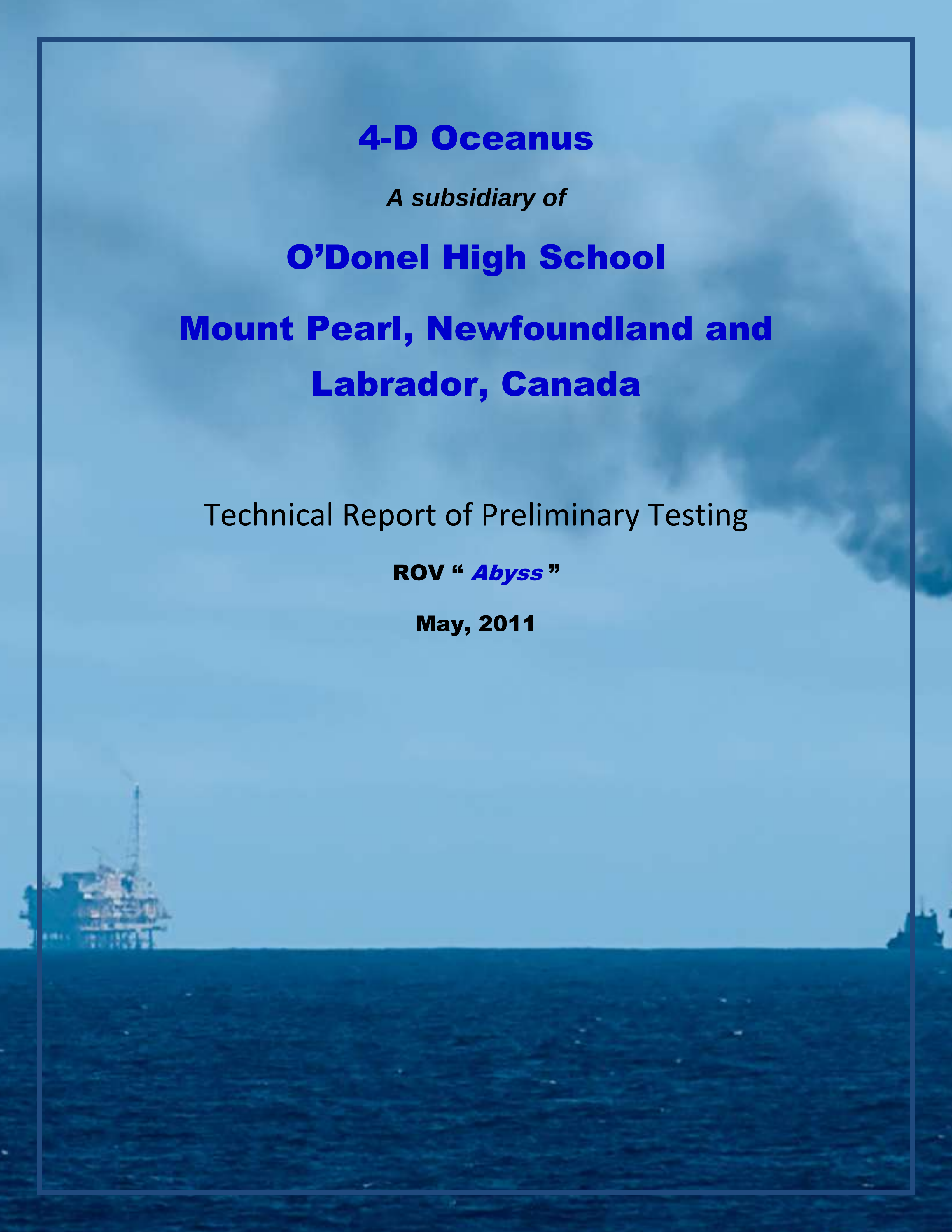

4-D Oceanus

A subsidiary of

O'Donel High School

Mount Pearl, Newfoundland and Labrador, Canada

Technical Report of Preliminary Testing

ROV " *Abyss* "

May, 2011

4-D Oceanus Staff

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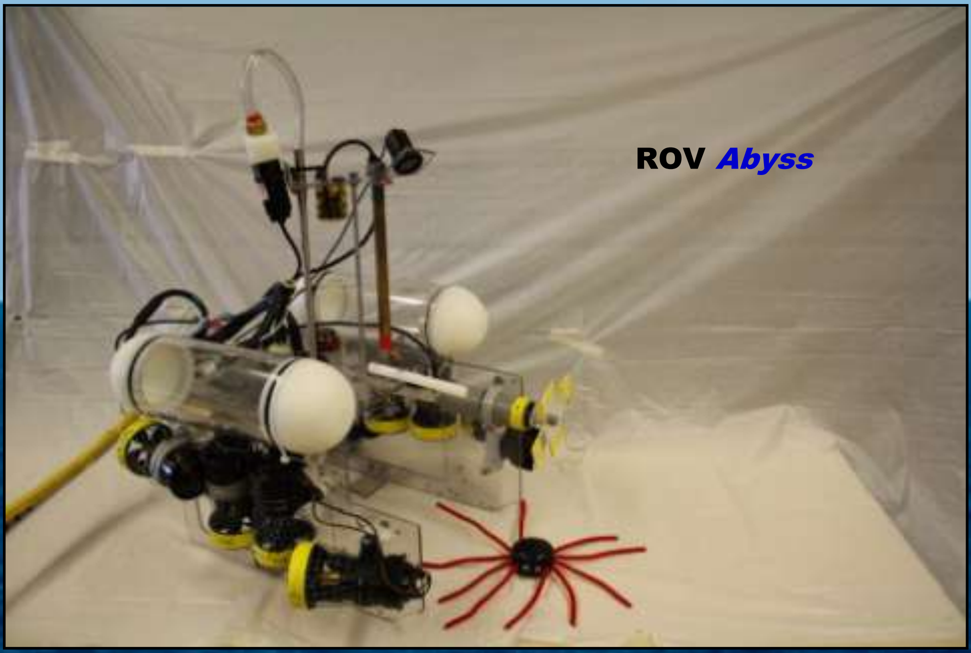
Abstract

4D Oceanus is a ‘spin-off’ company of O’Donel High School, Mount Pearl, Newfoundland, Canada. 4D undertakes technology development and fabrication in a number of environments, including land-based, aquatic and aeronautical robotics. This Technical Report deals exclusively with our most recent project in aquatic robotics, the ROV ***“Abyss”***, purpose-built for deep-water oil well blow-out investigation, intervention and remediation.   ROV has been designed to perform four tasks in a 15 minute mission, as follows:
TASK 1. Cut and remove a damaged riser pipe from a free-flowing well-head
TASK 2. Install a sealant hose, turn off the-wellhead valve and cap the wellhead
TASK 3. Collect a brine water sample from deep within a small aperture pipe
TASK 4. Sample benthic organisms (Chaceon crab, glass sponge, sea cucumber) near the well-head.

