than fabricated our own. 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, which transmit electricity to the electromagnets inside the motors, which creates an additional 40% thrust than our fabricated motors. The propeller itself is 70mm in diameter.

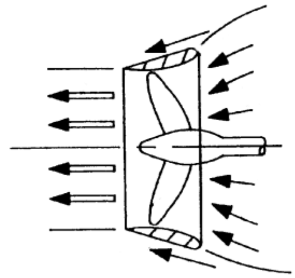


Figure 5: Kort Nozzle

The motors are configured as below (see table 3). They are mounted in two horizontal pairs vectored 20 degrees from the forward axis. This configuration allows for maximum precision with the ROV's maneuverability, as well as swift turning. There are two additional, individually powered vertical thrusters which are mounted on both the port and starboard side mid-ship.

Figure 6: BTD150 Thruster

Each thruster uses 9N of thrust. They have max amperage of 5.8A for 30 second duration; however, they use 4.25A during continual usage. They receive 13.5 volts, but have an optimal voltage of 19 volts. Each thruster weighs 350g in freshwater and 705g in air. Each thruster has a depth reading of 150m. They have a peak bollard thrust of 0.91kgm and a continual bollard thrust of 0.69kgm.

Table 3: Thruster Configuration

Port Side	Starboard Side
2 Horizontal Thrusters, fore and aft	2 Horizontal Thrusters, fore and aft
1 Vertical Thruster, mid-ship	1 Vertical Thruster, mid-ship

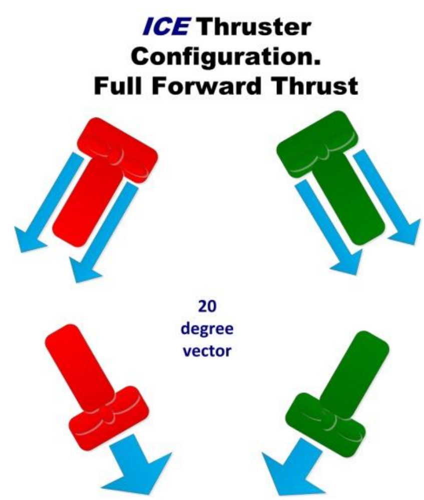


Figure 7: Thruster Configuration

2.1.3 Pneumatics

All manually operated controls on ***ICE*** are pneumatic.

Our source of air pressure is a 150psi rated air tank that is filled prior to launch. A regulator limits air output to 40psi to comply with safety standards. This output goes directly into the co-pilot's console and powers ***ICE***'s onboard tools.

Four pneumatic valves are installed in the co-pilot's console, in correlation to the tool's positions on ***ICE***. Each pneumatic valve admits pressurized air into tiny 1/16" ID tubes. We have one double-acting pneumatic cylinder that is powered by a pair of pneumatic tubes and three single-acting, spring-loaded actuators each powered by one pneumatic tube. (http://www.bimba.com)

