OD
4D

O'Donel High School

Mt. Pearl, NL

Canada

MATE 2016

Staff

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Joel Hatcher '16 - Manager, Public Relations
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Zachary Norman '16 - Fabrication Technician, Testing
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Matthew Butt '16 - Manager, Tool Development
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Harley Always '15 - Software Designer

Mentors: James Hickman, Joseph Santos

1.0 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. ROV ***ICE*** is specifically configured to support the need for ROVs in both inner and outer space.

ICE is able to measure depths and temperatures on the icy moon of Jupiter, identify and recover "CubeSats" in the Gulf of Mexico, and collect various items such as oil and coral samples. In addition, the ROV can connect an ESP to a power and communications hub, collect photographs of essential items, and transform an oil platform into an artificial reef.

ICE is equipped with a multitude of tools, each specially designed, fabricated, tested and modified with specific tasks in mind. ***ICE*** features tools and sensors such as our clapper, claw and of course our on board cameras which have proven to be extremely effective when tested.

OD-4D has spent countless hours preparing ***ICE*** for competition. In practice trials, ***ICE*** has completed all mission tasks efficiently and we hope to do so as well in competition. We look forward to demonstrating the capabilities of ***ICE*** at imminent trials in Houston, Texas, June 23-25, 2016.

Back Row (L-R): Matthew Butt, Michael Howse, Patrick Breen, Keeley Flynn, Kaitlin Genge, Joel Hatcher, Robin Murphy, Josh Edwards

Front Row (L-R): Zachary Norman, Clarke Payne, Melissa Mosher, Josh O'Keefe, Emily Wiseman, Harley Always, Aby Pike

Figure 1: OD-4D Staff

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2.0 PROJECT COSTING

OD-4D is a school-based company and therefore, our funding is limited to that which the school offers. We were lucky to have received donations from our very generous external supporters which helped lighten the out-of-pocket expenses. Table 1 below shows the 2016 Project Costing outline. The complete list of our financial contributors can be found in table 2.