The ROV ***Abyss*** was deployed as an observational and workclass vehicle to perform these tasks in support of the massive effort to close a free-flowing oil well in the Mississippi Basin, Gulf of Mexico. This petroleum leak was caused by an explosion aboard the *Deepwater Horizon*, a dynamically-positioned MODU, owned by British Petroleum.

Abyss has a polycarbonate frame and moveable buoyancy chambers, eight 12VDC in-house vectored thrusters, and onboard electronics to control visual aspect from four videocameras (including a team-fabricated tilting unit). It contains navigation, dept h and temperature sensors. Three payload tools are task specific, whereas a multi-function, pneumatic 2-axis robotic arm is used in three of the four tasks. A custom-designed tether and proportional control in six axes makes ***Abyss*** highly maneuverable.



ROV *Abyss*

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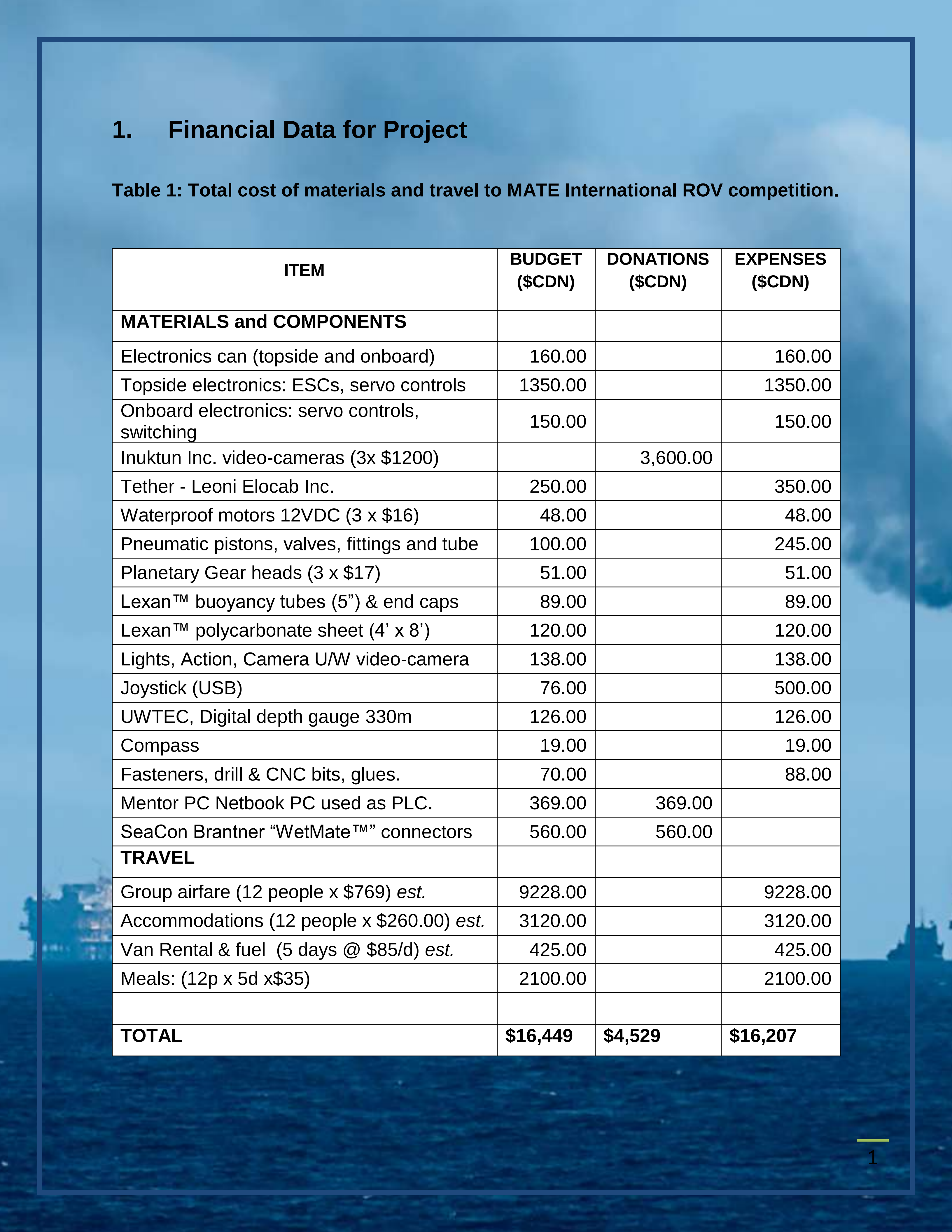


1. Financial Data for Project

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

ITEM	BUDGET ($CDN)	DONATIONS ($CDN)	EXPENSES ($CDN)
MATERIALS and COMPONENTS			
Electronics can (topside and onboard)	160.00		160.00
Topside electronics: ESCs, servo controls	1350.00		1350.00
Onboard electronics: servo controls, switching	150.00		150.00
Inuktun Inc. video-cameras (3x $1200)		3,600.00	
Tether - Leoni Elocab Inc.	250.00		350.00
Waterproof motors 12VDC (3 x $16)	48.00		48.00
Pneumatic pistons, valves, fittings and tube	100.00		245.00
Planetary Gear heads (3 x $17)	51.00		51.00
Lexan™ buoyancy tubes (5”) & end caps	89.00		89.00
Lexan™ polycarbonate sheet (4’ x 8’)	120.00		120.00
Lights, Action, Camera U/W video-camera	138.00		138.00
Joystick (USB)	76.00		500.00
UWTEC, Digital depth gauge 330m	126.00		126.00
Compass	19.00		19.00
Fasteners, drill & CNC bits, glues.	70.00		88.00
Mentor PC Netbook PC used as PLC.	369.00	369.00	
SeaCon Brantner “WetMate™” connectors	560.00	560.00	
TRAVEL			
Group airfare (12 people x $769) *est.*	9228.00		9228.00
Accommodations (12 people x $260.00) *est.*	3120.00		3120.00
Van Rental & fuel (5 days @ $85/d) *est.*	425.00		425.00
Meals: (12p x 5d x$35)	2100.00		2100.00
TOTAL	**$16,449**	**$4,529**	**$16,207**

Table 2: Contributions to 4D Oceanus Robotics

CONTRIBUTORS	VALUE ($CAD)
Government of Newfoundland and Labrador (NL) Materials/Parts	750
Government of NL via Marine Institute, MUN (Regional Winner's travel)	20,000
Individual contributions (12 people @ $200.00 each)	2,400
TOTAL Contributions	$23,150
TOTAL Expenses	$16,207
Balance (for materials and components for 2012 competitions	$6,943

2. Design Process:

The design process for ROV "*Abyss*", follows the classic procedure illustrated in Figure 1. As always, started with the Mission. Not understanding the mission requirements and design constraints imposed by the client, the Marine Advanced Technology Education (MATE) Center, is a recipe for disaster.