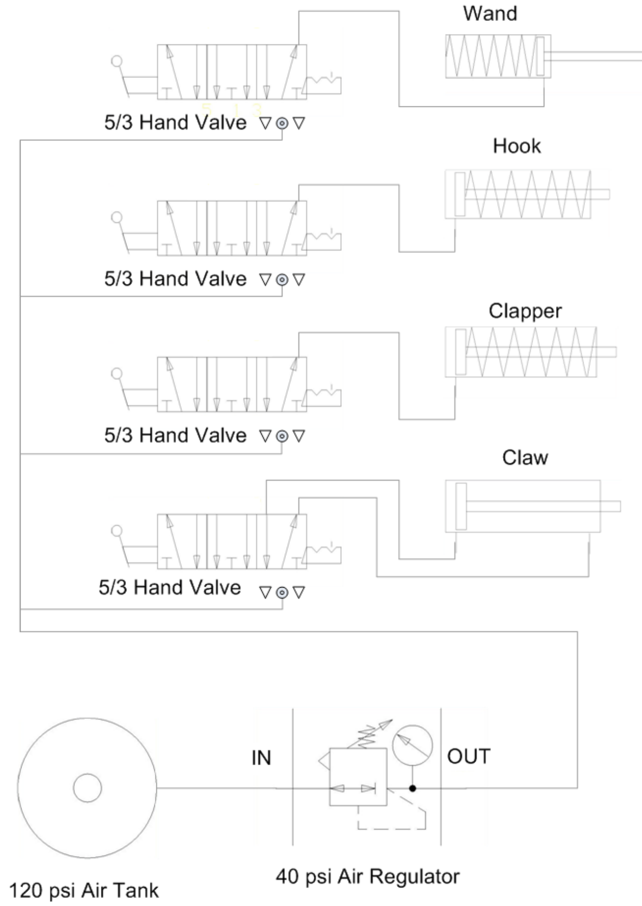


Figure 8: Pneumatic Schematic

Figure 9: Bimba™ Pneumatic Cylinder

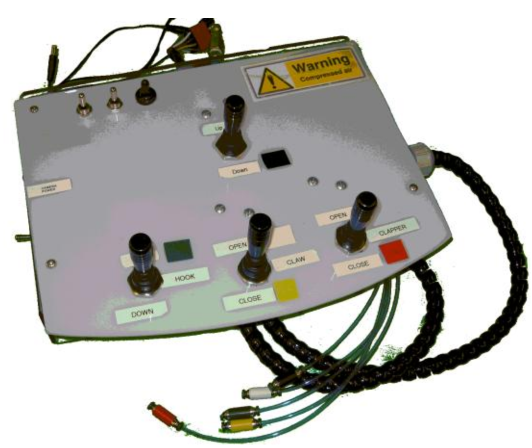


Figure 10: Pneumatic Control Panel

2.1.4 Video Cameras

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 and clear vision.

Figure 11: SS AquaCam™

-Sony 1/3" Super HAD CCD
-540 TV Lines Resolution
-3.6mm Lens
-8 White LEDs
-92° field view in air, 75° in water
(http://wolfcs.net/ssaquacam.php)

2.1.4.1 Nav-Cam

One SS-AquaCam™ underwater camera is located on the inside of the ROV's HDPE frame. This is a pivotal position for viewing all tools, as well as completing mission tasks with the utmost efficiency.

2.1.4.2 Downward-Cam

This SS-AquaCam™ is mounted on a 28cm Lexan™ bracket. This allows ***ICE*** to perform tasks such as lowering the SIA into the BIA and working with the ADCPs. With the use of the Nav-Cam in conjunction with the Downward-Cam, we have perfect depth perception.

2.1.5 Tether

Our tether is securely attached to the ROV by a number of Seacon-Brantner™ wet-mateable, in-line connectors for the thrusters. Nylon cable ties secure the tether to the ROV. We have two tether elements combined into a single unit with waterproof tape along its length. 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 in a "figure 8" 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 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.

2.1.5.1 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 tether minimizes drag and instability of the ROV.

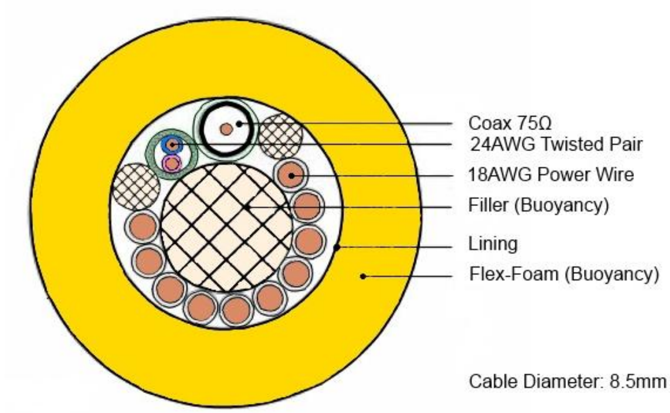


Figure 12: Primary Tether Components

Table 4: Primary Tether components.

Type of conductor	Number of wires	Size	Function
Power wires	8 (4 pairs)	AWG 18	Power to four thruster pairs
Power wires	2 (1 pair)	AWG 18	(UNUSED) Power to onboard water-proof can
Shielded pair	2 (1 pair)	AWG 22	(UNUSED) Serial signals to Onboard Can
Coax cable (shielded)	1	75 Ω	Video signal to the surface

2.1.5.2 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.

These components 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 5: Secondary Tether Components

Type of conductor	Number of Wires	Size	Function
Power wires	2	AWG 18	Power to video-cameras
Pneumatic Hoses	5	2 mm ID	Pressure to on-board actuators
Coax cable (shielded)	1	75 Ω	Video signal from cams

2.1.6 Electrical and Electronics

2.1.6.1 Topside Control Electronics

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

The topside output of this software is a USB signal, which when input to our Phidgets™ 4-port servo 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 6: 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 move ROV Stbd. or Port
Throttle toggle (HEAVE)	Analog Proportional	*Phidgets*™ 4-servo controller	Vert. Thrusters up/ down

2.1.6.2 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, C# is not taught in schools in our region and we had to learn most of it on our own. We learned C# through printed manuals and on-line tutorials. (C# in easy steps, Anderson) 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*** V3 are those derived from the joystick. The signal range in all axes is between -1000 and +1000 and a dead band was set to eliminate overly sensitive joystick movements.