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

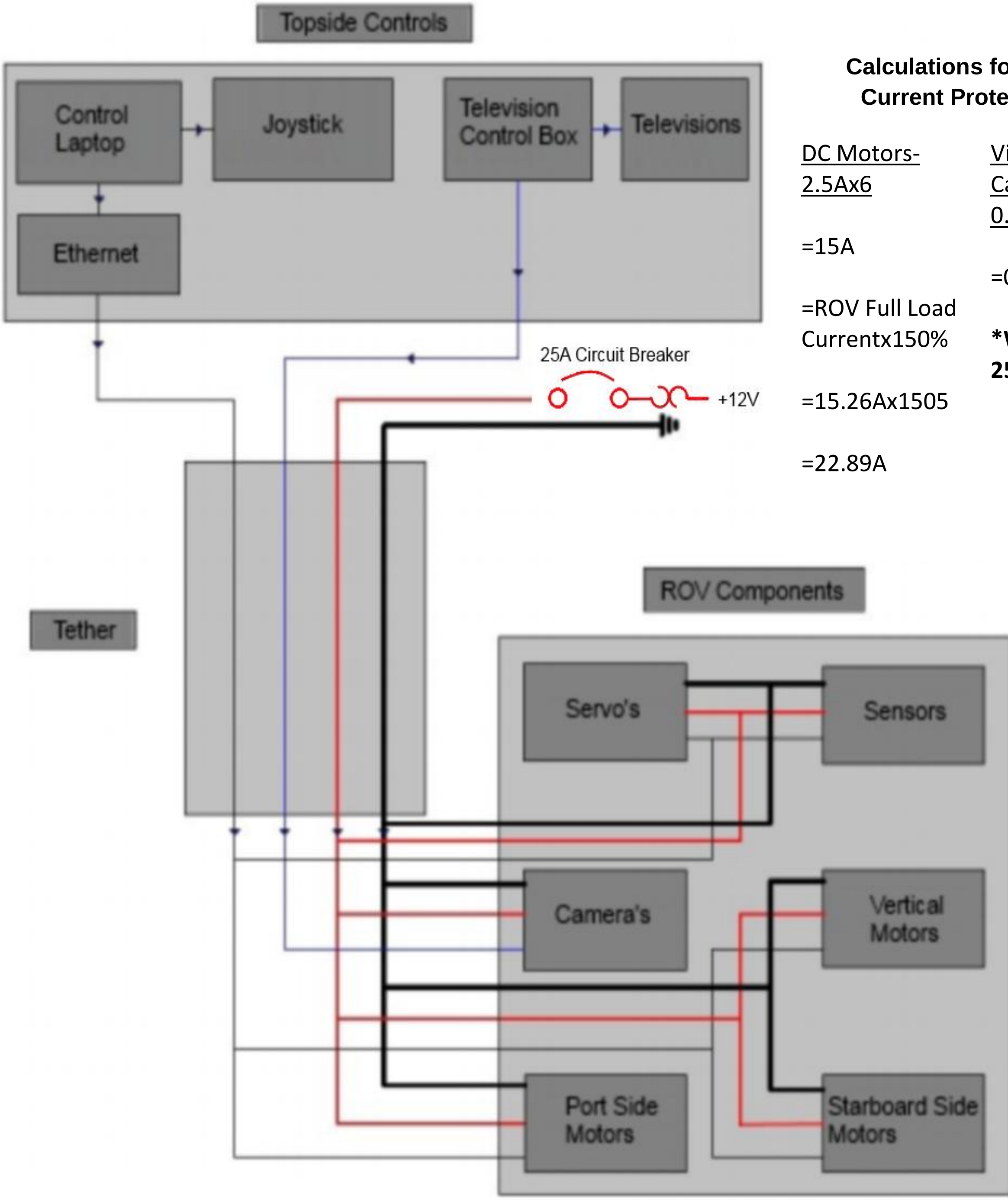
Type	Date of investment	Expense	Amount ($US)		Running Balance ($US)
			Spent	Donated	
Re-used	09/2013-05/2015	ESCs, Servo controls		1350.00	1350.00
		SS Aquacam™ composite video camera (two)		490.00	1840.00
		PC Netbook		699.00	2539.00
		Pneumatic components	463.00		3002.00
		Joystick (USB)	76.00		3078.00
		Fasteners, CNC and drill bits, glues	70.00		3148.00
Purchased new this year	09/2016	BlueRobotics™ T100 Thrusters	900.00		4048.00
	10/2016	Buoyancy /Electronics Can	135.00		4183.00
	09/2016	High Density Polyethylene	220.00		4403.00
Parts donated this year	10/2016	Tether		250.00	4653.00
Cash Donated		Travel Funds		15 000.00	19 653.00
		General cash donation		250.00	19 903.00
		TOTAL EXPENSES	***1864.00***	***18 039.00***	***19 903.00***

Table 2: OD-4D financial contributors

Contributor	Item donated	Value ($US)
Leoni Elocab Inc.	**Tether**	**250.00**

Private & Gov't of NL via Marine Institute, MUN (Regional Winner)	**Travel funds**	**15,000.00**
City of Mount Pearl Youth group of the year award	**Cash**	**250.00**

3.0 SYSTEM INTEGRATION DIAGRAM



Calculations for Over Current Protection

<u>DC Motors- 2.5Ax6</u>

=15A

=ROV Full Load Currentx150%

=15.26Ax1505

=22.89A

<u>Video Camera 0.13Ax2</u>

=0.26A

***We use a 25A fuse**

4.0 DESIGN RATIONALE

4.1 Design Process

The design process for ROV ***ICE*** always starts with gaining a complete understanding of the mission tasks; these are provided by the client and received in January of the competition year. This is achieved through researching the mission tasks, analyzing the requirements, and building the mission props for practice. From this experience, a set of precise design specifications are developed. These specifications are later used as the ‘gold standard’, by which are used to measure the effectiveness of all ROV systems and payload tools. One example of a ‘gold standard’ for this year was that the ROV would have an overall small size and weight.