The mission description and design limitations were provided by the client in December 2011 in the form of tender documents. Members of the 4D design team were assigned sections of these documents for analysis and reporting, which was achieved over a two-day meeting.

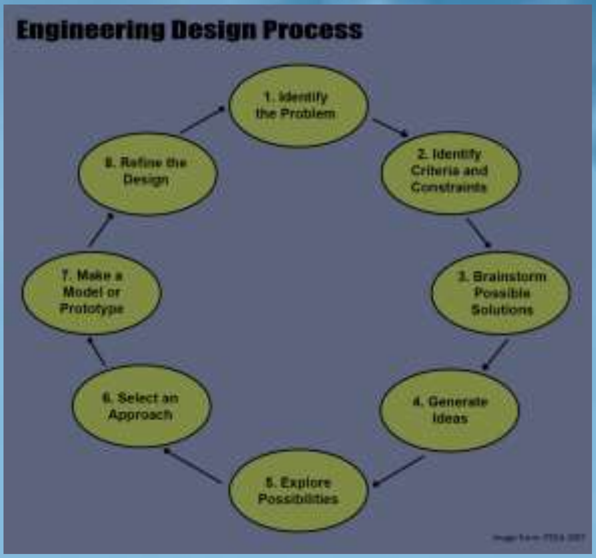


Figure 1. Engineering Design process

During the analysis meetings, brainstorming multiple ideas and SCAMPER methods were used in arriving at a preliminary list of design requirements. The outcome of this analysis was a list of design specifications, as follows:

- ✓ Small size to maneuver around well-head structures;
- ✓ Adequate storage capacity for collected samples;
- ✓ Capable of multi-axis movement (5-axis: surge, roll, yaw, sway, heave);
- ✓ Capable of low-speed precision movement;
- ✓ A variety of specialized tools for efficient task performance;
- ✓ Multiple videocamera views to see a number of tool operations;.
- ✓ Additional videocameras to provide situational awareness in a close quarters;
- ✓ Combining task operation capacity in multi-function tools;

- ✓ Thrust capacity to permit lifting Mission Task items
- ✓ Simple, intuitive control of the operations of ROV and payload tools.

These specifications guided the whole rational process of design, development, demonstration and mission task testing.

This stepwise process is cyclical. As new information emerges from testing, refinements in design are made. Sometimes, radical shifts in technology are adopted to enhance the ROV or the payload tools it carries. One of the tools (the pneumatic arm) has undergone 12 iterations, some minor, others signiticant such as reducing the axes of movement for purposes of simplicity. Often these refinements are the product of our using the SCAMPER method. (http://open-your-eyes-dnt.blogspot.com/2008/08/scamper.html)

S-Substitute
C-Combine
A-Adapt
M-Modify, Magnify, Minify
P-Put to other use
E-Eliminate
R-Reverse, Re-arrange

2.1 Structural Frame

In accordance with the design specifications, ROV "***Abyss***" has an open-bottomed, box-shaped structural frame fabricated from one folded piece of 4.75 mm (3/16") thick polycarbonate plastic (Lexan™). Frame size is 35 cm L x 25cm W, x 25 cm. This durable, easily cut and thermo-formed material affords:

i. a transparent structure that permits camera vision through the frame;
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 ($\rho = 1.18$ g/cm^3) material which requires little additional buoyancy;

The frame design was designed in SolidWorks™ 3-D CAD and converted to G-code in MasterCAM, for cutting on our RedCam™ CNC Router. It accommodates the vectored thrusters and has special cut-outs for our pneumatic mult-purpose robotic arm.

Buoyancy is also provided by clear Lexan™ structures. Two 12.7 cm OD x 22 cm long extruded polycarbonate pipes are enclosed on each end by plugs CNC lathed from HDPE (high density polyethylene). The plugs have O-ring groves which seal water entry between 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 electonics, however they have this potential in future designs. These sealed tubs have been pressure-tested at 2 ATM for one hour without detectable leaking.

Preliminary trials in water confirmed the flow analysis which is provided as Appendix 1.

2.2 Propulsion

ROV “**Abyss**” is propelled by four pairs of thrusters fabricated in our shop. Mayfair™ brand 1250 gph bilge pump replacement motor cartridges were used as the basis of our thrusters (Johnson Pumps, Inc.) . They are distributed as tabled below. (c.f. Figure 3):

Port Side	**Starboard Side**
2 Horizontal Thrusters	2 Horizontal Thrusters
2 Vertical Thrusters	2 Vertical Thrusters

These thruster units have been repeatedly tested in 4m fresh water and 7m ocean water without any detectable failure. Furthermore Protective cowlings were fabricated by cutting 2” (5.08 cm) x 1.5 ” ID, ABS pipe reducers and 1.5” ID ABS pipe. (ABS is acetyl-butyl styrene, a tough, resilient plastic used for plumbing and transport cases.) Each motor is joined by a 1.75 cm OD x 3 cm long brass hub to a carbon fiber-reinforced, ABS plastic propeller. The propellers are 3-blade, Grüpner™, 60mm OD x 35 mm pitch and fit snugly inside the large end of the ABS reducer. Each thruster draws 3.2 Amps under load at 13.5 VDC from source (12 VDC nominal), and provides 6.1 N of thrust. The voltage drops in the 18 AWG power wires, over the 14 m length of tether by 3.3V, resulting in a voltage onboard the ROV of about 10.2 VDC. We hope to correct this deficiency in future designs.

The horizontal thrusters are mounted forward and aft on ***Abyss*** with plastic 1.5” electrical conduit clamps, and are *torqued* at 30^o off the vertical forward plane, to avoid blocking water flow and promote turning maneuverability. The vertical thrusters are exactly that, and positioned in tandem, amidships.

Figure 2. In house designed and fabricated thruster.

2.3 Videocameras

Videocamera vision is a critical requirement to complete the mission tasks. With multiple mission tasks, requiring different camera angles, three different videocameras were fix-mounted on Abyss as well as one, vertically-tilting camera.

2.3.1 Fixed position Videocameras:

Two *Inuktun*™ brand *FireFly*™ model underwater cameras were donated by *Inuktun*™ Subsea of Port Moody, BC. One of them is one fixed inside the rear of the ROV, looking forward, for navigation, tool inspection and critter sample confirmation. Another is fixed to the top of the water sampling tool protruding through the roof of the ROV, and provides a vertical view of the tool and its target, a small pipe on top of a bucket. It also monitors the use of the aquatic critter sampling device in action. Since its height can be altered by activating the water sampling tool, this camera, in effect, has a zoom function. A third fixed camera LCA (400 TVL, 0.0 Lux @30cm via LED illumination) is located adjacent to the high positioned *Inuktun*™ camera and permits a view of the robotic arm from a 35^{o} angle looking forward and downward, such that the operations of our pneumatic arm can be viewed.