Output 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 an 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.

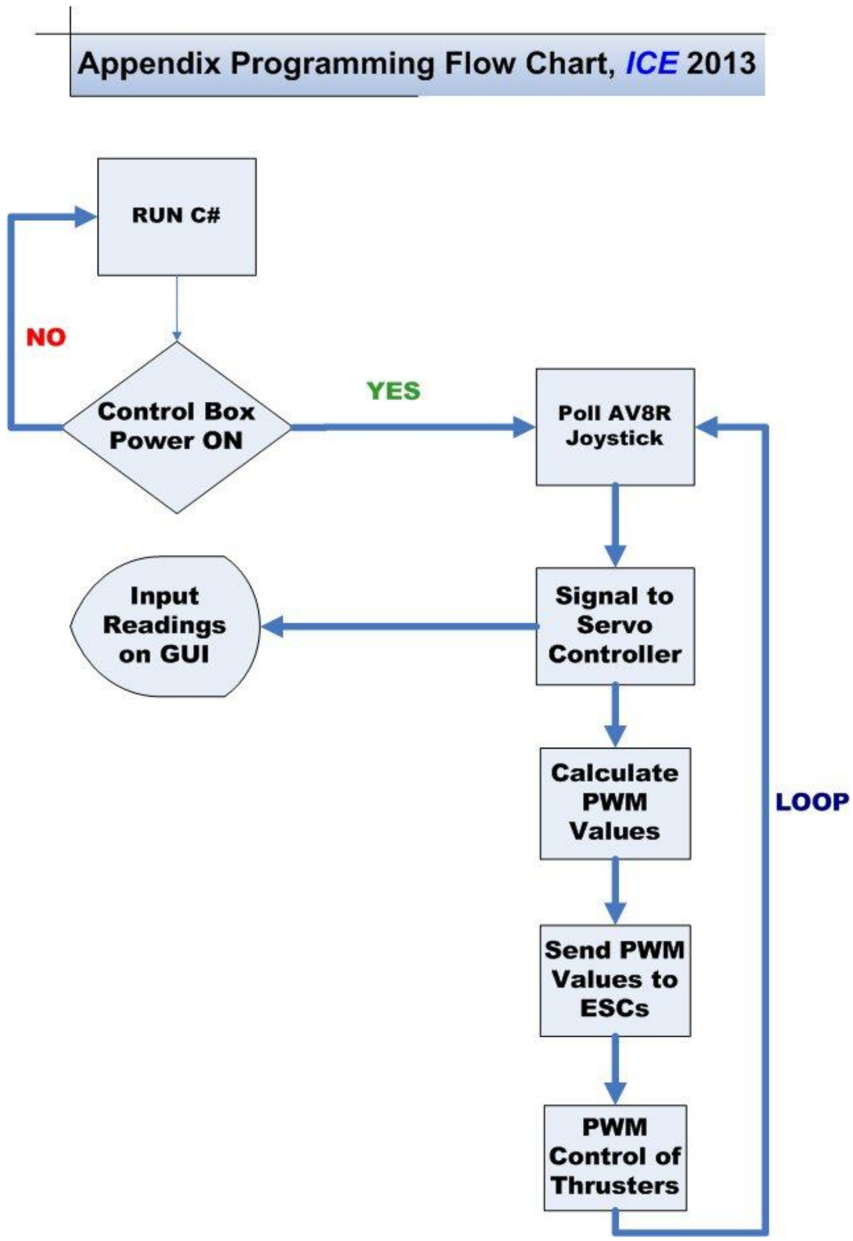
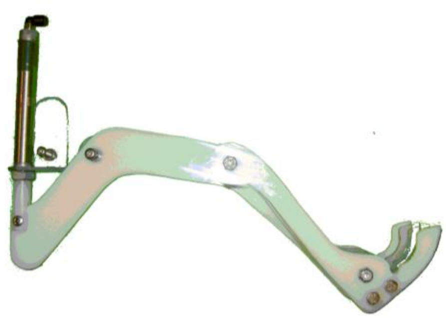
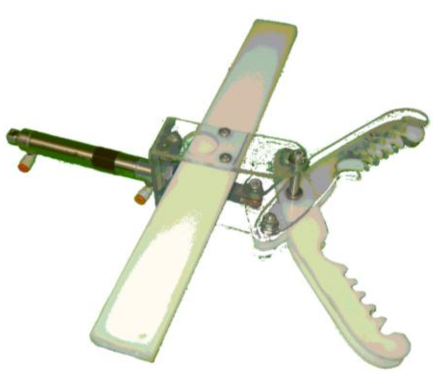