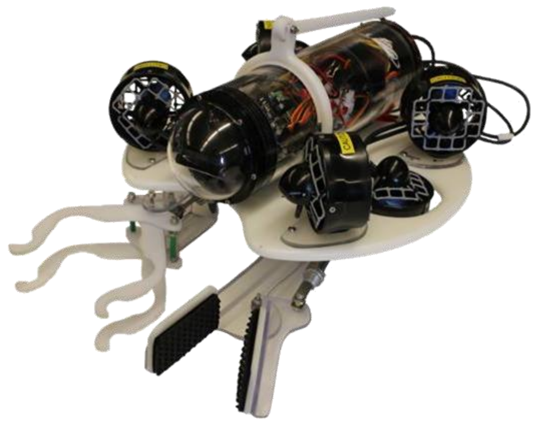


Figure 2: ICE ROV

The design process for ***ICE*** followed a multi-step process. All components were chosen carefully and specifically based on the needs of the client. Factors such as cost, simplicity, functionality and ease of build were our major considerations when making decisions. 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 presented and evaluated by whole staff
iv. Top designs are prototyped and further tested

The design process is cyclical. As new information emerges from testing and research, refinements in the design are made. Sometimes, radical shifts in design or technology are adopted to improve the ROV or the payload tools it carries. All modifications are accepted only if they contribute to the effectiveness of the final product.

4.2 Design Evolution

OD-4D has been working on and improving ROVs since 2006. ***ICE*** was specially designed this year for work in the depths of inner space and the unexplored environments of outer space. The company had to evaluate which components could be reused from previous works; which components needed to be built from scratch; and which components would be justifiably purchased. Our experience and know-how from previous projects guided us in creating a nearly brand-new ROV to meet these diverse challenges. r example, ***ICE***’s tools and frame are all new this year to accommodate the varied tasks required in the mission scope.

After many prototypes and trials, the company arrived at a final product, which is superior to any from past years. As new information and test findings surfaced, the ROV was modified time and time again until we finally arrived at a near flawless design. The company works collaboratively to make design decisions. This way, all our expertise is used to brainstorm, design and refine the best innovative ideas..

As OD-4D continuously grows and develops, ***ICE*** itself has quickly evolved into a top of the line remotely operated vehicle.

4.3 Frame

OD-4D spent a great deal of time working on the frame for ***ICE***. We were challenged to find a design which fit the size and weight requirements while also remaining robust and reliable. The ROV started out as a box shape with rounded edges and two curved platforms to house the thrusters. Unfortunately, there were minor errors in our fabrication and the frame was not quite small enough. After the MATE regional competition, we realized the design would not work for the international competition. We got together as a company to brainstorm new ideas which may be more efficient. We continued the stepwise design process listed in ***4.0*** until we arrived at our current design.

We decided that for our ROV to fit through a circle, required for size and weight bonus points, we should make our ROV circular in profile. The newest design iteration of our frame is a circle with a diameter of 42cm, cut from 1.25 cm (½ inch) thick HDPE. It is affectionately referred to by company members as the "***UFO***".

Figure 3: Mock Frame Redesign

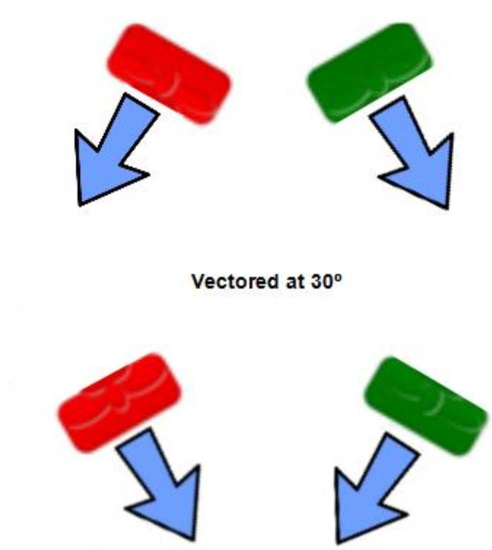
This design allows for optimal positioning of all six thrusters, our tools, onboard electronics can, while fitting within the size points more easily than our previous model. The construction material for both our previous and current model is HDPE. We selected this material due to the fact it is very robust and durable, as well as being easy to work with, and neutrally buoyant in fresh water, with a density of $0.96 g/cm^3$.