Figure 3. Inuktun videocamera - fixed

2.3.2 Tilting board camera

In addition to these three fixed videocameras, an in-house built, tilting camera with a 150^{o} range of vertical rotation serves as a redundant and supplemental visual system.. This unit uses a 12V *Supercircuit*™ PC823UXP high resolution (460 TVL), low light (0.5 Lux) color board camera and a micro-servo for tilting it, inside a clear, 3.8 cm OD waterproof cast acrylic pipe. Its primary function is to display all the tool operations on the ROV from a different perspective than the navigation camera. This is especially important for all tasks where using the arm is necessary and more than one views are needed to provide perspective for completing precision mission tasks in 3-D space.

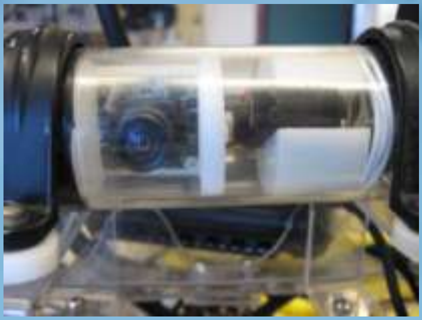


Figure 4. Super Circuits videocamera - tilting

2.3.3 Camera views

Only two camera views are possible at one time. The two fixed *Inuktun*™ cameras and the tilting camera use the same 75 Ω coax cable in the tether and their video signals are switched onboard, so only the one view is possible.. The other forward looking fixed video camera uses an independent 75 Ω coax cable.

2.4 Electrical and Electronics

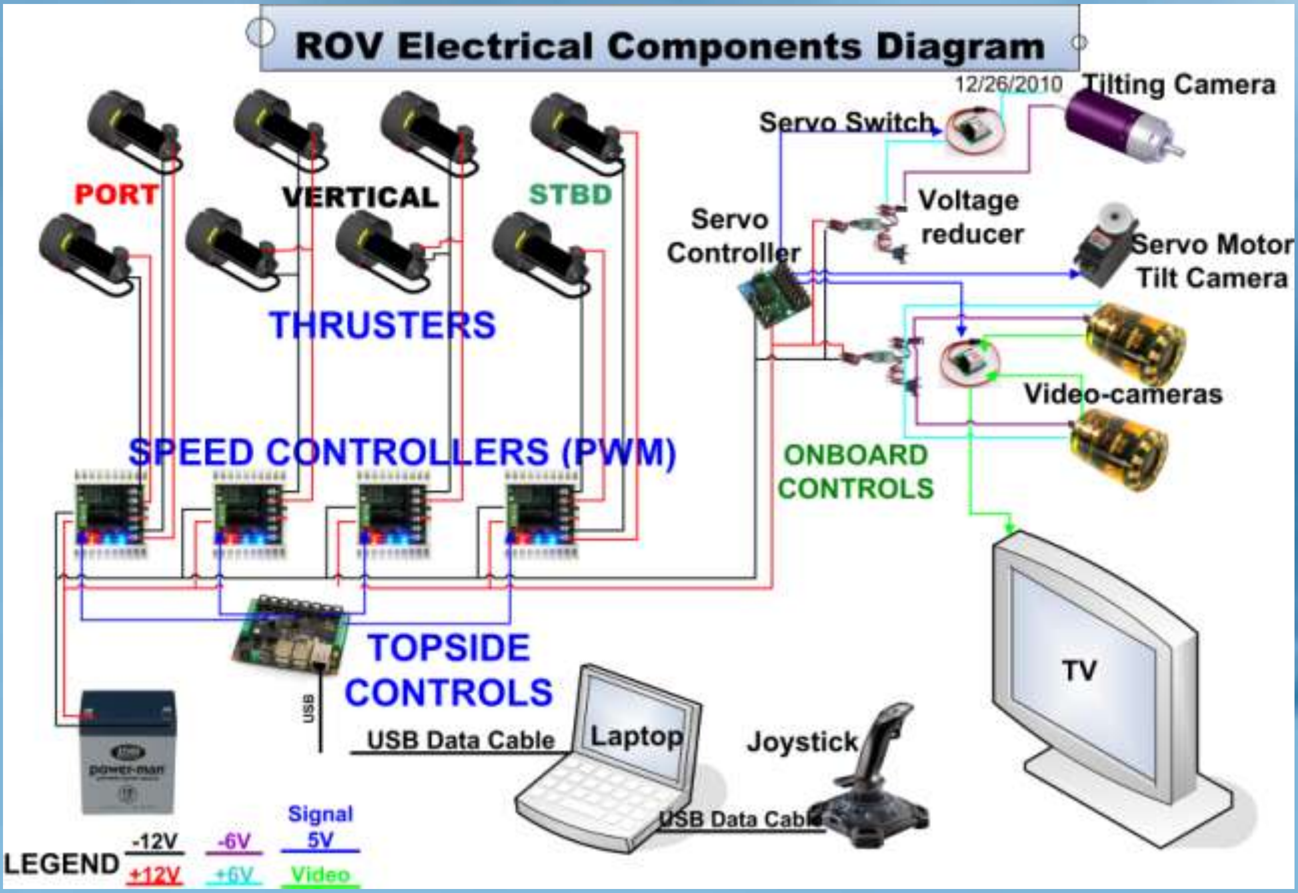
2.4.1 Topside Control Electronics

Abyss is highly maneuverable. The topside electronic controls permit proportional control in all directions and movement in three axes, as well as 360^o horizontal rotations and sway. We obtain proportional control through the use of four PWM (pulse width modulation) ESC units from IFI Robotics - one for each of the four thruster pairs.