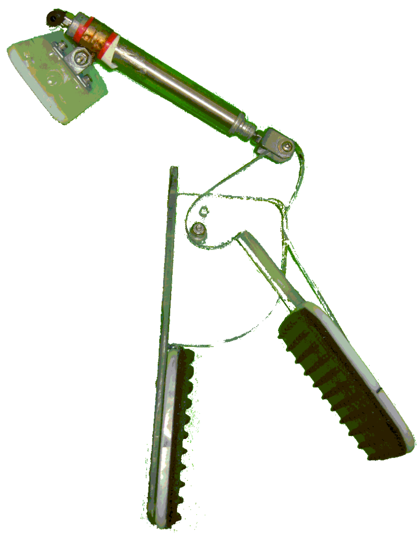
Figure 13: Programming Flow Chart

2.1.7 Payload Tools

Purpose-built tools were uniquely designed for the tasks in the 2013 mission. With limited space onboard the ROV and the desire to keep ***ICE*** simple; our tools were designed for multiple functions. To avoid complications with electronics and for an increase in safety, our tools actuate using surface-supplied pneumatic air pressure.

Table 7: Payload Tools and Description

TOOL	Description	Tasks performed
Hook 	The hook is actually a multiple hook tool, shaped to grasp, lift and hold a number of items. It is fabricated from Lexan™ in clear and white colour to aid visibility of and through the tool. It is pivoted on a bolt and moved vertically by actuating a pneumatic cylinder.	**Task 1.** • Deploying the OBS **Task 3** • Open and close hatch • Lift/replace ADCP • Turn handle, 2 ways • Pick up/orient CTA **Task 4** • Remove bio-fouling
Claw 	The claw is a pair of toothed jaws, fabricated with clear Lexan™. The jaws rotate horizontally from a pivot point to an open angle of 120^o, using a pneumatic cylinder, though simple levers.	**Task 1** • Moving the SIA • Moving the OBS (optional) **Task 2** • Picking up the old ADCP **Task 3** • Turn handle to close

Clapper 	The clapper has two flat palms, oriented vertically with the inside faces covered with studded rubber pads. 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 pneumatic cylinder.	**Task 1** • Grasping/inserting CTA • Pulling pin from Elevator • Opening door of BIA • Retrieving & inserting OBS connector **Task 2** • Deploy Temp. Sensor **Task 3** • Remove/replace CTA • Pick up ADCP /bottom • Close hatch **Task 4** • Remove bio-fouling
Wand 	The wand accompanies the clapper. The wand is a HDPE rod with three rare earth magnets embedded within and is actuated by a fourth pneumatic cylinder.	**Task 1** • Used to help the clapper pick up the CTA when it falls over **Task 3** • Used to help the clapper pick up the CTA when it falls over

3.0 SAFETY

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.

We have developed extensive safety protocols for all company activities. Our safety checklist is provided in our appendices.

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 with multiple operations occurring in the shop
- Appropriate behavior: no running/horsing around
- Safe materials handling: long or heavy stock is moved by 2+ people; use trolleys
- Instruction and apprenticing for all shop equipment usage (power tool, heating, etc.)
- Hazardous or toxic chemicals removed from shop permanently

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 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.

4.0 CHALLENGES

4.1 Organizational

OD-4D is fortunate to have such a diverse group of very compassionate and devoted members to work on company projects. Having such a committed and well driven team resulted in strong commitment to not only the company, but also to their personal projects such as individual volunteer endeavors throughout the community. Unfortunately, this involvement had the tendency to prolong our design process. Attendance at meetings would dwindle due to prior commitments which proved to be challenging. Through the use of a pre-planned schedule, planning software (MS Project) and the use of online communications which involved a weekly report including future projects, we were able to work with the teams various schedules. As a result, our group members learned the importance of teamwork.