4.4 Propulsion

ROV ***ICE*** is propelled by six BlueRobotics™ T-100 brushless motor thrusters. We opted to purchase new thrusters this year, as one of the company's priorities was to create a vehicle which was not only powerful, but also maneuverable to perform precision movements.

The company decided on basic standards that the thrusters must meet. Several staff then researched thrusters individually and presented their best findings to the group. We agreed on these specific motor thrusters as they presented a great compromise between size, simplicity, and power. They are extremely light with excelt thrust to weight ratio.. When powered at 12V DC, our Bollard pull tests measured 9N of thrust from each thruster.

Figure 4: Thruster orientation



They draw maximum amperage of 5.8A for 30-second durations. However, the amperage required decreases to 4.25A with continued usage.

These thrusters, like all other components on ***ICE***, are securely attached to the frame by stainless steel machine screws and lock nuts. The position and orientation of the motor thrusters (as seen in figure 4) was chosen based on efficiency. We have two individually powered vertical thrusters onboard ***ICE***. These are positioned symmetrically both starboard and portside. Our four horizontal thrusters are located on 90o radians from the centre of the ROV,, so that the weight is equally balanced throughout. They are vectored at 30° from the forward axis. This configuration allows ***ICE*** to move in all axes rapidly and provides incredible precision. The vectoring of the horizontals ensures that thrust from the respective verticals remains unobstructed and offers movement in sideways direction (Yaw), as well as forward and reverse (Surge), rotation turning (Pitch) and vertically(Heave)

4.5 Pneumatics

All manually-operated controls on ***ICE*** are pneumatically actuated. Fluid power was chosen as the safest, most reliable and most efficient option. This is because it uses a power source which does not compete for electrical power. The OD-4D staff is extremely familiar with pneumatic power. It has proven to be safe and efficient in the past, so we decided not to make unnecessary changes.

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 5) in which manual, two-way valves divert the pneumatic power to ***ICE***'s onboard tools through individual 1/8" OD flexible polyethylene tubes.

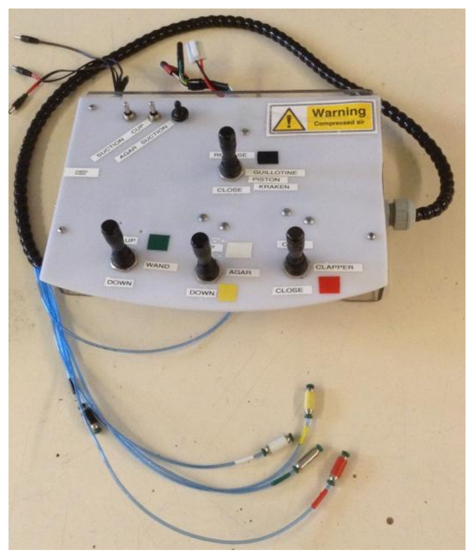


Figure 5: Co-pilot's Console

Three 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" OD tubes; this pressure is rated to 250 psi. The pneumatics required for the mission tasks this year are:

i. one, double-acting pneumatic cylinder that is powered by a pair of pneumatic tubes to operate the "*Claw"*
ii. one, double-acting pneumatic cylinder which operates the "*Clapper*"
iii. one double-acting pneumatic rotary cylinder and one single-action pneumatic cylinder to operate *"Magneto"*

4.6 Buoyancy

To achieve neutral buoyancy on ***ICE,*** our company incorporated various strategies. Our primary source of buoyancy comes from our acrylic electronics "can". The "can" is

30 cm in length and has an inside diameter of 10.2cm with a dome on the front. The total volume of the can is 1.5 L.

We also have a neutrally buoyant tether to assist in the vehicle's overall buoyancy. This is achieved through the use of a floating housing wrapped around our primary tether. In the secondary tether, neutral buoyancy is maintained with an appropriate combination of pneumatic tubes and sinking wire.