The Pilot's joystick generates signals as input to a computer program written in C# which controls all ROV functions:

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	Analog Proportional	“ “ “	Hor. Thrusters move ROV Stbd. or Port
Joystick Rotation (ROTATE - YAW)	Analog Proportional	“ “ “	Hor. Thrusters in opposite directions
Joystick Full X (SWAY)	Analog w/ dead band.		
Throttle toggle (HEAVE)	Analog Proportional	“ “ “	Vert. Thrusters up/ down
Left top button	Analog	*Pololu*™ 8-Servo Micro-controller	Switches on navigation camera
Right top button	Analog	“ “ “	Switches between on side survey and tool cameras

Figure 5. Electrical Schematic



2.4.2 Tether:

The student-designed tether, produced by Leoni Elocab, in Etobicoke, ON, is almost neutrally buoyant in fresh water. It contains:

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

Our tether is securely attached to the ROV by a number of commercial connectors of two types:

i. wet-mateable bulkhead connectors on the electronics “can”, and
ii. wet-mateable in-line connectors

All are donated by the Canadian distributor for Seacon-Brantner, Edgetech in Eobicoke, Ontario. Most of the component wires are bundled within a single tether cable and protected by a buoyant coating and a slick surface coating. This tether minimizes drag and instability of the ROV. Five (5) tiny (1/16” ID, 250 psi) capacity air lines are secured along the length of the tether to actuate the pneumatic tools. This also makes the tether perfectly neutrally buoyant. Two additional miniature cables bring signals from an additional two cameras to the surface. The wires and miniature hoses are bundled using *SpiralWrap*™.

2.4.3 Onboard Electronics

This is the fifth year we have had some electronics onboard our ROV in a waterproof plastic *Otter*™ box. This waterproof box receives:

i. One pair of the 12V DC power wires
ii. A pair of shielded serial signal wires
iii. The 75 Ώ coax cable inside the tether

The 12 VDC power wires are split to provide 5 and 6 V regulated power to other devices using *Firmtronics*™ Battery Elimination Circuits (BECs). These electronics are used for the exclusive purpose of powering and selecting one of the three video camera signals to send up the coax cable in the tether for viewing on the surface.

The video signal switching is achieved by operating two electronically controlled *Dimension Engineering*™ “Battleswitches” - one which switches from the navigation to the mission cameras and the second which toggles between the two mission cameras., as follows:

Voltage	**Source**	**Destination**	**Purpose**
12V	Direct from tether	*Pololu*™ 8-port Servo controller	Provides 12 VDC power to: i. *Pololu*™ 8-port servo controller, ii. ‘Board’ video-camera iii. 6V DC S-BEC regulators
6V	S-BEC switching regulator (yellow)	*Pololu*™ 8-port Servo controller for output signal	Powers the two (2) Dimension Engineering™ “Battleswitch”s one which selects video signals from two (2) onboard video-cameras and the other which turns on valve wheel rotator tool.
5V	S-BEC switching regulator (blue)	Video cameras	Powers video-cameras and LED lights

These electronic switches can handle up to 60 Amps.

The “Battleswitches” are controlled by a serial signal sent from the joystick and computer (topside) to a **Pololu**™ brand 8-port servo controller in a waterproof box (“can”) onboard the ROV. The critical technology which enables us to safely use a submerged electronics “can” are water-proof bulkhead electrical connectors donated by *Sea-Con - Brantner*™.

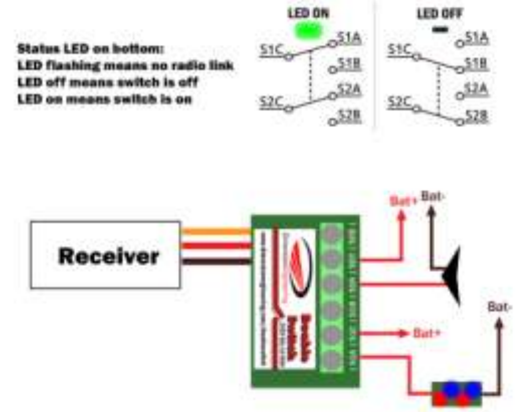


Figure 6. Wiring Diagram: video signal switching

2.4.4 Software

Our control design uses a PC laptop as a Programmable Logic Controller (PLC) for the operation of the electronics 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. The code in C# was designed by students, with some guidance from senior students. The code was segregated in functional libraries, to permit ease of selecting code for the use of different tools.

Given that we were novices, we were looking for simple solutions. We discovered stock programming from electronic component suppliers and MS.NET libraries such as DirectX.

i. Stock programming in C# for the multi-function, USB joystick we used was found as a compiled program from MS DirectX.
ii. The *Phidgets*™ 4-servo motor controller has a C# compiled program available from the supplier.

Our programming is broken into three sections:

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

Input Operations:

The only input operations on ICE V2 are those derived from the joystick. The signal range in all axes is between -250 and +250 is a dead band to eliminate overly sensitive joystick movements.

Output Operations:

Forward and reverse thruster operations involve the same values of signal throughout the full range (150-1000) 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 thrusters rotating in opposite directions and the ROV moving in a 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..

2.5 Safety Features and Precautions

Safety was a major concern of 4D Oceanus throughout the whole process of design, building, development and testing of the ROV “Abyss”. Team members received training from mentors in workshop safety and were instructed in the use of potentially hazardous tools such as saws, drills and soldering irons.

ROV “Abyss” has a number of safety features, including:

i. circuit breaker protection (25A) on the positive power feed, combined as a
ii. kill switch for emergency stoppage
iii. completely shrouded thrusters to prevent accidental injury and entanglements
iv. rounding and removal of all sharp edges
v. Complete Potting of electrical connections and components in onboard electronics boxes and motor containments
vi. Use of “*WetMateable*”™ SeaCon Brantner, Inc. electrical connectors to prevent water entry
vii. secure tether attachment and strain relief to avoid breakage or damage
viii. master valve cut to pressurize the pneumatic robot arm until the ROV is “away” and on Mission;
ix. output air pressure gauge to ensure compliance with safe limits;
x. warning symbols or signs located near moving components, such as props and pneumatic arm.

Operational safety procedures include:

i. safe practices were developed for transporting the ROV and auxillary equipment on a wheeled cart;
ii. a staff member was “Safety Point” when the Deck Team procession moved;

iii. a pre-dive check protocol requires “Power off”, except when “All-clear” is designated by the deck manager
iv. PFDs are worn by all deck crew during testing
v. command Instructions used on deck have been defined and are used;
vi. careful stowage, deployment and management of the tether during mission operations to avoid tripping

3.0 Payload Tools

Purpose-built tools were uniquely designed for the our tasks in the 2011 mission. The complex, multi-step tasks, required a number of tools. With limited space onboard the ROV; some tools were designed for multiple functions. All tools requiring actuation use surface-supplied, pneumatic cylinders.

3.1 TASK 1 Remove the damaged riser pipe from the well head

This task simulates the removal of a damaged riser pipe which formerly carried the crude petroleum products to the surface and the oil rig.