4.2 Technical

Right out of the gates, the team had to find a solution to the failure of the onboard waterproof can, which was used to select which signals to send up to the surface from the camera. This proved to be challenged, but also beneficial. The flooding of the can destroyed all electronics. The solution was to simplify all electronics. During the process, we found the simpler layout of electronics proved more reliable. This year the company experienced difficulty with creating an efficient means of picking up the CTA bulkhead connectors. We designed at least five prototypes before we established that our magnetic Wand positioned over the Clapper was the most efficient method.

5.0 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 ESCs arranged in a logical sequence consistent with the position of the thrusters, so that we can easily trace problems in a single thruster to a specific ESC.

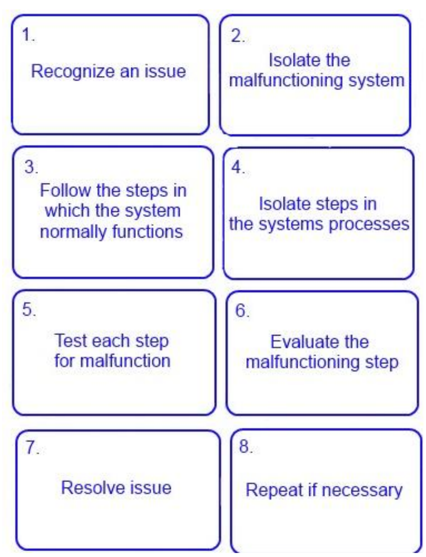


Figure 14: Troubleshooting Method

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.

Our thrusters have been repeatedly tested in 4m fresh water and 7m ocean water without any detectable failure. They have also been tested at numerous vectoring arrangements for finding the perfect angle for the desired thrust.

6.0 FUTURE IMPROVEMENT

6.1 Technical

Our major technical goal is to move electronic controls onboard the ROV These electronics will be fitted inside a waterproof Lexan™ box, and mated with a new tether containing and two 14AWG power cables, one 75Ω coax cable and an ethernet cable. There are many advantages, including: more power to the thrusters and motors, options for more sensors and actuating motors, and programming for some simple autonomous controls.

6.2 Organizational

We would like to implement two initiatives:

- an active recruitment of incoming students, and
- more extensive use of project planning and management methods (e.g. MS Project)

7.0 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, 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 amount of 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 closer to realizing the value of the Chinese proverb: “What I hear, I forget; what I see, I remember; what I do, I understand.”

iii. We have come to realize that the essential skills of planning and organization require time and resource management as the foundation for success in our postsecondary academic life and in our future careers.

8.0 REFLECTIONS

As a company we have learned and accomplished a lot as a result of our participation in this year’s ROV competition. Unlike last year, our company only took on four new members. Most of our time was spent refining issues from last year and brainstorming new ideas. As a team we all worked together to educate the new members to bring them up to speed with our process.

The members of our company’s deck crew, both old and new, gained experience while operating under time restraints. This allowed our deck crew to feel the pressure of competition. We were able to evaluate how we worked as a team under high stress situations.

What we also accomplished, from rigorous practice, was a strong engineering panel presentation where we received a near perfect score. Every member played a crucial role in the presentation on an individual level. However, we were also able to show the ability of the company’s teamwork through the panel under more casual circumstances, during the Q&A session of the presentation. This proved that we all knew a basic overview of the ROV, but specialized in certain sections. We are also very proud of our mission score. Our company came 2nd in the mission out of 20 teams in our region. The most important thing our company has gained from a judged evaluation is confidence! We’ve discovered that our practice has really paid off and that if we continue to practice we will do just as well, if not better, in our future endeavors.

9.0 TEAMWORK

During the design, building and testing process, the team met on Wednesday afternoons starting in October, as well as extra days when more work was needed to be done. We took part in weekly group discussions to innovate new ideas for every aspect of the ROV: different mission tools, frame and buoyancy, propulsion, electronics, software, etc.

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 speaking during the Engineering Panel were very 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 2008 C# program, along with becoming comfortable with our electrical schematics.

10.0 ACKNOWLEDGEMENTS

We would like to thank the following contributors and individuals for their contributions. Without their support we would have been unable to participate in this year's MATE competition and our ROV would not be of the caliber that it is today. A special thanks to the Eastern School District of Newfoundland and Labrador for the use of their facilities and mentor guidance.