Finally, ***ICE*** is neutrally buoyant due to the entire chassis being made of high-density polyethylene (HDPE). HDPE has a density of 0.96 g/cm^3. This gives our entire structure floatation to balance out the additional weight of our tools and thrusters on the ROV.

All of the materials used in the design of the ROV were chosen strategically to achieve overall neutral buoyancy. We fabricated ***ICE*** in such a way that makes it easy to adjust the weight of the vehicle, in the case that any modifications must be done to the onboard tools or components. This way, we can ensure that the ROV is always impeccably buoyant.

4.7 Sensors

We use a number of cameras and sensors onboard ***ICE***, each chosen to serve their specific purpose effectively. As with all components of ***ICE,*** we underwent an extensive group brainstorming, design and refinement process before deciding on which sensors and cameras would be used on our ROV, as well as their placement and orientation. The sensors onboard our ROV include:

i. A Phidgets™ humidity and temperature sensor, which is mounted inside of our onboard electronics can. This sensor is able to monitor the conditions inside the can, and detect any potential water leaks that may damage our electronics, or the overheating of components that may also damage our electronics.

ii. A Vernier Lab Quest Mini temperature sensor, which will be mounted in our claw. This sensor will be used to measure the temperature of the venting fluid. Our temperature sensor has an accuracy of 0.1^{o}C.

Our ROV also features two SS AquaCams™ these use a 540 TV line resolution and composite video signal. We use these cameras due to the fact they are extremely reliable. Throughout many test runs this year, we have not once encountered a problem with these cameras. They are also waterproof, eliminating the need to make a protective casing around them. The cameras are mounted such that they offer a fully optimized field of view:

Figure 6: SS AquaCam™

i. "Nav Cam" is mounted inside of the electronics can, facing forward in order to provide the necessary angle to effectively navigate between mission props.

ii. "Tool Cam" is mounted on a bracket which extends above the ROV, in order to provide a "Birds Eye View" of our tools. This is needed when performing very precise tasks.

4.8 Tether

Our tether was chosen because it is lightweight and compact, while also containing all of the necessary components. It is comprised of two portions: the primary and secondary tether.

4.8.1 Primary Tether

Our Primary tether is bonded to a flotation jacket that makes it neutrally buoyant. It was donated to us from Leoni-Elocab™. It includes:

i. 2- 12 gauge copper wires for power. Black is ground and red is positive
ii. 8- 22 gauge Ethernet cables in twisted pairs, through all signals to the motors, as well as the signal from our digital camera, are transmitted.
iii. Coax cable-75Ω (unused in the current configuration)

4.8.2 Secondary Tether

Our secondary tether includes:

i. 3- 1/8 inch OD pneumatic hose, used to supply air in order to power our onboard pneumatic tools.
ii. 1- coax cable-75Ω, which is used to transmit the signal from our TV video camera to the surface.

4.9 Electronics

4.9.1 Topside Control Electronics

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

We use a laptop as a central hub for all our electronics and video distribution. We send our joystick signals to the computer through a USB signal, this data is then processed and sent to our on-board computer, a Phidgets™ SBC (Single Board Computer). The SBC then relays information to various sensors, as well as sending our video signals to us. These are MJEG which we can view on various devices as it is stored on a web service. It also sends data to our Phidgets™ 8-Pin Advanced Servo Controller. The Advanced Servo Controller controls our six Afro ESC's (Electronic Speed Control) which in turn controls our 6 BlueRobotics™ -100 thrusters. The SBC receives signals from the fiber optic wires in our tether and then tells the motors ESC's how to act. Having six ESC's provides us with the ability to have independent control of all our thrusters and allows us to work with our ROV even if one motor fails. We also use this independent control to allow our ROV to sway as the motors are vectored at 30^o.