Figure 7. Riser Pipe Connector

Step 1. Connect to the damaged riser pipe

The device designed for this step is an array of three small carabineers, with their spring-loaded pins facing forward. It is pushed into the large U-bold at the top of the riser pipe and the spring-loaded pins snap onto that structure. The array of three carabineers requires less precise piloting. They are held in place on a Lexan™ bracket. The original springs in each carabineer were found to be too strong for this function (35 N) and were replaced with ball-point pen springs requiring less compression force (5 N). Extender guides, also made of Lexan™, attach to each carabineer and form a funnel structure to permit easy targeting. This tool has a horizontal handle of 1.25cm (½”) ID PVC pipe which fits over a short length of HDPE (High Density Polyethylene) projecting forward from the top of the ROV. The Tool handle is secured by a vertical pin through it’s outside wall and penetrating the HDPE rod. A pull on the same rope which is used lift the damaged riser pipe removes this security pin from the handle and permits it to be detached from the ROV, after attaching to the damaged riser pipe.

Step 2. Pull the Velcro tab ring

This step simulates the cutting of a damaged riser pipe from a well head.

Figure 8. Pneumatic Arm

This was achieved using our multi-functional, two-axis, pneumatic arm. The structural frame of this arm was fabricated with clear Lexan™ plate, cut to size, and white Lexan claws on the gripper for so it can be seen easily with our cameras. The lower arm can be raised over a 45 degree range from horizontal by a dual-acting stainless steel SMC™ cylinder of 1.42 cm (9/16”) bore and 3.8 cm (1.5”) stroke . The gripper is operated by a single-acting, spring open, Parker™ stainless steel pneumatic cylinder with 1.90 cm (3/4”) bore and 3.8 cm (1.5”) stroke. This gripper has multiple claws or fingers, which our considerable testing has demonstrated to have the ability of gripping items of quite different shapes and materials.

As described above our pneumatic arm completes multiple mission tasks:

1. Holds the riser pipe hook
2. Pulls the Velcro™ tab
3. It is used to place to cap on the oil well
4. It is used to insert the hot stab into the well-head
5. Can collect critters if required.

Step 3. Remove the damaged riser pipe

The rope attached to the carabineer gripper used in Step 1, is now used by a deck hand to manually lift the damaged riser pipe off the well head and into a space away from the wellhead, to facilitate conducting the other tasks.

3.2 TASK 2. Turn off the crude oil flow from the well head and cap the well

This task also has three steps and they must be accomplished in the logical order described below.

Step 1. Insert a high pressure hose line into the well head

The nozzle of the high pressure hose is removed from its pipe cradle on the ocean floor and flown to insert in the receiving pipe on the oil well BOP by use of the multipurpose pneumatic arm. The arm is in the horizontal position with the gripper claw open when it approaches the hose nozzle pipe cradle. It encircles the cradle pipe (3.8 cm [1.5”] ID) and then is actuated first to grip the pipe and then to lift the nozzle out of the pipe in a 45^o angle position. This angle is maintained as it is the ideal angle of approach to insert the nozzle into the 45^o pipe receiver on the well head.

Step 2. Turn off the well head oil valve.

Closing the oil well valve requires turning a wheel of 30 cm diameter made from 1.25 cm (.5”) ID PVC plastic pipe and fittings. This wheel must be turned three full rotations (1080^o) to close the

Figure 9. Oil well valve rotator

oil well valve.   Our oil well valve rotator is specifically designed to achieve this task. It uses a miniature waterproof motor attached to a planetary gear head which has been sealed and water proofed with self-sealing tape . The part of the tool which actually engages the wheel is fabricated from clear Lexan™. It fits between the spokes of the valve wheel and grips it during rotation, but releases immediately upon reverse rotation. This step requires just 6 seconds to complete with our efficient tool.

Step 3. Cap the well head

The simulated well head is a 1.91 cm (3/4”) straight coupling positioned at the end of a vertical pipe. The multi-purpose pneumatic arm is also used to retrieve the well head cap from the pool bottom, where it was initially located when brought from the surface by the ROV. It is retrieved with the arm in the horizontal position and is maintained in that orientation to fly to the top of the well head, drop the large bottom opening over the well head and then open the pneumatic claw to release the cap.

Figure 10. ROV “*Abyss*” capping the well head

3.3   TASK 3: Collect a saline water sample from a small opening

This task simulates the collection of a sample of water at a specified depth as required to determine the levels of CDOM in the water near an underwater well blow-out. The small aperture from which the saline water sample is to be collected is simulated by a bucket having a short (7cm) length of 1.91 cm (3/4”) ID PVC pipe protruding vertically from the cover of a 7 litre (2 gal) plastic bucket. Three buckets are located at different depths in the pool. The team is informed of which bucket must be sampled. Each bucket has a 1 litre plastic bag attached to the bottom end of the 1.91 cm (3/4”) PVC pipe and each is filled with brine water with a different food coloring added.

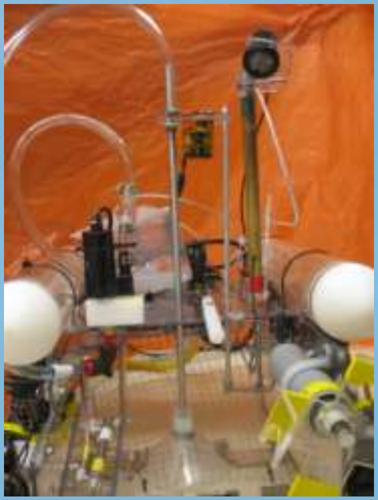


Figure 11. Water Sampler Tool (front view)

Step 1. Analyse a graph of CDOM concentration over a depth range and select the correct depth at which to collect the water sample.

The graph is presented and the Deck Crew is required to indicate the depth at which the highest concentration can be found. That information is then used to determine the depth from which the brine water sample is to be taken.

Step 2. Collect the brine sample from a designated depth

Our water sampler consists of a miniature bilge pump which is used to pump the saline sample through a 1-way valve, into a flexible bag. The bag is totally empty of air throughout the task performance. A small bore 0.95 cm (3/8”) ID thin-walled, stainless steel pipe is extended downward into the sample opening by use of a 1.25 cm (1/2”) bore, 21 cm (8”) stroke, double-acting pneumatic cylinder. The small pipe is extended through a transparent funnel which makes targeting the sample opening much easier. The head of the funnel contains a thick closed cell foam seal which seats on the top opening of the sample pipe, preventing seepage of surrounding (ambient, fresh) water into the saline sample. This tool collects 1 litre of saline sample in 9 seconds. The large sample diminishes the impact of any unexpected dilution, providing a pure brine sample.

3.4 TASK 4. Collect several different species of benthic animal

Three different types of bottom dwelling creature are simulated in this task. They are sampled to determine the level of impact of the oil blow-out on the surrounding fauna. There are fine of the following creatures within the sample area: Caceon Crabs, Sea Cucumbers and Glass Sponges.

Our first tool to collect these specimens relied on the fact that all three contain ferro-magnetic materials in either the pipe cleaners or the screws used in their fabrication This was found to be inadequate.