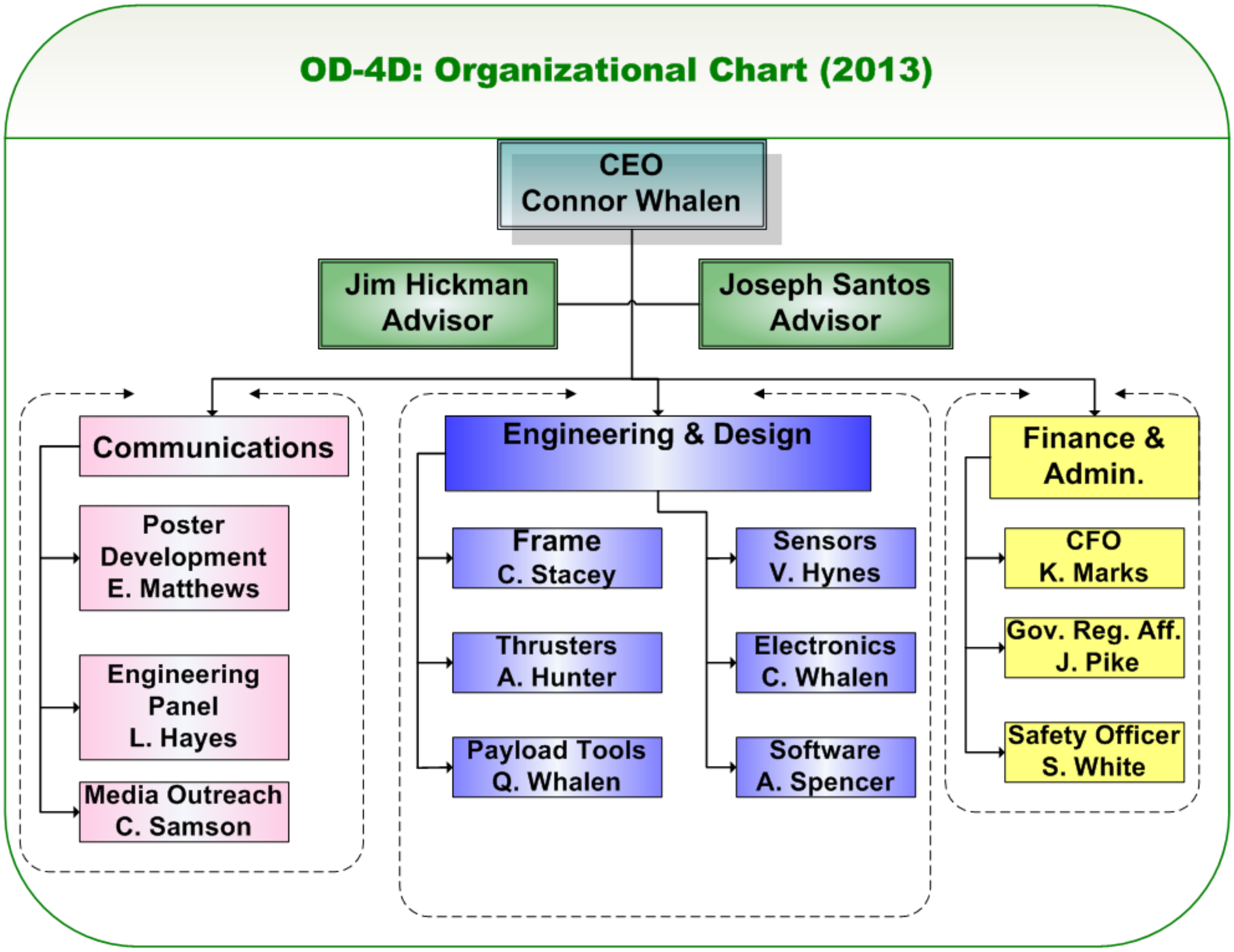
10.1 Financial Contributors and Donations in Kind