Table 3: Topside Proportional control process

Joystick Control	Signal	Processor	Function
Joystick Y axis (SURGE)	Analog Proportional	*Phidgets™* 8-servo controller	Hor. thrusters forward and reverse
Joystick X- axis diagonal (mixes X & Y axes)	Analog Proportional	*Phidgets™* 8-servo controller	Hor. thrusters move ROV Stbd. or Port
Joystick Rotation (ROTATE - YAW)	Analog Proportional	*Phidgets™* 8-servo controller	Hor. thrusters in opposite directions
Joystick Full X (SWAY)	Analog w/ dead band	*Phidgets™* 8-servo controller	Vert. thrusters roll and sway ROV
Throttle toggle (HEAVE)	Analog Proportional	*Phidgets™* 8-servo controller	Vert. thrusters up/down

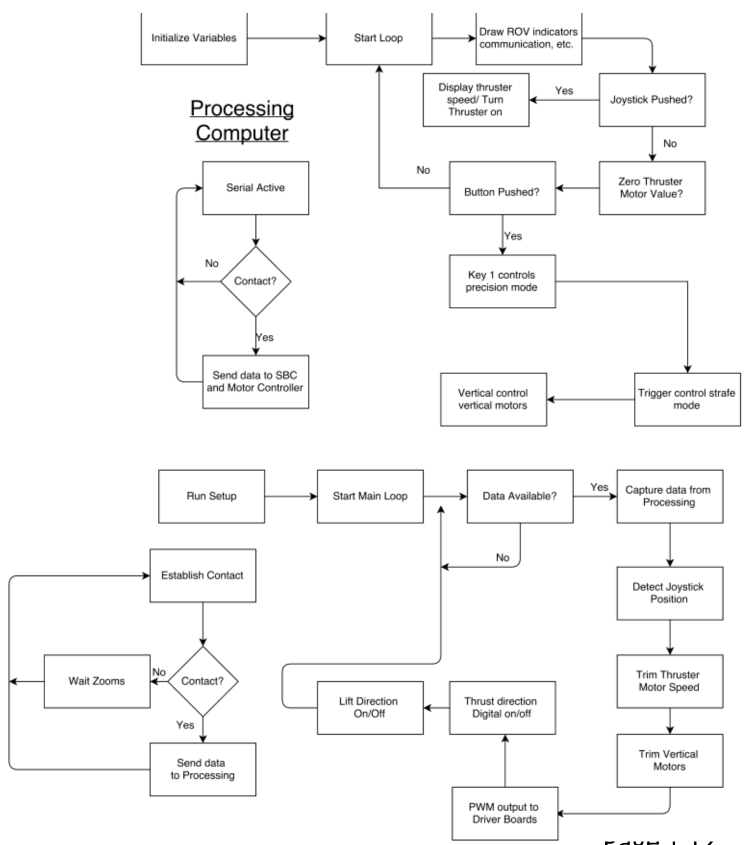
4.9.2 Software

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 due to the following reasons:

i. it is a more widely used language in industry and research than Visual Basic, which is more commonly used in schools.
ii. it was free, from Microsoft, Inc., 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.

Figure 7: C# Software Flowchart



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

<u>Input Operations:</u>

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.

<u>Processing Operations:</u>

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

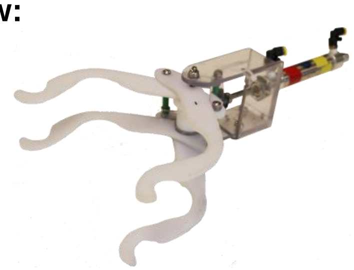
<u>Output Operations:</u>

Mixing the ranges of horizontal thrusters (ex. +500 in the Port and +500 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.

4.10 Payload Tools

To avoid complications with electronics and to promote safety, our tools actuate using surface-supplied pneumatic air pressure. All of the tools are made predominantly of Lexan™ and HDPE as these are light-weight, cost effective and durable materials. All tools were chosen based on an intensive trial process which involved group brainstorming followed by individual research.

Table 4: Payload Tools and Description

Tool	Description	Task
Claw: 	Two-level gripper spaced vertically such that it can hold a number of mission props. Effectively designed to successfully complete various mission tasks.	• Moving coral and oil samples • Flipping and transporting CubeSats • Attaching flange and cap
Clapper: 	Pneumatic powered Lexan™ gripper which can hold a variety of attachments and props. Efficient multiuse tool which was designed to complete a multitude of tasks.	• Moving coral and oil samples • Flipping and transporting CubeSats • Inserting temperature sensor • Retrieving cable connector • Opening door to power and communications hub • Installing connector to port

4.11 Attachments

Our main tools were built to support multiple attachments. After analyzing all of our options as a company, we decided to design these attachments separate from the ROV to avoid bulkiness and to enhance the effectiveness of the overall structure while these components are not in use.