The second design involves a more active collection method. A small, planetary geared 12VDC waterproof motor is switched on to rotate a thin aluminium rod around which are attached shortened ends of cable ties. The rod is positioned across the mouth of the ROV at a height of 5 cm from its bottom. The unit looks like an enlarged tooth comb which sweeps the benthic sea critters into a containent inside the frame of the ROV. It also serves to prevent their escape. A simple ramp at the bottom of the ROV skims the bottom of the pool and provides a smooth surface for the critters to enter the ROV interior. Magnets inside ROV frame provide

Figure 12. Benthic critter sweeper

4. Challenges

Throughout the design and construction of the ROV, our team faced multiple challenges. Some of these challenges with the design process, or challenges with the construction of a tool. The design and construction of the brine water sampler posed multiple difficulties and the tool was put through various refinements and redesigns.

The tool originally had a 21cm stroke length piston that pushed a stainless steel tube into the brine water sample, while at the same time pushing down three 60ml hypodermic syringes. A hose ran from each syringe to a three way manifold, which combined them into one hose, attached to the stainless steel insertion tube.

As the piston extended, it would push the tube into the brine water sample and the syringes down, which created a vacuum in the tubes that would draw water into the syringes. In theory and practice before it was mounted on the ROV it seemed as a flawless design. When it was mounted and tested we realize that as the piston is extended it hits off the top of the bucket containing the brine sample and pushes the ROV in the opposite direction. It was a design flaw that could have been avoided, so this issue provided a challenge for us to overcome.

5. Troubleshooting Techniques

Trouble shooting techniques tend to be domain specific. They differ depending on the environment, issue, process being affected. Generally, they are only realistic having knowledge or experience with the system in question. We had an issue with our tilting camera, described previously. This unit is a 12VDC small CMOS video camera, installed inside a clear cast acrylic tube with a miniature servo motor to rotate it vertically. It produced no video signal. We used the KISS Principle as the method of analyzing the problem…starting from simple causes.

1. We changed the monitor then tried a different camera on both monitors, to ensured they were working.
2. We tested the voltage at source, which was a small battery at the time. It checked out at 12.7 VDC
3. We followed the voltage on power leads through the bulkhead connector into the waterproof acrylic tube using a multi-meter. All good! So the video camera was getting adequate power.
4. Next we checked continuity of the video signal cable by testing resistance through the wires from the output connector into the monitor to the source. There was no break in the video conductors.
5. Next we attempted to get a video signal directly from the camera, again measures with the multi-meter. None was detected.
6. We noticed some tiny signs of corrosion on the printed circuit board on which the camera was mounted.

7. Our conclusion was that there had been some small leakage of water into the supposedly sealed tube which had probably shorted the circuitry and ruined the camera. Solution…we ordered another camera. It still hasn’t arrived.

6. Future Improvement

4D Oceanus has a history of technical excellence, but to remain competitive, we recognize that our potential clients require that our level of ROV technology and thus of service must keep improving. The firm had significant plans for enhancing the technology used in our ROV ***Abyss*** this year, but we were hampered by the availability of funds. We set two goals in light of this reality. We had to secure funding to acquire the new technology which we hoped to add to our ROV, and we had to design around the limitations of our current model. These limitations were as follows:

6.1 Robotic Arm

Our current robotic arm is powered by pneumatics (compressed air) from the surface. We are limited to 40psi air pressure at the surface and this working air pressure is considerably decreased as the depth of water in which the mission is to be conducted increases. A further complication is that each pneumatic cylinder used onboard the ROV needs a minimum of one airline (single acting, spring return) or two airlines (double acting). In order to increase the number of axes of movement of this arm to enable more precise and varied movements, the number of air lines running down our tether becomes unwieldy. We examined two alternatives to overcome these limitations:

i. Reducing and simplifying the robotic arm to reduce the numbers of air lines

ii. Finding a way to distribute the air from a single air line, onboard the ROV

iii. Converting from pneumatic to low pressure hydraulic power onboard the ROV

6.2 Electronics Onboard

The second and third solutions identified above, all require onboard distribution of power and control signals. Currently, our tether is unable to carry more than a serial signal down a shielded twisted pair of AWG 22 wires. If we were to place control of some fluid power onboard, the control of these solenoid valves would be difficult due to the control limitations.

We have devised solutions to the two significant problems described above:

6.3 Finances:

The team, this year, accepted responsibility for all the recycling in the school and has been earning modest but consistent amounts of funding for this rather smelly task. The fund-raising is slow but assured. There will be adequate capital in our budget for next year's improvements.

6.4 Future Technical Improvements:

A significant part of our effort this year has been researching for the future. We have been researching a new design that will improve performance I several areas. This new design will require new components, which fortunately by Autumn 2011 we will have. The new design will include:

- i. A tether which includes a single pair of power wires; an imbedded Ethernet cable and a 75 Ω coax cable. It will be smaller in diameter, lighter, and more flexible than our current tether. It will also enable significant expansion of our power and signal distribution from the ROV.
- ii. A high quality enclosed waterproof "can" in which to contain onboard electronics.
- iii. Some commercial grade (expensive) bulkhead penetrating connectors to enable power and signal distribution outside the waterproof can.
- iv. The use of USB-format electronics line which are controlled through the Ethernet cable to permit multiple control of thrusters, payload tools and sensor input and movement up the tether.
- v. Some miniature low pressure hydraulic equipment to actuate the robotic arm and other linear actuators. It will not require surface pressure and could use ambient water as the fluid power.

7. 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. Some of these are described in the section above. 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 and capability. We have had visitors from other schools attending this competition who have come to our school to lean the use of this equipment and to fabricate some of their own ROVs.

However, the most important lessons learned – those which we will carry with us for the rest of our lives were affective outcomes. 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 management. 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 breadth of opportunity that lies 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 book learning 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 com 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 the essential skills of planning, organization, and human, time and resource management as the foundation for success in out post-secondary academic life and in our future careers.

8. Reflections

As a company we have learned and accomplished a lot as a result of participation in this year’s ROV competition. The members of our company’s deck crew gained experience while operating under time restraints, and in an actual pool of significant depth. This allowed our deck crew to feel to stress of competition, and we as a company, were able to evaluate how we worked as a team, and how we worked in high stress situations.

What we also accomplished, from rigorous practice, was a strong engineering panel presentation where we scored thirty-two points out of a total of thirty-three. Every member of our company feels as if we have done very well in our presentation and have really proven our proficiency in this area. One important thing our company as 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 in future presentations.

9. Teamwork

The firm’s organization focused on the four major requirements of the competition: ROV Performance; Engineering Panel; Poster Presentation; and Technical Report. Project management (of materials, people, and work) was enhanced by using MS Project software.