Table 7: Financial Contributors

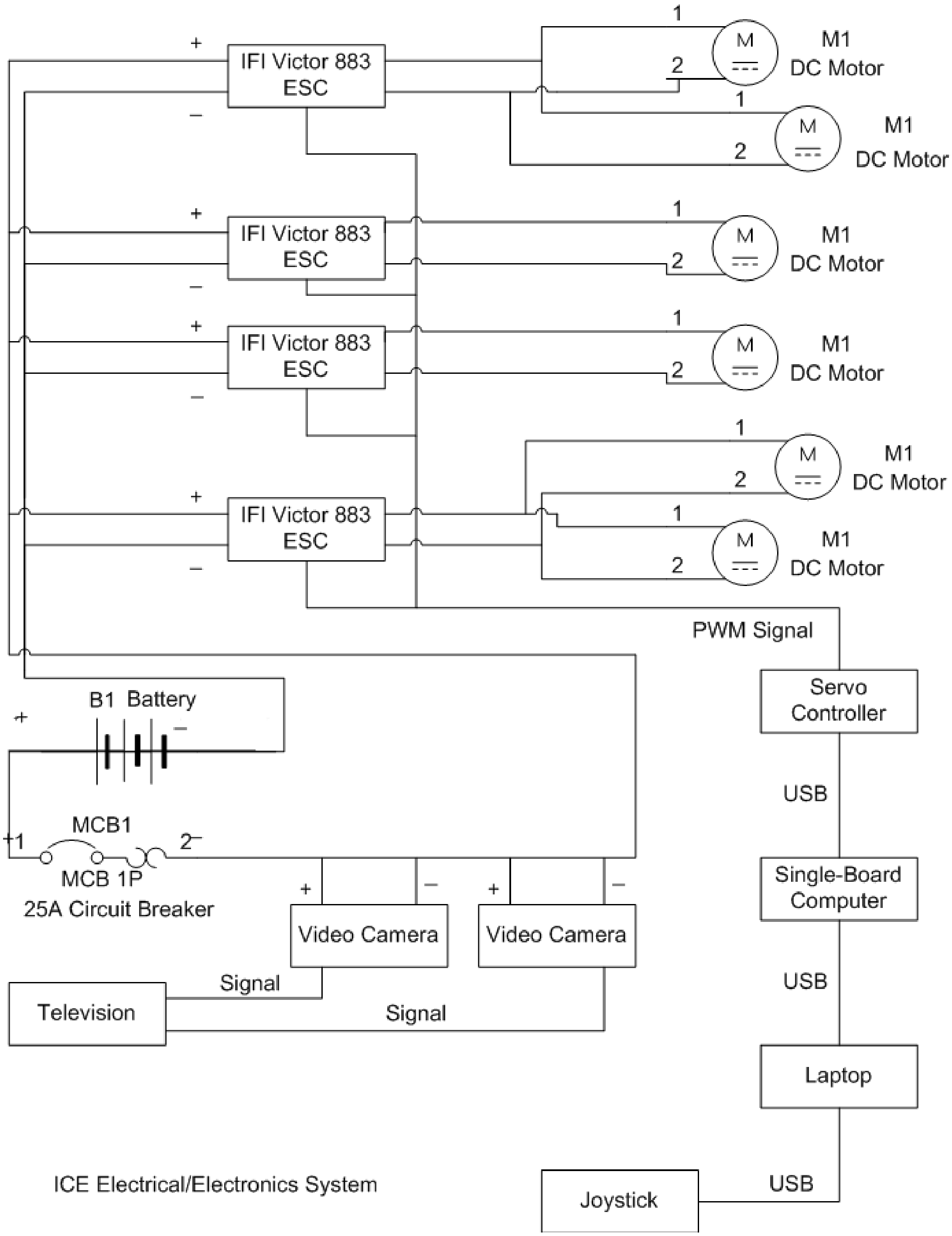
Contributor	Type
Business, Innovation, Trade and Rural Development (NL)	**Financial**
Exxon Mobil	**Financial**
Statoil	**Financial**
Phidgets Inc. , Calgary, AB	**Donation (Electronics)**
SeaCon Branter, Santa Barbara, CA	**Donation (U/W Connectors)**
Thomas Glass, Mt. Pearl, NL	**Discount (Plastics)**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

APPENDICES

Appendix 1. OD-4D Organizational Chart



Appendix 2. ROV ICE Electrical Lay-out



APPENDIX 3. Safety Protocol

SAFETY PROTOCOL for OD-4D SHOP and ROV OPERATIONS

Revised, January 30, 2013

SHOP OPERATIONS CHECK LIST:

Safety Procedures during shop operations include:

- ✓ Safety a priority in discussions, displays and actions.
- ✓ No loose clothing
- ✓ Long hair tied up
- ✓ Closed toe footwear
- ✓ Safety glasses at all times since multiple activities occurring in shop.
- ✓ Appropriate behavior: no running or horsing around
- ✓ Safe materials handling: long or heavy stock moved by 2+ people; use trolleys
- ✓ Instruction and apprenticing for all shop equipment usage (power tools, heating, etc.)
- ✓ Hazardous or toxic chemicals removed from lab permanently.