Table 5: Attachments and Description

Tool	Description	Task
Magneto: 	The *Magneto* is a contained magnet powered by pneumatic piston. The cylindrical structure is mounted on a rotary actuator which allows the tool to rotate 90°.	• Retrieving bolts • Inserting bolts into wellhead
Measuring Tape: 	In contrast with *Magneto*, the measuring tape is our most simplistic component. A tradesman's measuring tape is held by the *Clapper* with a plastic loop on the end to complete the measurement portion of the competition.	• Measuring ice thickness and water depth

5.0 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. 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 incidents happened this year. A new member was using the band saw without safety glasses. Fortunately we saw what that member was doing and we stopped him. Although it was only a moment of forgetfulness we had to take it very seriously due to the importance of safety in the shop. That member was 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. All of these protocols have been set in place to ensure staff members remain safe at all times.

6.0 CHALLENGES

6.1 Organizational

OD-4D is fortunate to have such a diverse group of very passionate and devoted members. Many of our staff members are quite talented in other areas, from fine arts to sports. 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. We started by meeting on Wednesdays, which worked out to be the best day for all staff. As competition approached, time commitments increased and each day after class, available members would meet and work on their own pieces. On Wednesdays when everyone was present, individual work was presented to the group. As a result of our optimal planning, the company overcame this challenge. Our group members have come to appreciate the importance of teamwork, and filling in when needed.

6.2 Technical

ROV Size: One issue we faced when designing the ROV was ensuring that it fit the size and weight requirements. ***ICE*** and its tools were fabricated using light weight materials such as Lexan™ and HDPE. Our frame underwent several trials before finally reaching the final product, which proved to be sleek, compact and light weight, while still maintaining its robustness and reliability.

Electronics Can: This year, we made the decision to incorporate onboard electronics into our ROV. This brought it's own set of challenges. Firstly, we encountered some problems with fitting all of the necessary electronic components into the can. Eventually, with an extensive process of design and refinement, as well as the shortening of many cables, that were far longer than they needed to be, we were able to incorporate all the components needed. Another challenge presented to us by our new onboard electronics was devising a method of keeping them all waterproof. In our first few practice sessions, we encountered problems with small amounts of water leaking into our electronics can. This was able to be fixed by changing out an O-ring, that was too small, and utilizing waterproof caulking in areas that may be susceptible to water. We considered falling back to our old method of topside electronics, but the company worked as a unit to overcome the challenges presented.

The Claw: One of our tool designs this year is the claw, a multi-level gripper, spaced vertically such that it can hold a number of mission props, for example, the well-head flange and caps. We ran into trouble with this tool, as the grippers did not open wide enough to grasp neither the flange nor cap after the pneumatic piston was released. The tool was thoroughly analyzed and the company made necessary modifications such that it now works to its full potential.

7.0 TROUBLESHOOTING TECHNIQUES

To ensure that troubleshooting goes smoothly, we follow the "Circle the Wagons" method. We look at each of our main systems, such as our computer, and co-pilot's console and draw an imaginary circle around each. We then examine each input, output, and power conductor which passes the imaginary boundary for any signs of 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.

In addition to the electronic troubleshooting, there are physical refinements which sometimes need to be made. For example, 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 electronics/buoyancy tube alone has undergone many design refinements and tests. We find that physical testing is the best way to ensure that any problems in design are fixed.