With small number of team members, however, individuals adopted several roles. It was difficult to assign anyone to a single role….we became whatever was needed. Small groups took ownership of the design of the ROV and multiple tools. However, these tools had to fit together on a single small frame, and communication between the groups was critical to brainstorm consensus solutions. We did this by having a review session and planning session at the beginning of every meeting to keep team members abreast of the most recent design changes and priority work commitments.

The group really knit together as a team in two different environments.

Team building:

We had team-building sessions at the beginning of our meetings this year as a method of “ice-breaking” and rapidly becoming comfortable with each other. We also were encouraged to try SCUBA Diving by our mentors..”Just to get a feel for the environment in which the ROV operates.” It was activities such as these that developed the following code of ethics of our team:

i. We will help one another, particularly in areas where I am strong and they are not;
ii. We will not criticize the efforts of others, but encourage them;
iii. No idea is stupid…all may blossom into something great;
iv. We will expect the best from us all and we will each demonstrate our commitment.

Competition:

It was remarkable how we seemed to become a closer unit during the recent Regional competition. It was if ‘trial by fire’ forged our relationships. I guess if was because we all faced the same fears and challenges.

10. Acknowledgements:

We would like to acknowledge the following contributors, and people, for their contributions. Without their efforts, donations, and time our attendance to this competition would not be possible and our ROV would not be the vehicle that it is today.
Eastern School District of Newfoundland and Labrador (for use of facilities and mentor guidance)

10.1. Financial Contributors:

Innovation Trade and Rural Development (Government of NL)
SunCor Energy.

10.2 Donations in Kind

IPEX inc. (donated plastic piping, fitting, frames for competition props)
Phidgets Inc. (donation of digital components such as Motor controllers)
Mayfair Marine, Johnson Pumps/ SPX (reduced educational price on thruster motors)
Seacon-Brantner (“wet-mateable” U/W connectors for thrusters and bulkhead connectors for onboard waterproof box)
Thomas Glass Ltd. (discounted Lexan™ materials for frame and tool fabrication)
Our mentors (for their guidance, patience and dedication)
Our parents (for their generous support):

APPENDIX 1.

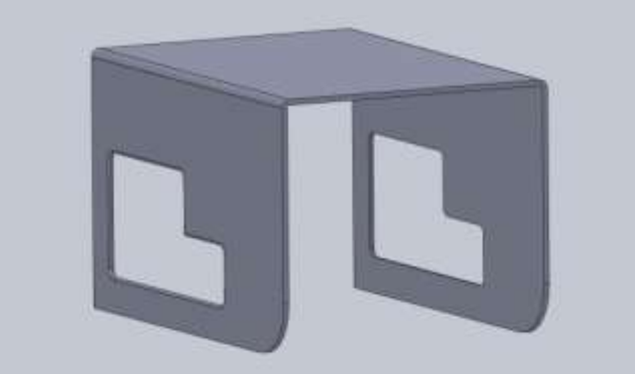


Figure. 13 Solidworks Drawing: Lexan ROV Frame

Figure 14. Solidworks Drawing: Full Assembly

APPENDIX 2.

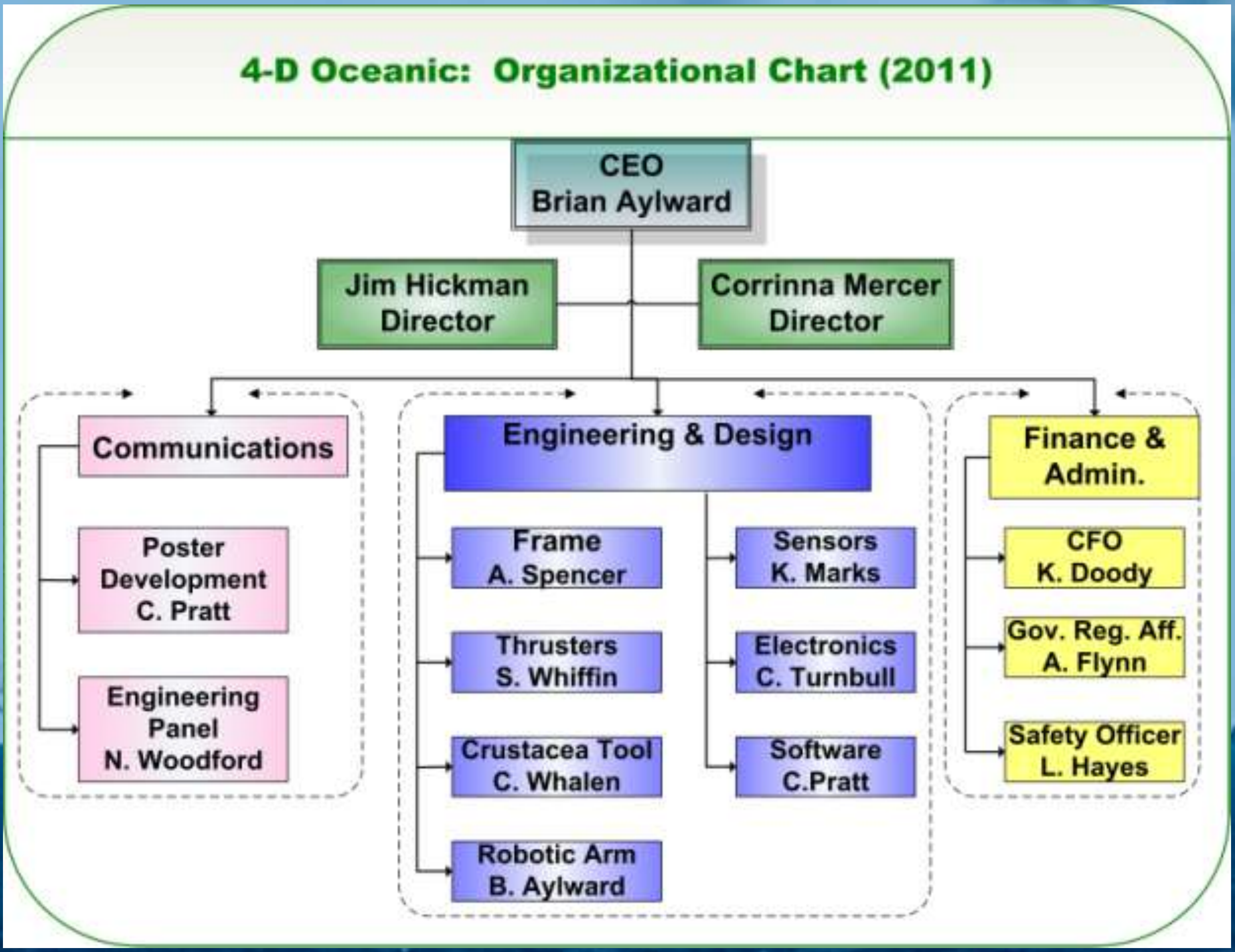


Figure 15. 4-D Oceanus Organizational Chart