OD-4D ROV OPERATIONS SAFETY CHECK LIST:

Safety procedures during ROV Operations

Pre-mission preparations:

- ❑ All fasteners are tested and tightened as required
- ❑ All pneumatic hoses are inserted in pistons.
- ❑ Check for leaks (listen and moisten with soapy water)
- ❑ Pneumatic tank is filled to specified limit (120 psi)
- ❑ Regulator is set to allowable limit (40 psi)
- ❑ Pneumatic connectors to tank match the Control Panel
- ❑ Control Panel electrical power available for cameras

- ❑ All electrical cords available
- ❑ Charge computers fully
- ❑ All video cords available (check requirements for TVs on deck)
- ❑ Safety Check sheet available to show to Referees
- ❑ Mission Plan sheet available
- ❑ Pre-dive check list sheet available on clipboard.
- ❑ Timer(s) available
- ❑ Safety equipment available:
  - i. safety glasses for all deck personnel crew
  - ii. *fluorescent* vests and life jackets for standing crew.
- ❑ Remove loose clothing.
- ❑ Tie up long hair.
- ❑ Check operations of all tools (notice any loosening of components)
- ❑ Check operations of all thrusters

Operational safety procedures: ROV Team In-transit:

- ❑ Use a wheeled cart for moving the ROV and auxiliary equipment
- ❑ Place equipment on wheeled cart in a secure way
- ❑ Put on safety vests for visibility.
- ❑ Wear Safety Glasses at all times
- ❑ Select a team member as ***"Safety Point"*** when the Deck Team procession moves, to ensure clear passage and avoid collisions with other teams, open doors, remove debris from trolley path, etc.
- ❑ Identify roles of Deck Team members during ***in-transit*** operations

Pre-Dive Check List:

Safety First:

- ❑ Mobile (standing) Deck Crew put on PFDs
- ❑ Wear Safety Glasses
- ❑ Remove loose clothing
- ❑ Tie up long hair
- ❑ Place ROV in secure location on deck

DECK HANDS and DECK MANAGER

- ❑ Unwrap tether and extend along the pool deck.
- ❑ Check for NO TWISTS!
- ❑ Prepare SIA, Temperature Probe and ADCP for insertion on ROV
- ❑ Start Computer program for Temperature Recording
- ❑ Insert these items into the ROV when pneumatics are operating.
- ❑ Prepare to launch ROV.

CONTROL PANEL CREW

- ❑ Place small TVs in suitable location Place control box and panel in suitable location
- ❑ Use Banana Plugs to connect to main power supply
- ❑ Connect Video cameras to Control Panel power supply
- ❑ Connect Control box to Computer (already running)
- ❑ Connect video cameras to TVs
- ❑ Turn on Main Power switch (breaker) in Electronics Box
- ❑ Turn on Secondary circuit breaker on Control Box
- ❑ **SAFE call:** All Clear for power start-up. **REPLY:** All Clear
- ❑ Commence pre-dive check on systems: Cameras, Tools and Thrusters

- **REQUEST:** Cameras Operational — **REPLY:** Check Operational
- **REQUEST:** Port Horizontals Operational — **REPLY:** Check Operational
- **REQUEST:** Port Verticals Operational — **REPLY:** Check Operational
- **REQUEST:** Starboard Verticals Operational — **REPLY:** Check Operational
- **REQUEST:** Starboard Horizontals Operational — **REPLY:** Check Operational
- **REQUEST:** Port Hook Up — **REPLY:** Check Operational
- **REQUEST:** Centre Claw Closed — **REPLY:** Check Operational
- **REQUEST:** Starboard Clapper Closed — **REPLY:** Check Operational
- **REQUEST:** Starboard Wand Down — **REPLY:** Check Operational
- **Deck Manager:** All systems Operational

PRE-LAUNCH PROCEDURE

- **REQUEST:** Payload on-board — **REPLY:** Check on-board
- **REQUEST:** Ready to Launch — **REPLY:** Aye Sir – Ready!
- **REQUEST:** Splash ROV (put in water) — **REPLY:** Splash – Aye Sir!
- **REQUEST:** Launch ROV ICE — **REPLY:** Launch – Aye Sir, Launched

ROV RECOVERY PROCEDURE

- **REQUEST:** ROV Surfacing — **REPLY:** Aye Sir, Surfacing....Surfaced
- **REQUEST:** Hands-Off Power — **RPILOT:** Aye Sir, Hands-Off Power