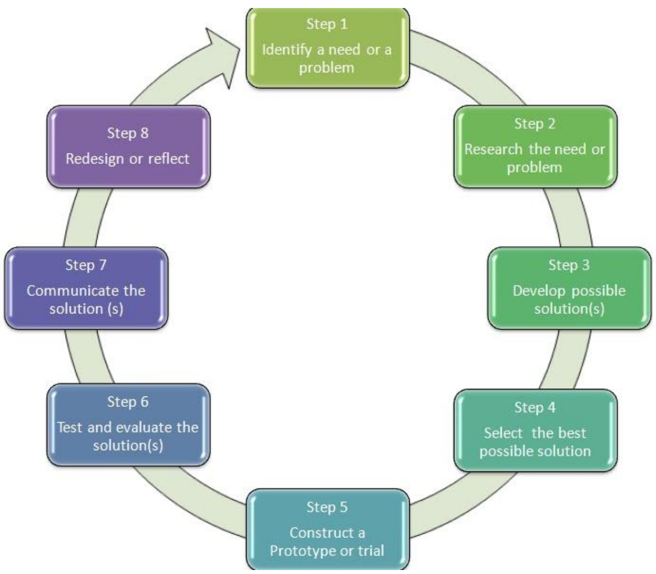


Figure 8: "Circle the Wagons" troubleshooting process

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.

8.0 VEHICLE SYSTEMS

Figure 9: Solidworks frame

The vast majority of our components have been designed and built in-house. The basic HDPE frame for ***ICE*** was originally designed using Solidworks™ (As seen in figure 9) to be very adaptable to different mission tasks and to fit size and weight requirements. The frame and tools are made predominantly of Lexan™ and HDPE as they are light-weight, cost effective materials. Due to the new size and weight bonus points this year that our previous model could not possibly have reached, we decided to start from scratch on an entirely new ROV. We used the unique opportunity to explore each possibility for the components of the ROV, and pick the best solution in each area. Because of this, the vast majority of components on our ROV are brand new this year. Some of the new components include:

- Frame. Our frame this year is all new, and was specifically designed to fit the new size and weight requirements, while still maintain a certain standard of robustness, and still being able to complete all mission tasks efficiently.
- Tether. Our tether for this year is completely new, as we needed to find one that could be much lighter, in helping to reach the weight bonus points. Our tether this year utilizes Ethernet for all signals, and uses a much smaller jacket.
- Electronics. Our electronic components this year were entirely re-designed. We decided to make the transition from topside to onboard electronic systems. The components contained within our electronic systems were also altered to account for our change to using Ethernet.
- Programming. Our programming this year, while similar, went through some changes. It was reviewed and simplified by our team of computer scientists. It was also altered to account for the addition of sway, as well as the change from brushed to brushless motors.
- Tools. All of the tools this year, while partially influenced by previous designs, have been completely remade and specifically designed to correspond to this year's specific set of mission criteria.

Of course, some of the components of our previous model were found to serve their purpose perfectly, so they were retained. These include:

- Our SS Aqua cam TV cameras. After extensive use and testing of webcams, they were found to be extremely unreliable. For this reason, we returned to the TV signal cameras we had used in previous years.
- ‘*The Kraken*’. Our topside copilot’s console, which controls our pneumatics, was retained from last year. We evaluated possibilities for replacements, but found none that could accomplish the task more efficiently that our old ‘*Kraken*’

At the beginning of this year, our company evaluated each of the systems that would be utilized in the design of our ROV, and determined which could be constructed “in-house” and which would have to be purchased. We looked to manufacture components ourselves whenever possible.

Examples of original components include:

- Frame. Our ROV frame was designed, manufactured and assembled by our company, without external commercial assistance.
- Programming. Our software was designed and written by our team of computer scientists with assistance from former members.
- Tools. All of the tools utilized on our vehicle were sketched, prototyped, tested and refined by our experts in the field of Tool design and fabrication.

It was outside of the realistic resources of our company to construct some components. These include:

- Electronics. It was unrealistic for our company to manufacture individual electronic components. Each of these was either purchased or donated. The entire electronics system however was designed and assembled by our company staff technicians.
- Tether: The tether that was utilized this year was donated to our company by Leoni-Elocab, Kitchener, Ontario, Canada..
- Thrusters: The thrusters used by our company were purchased from BlueRobotics, mainly because they were of a much higher quality than could have been made by our members.

The team’s original 2016 budget was developed based on an extensive design process. A totally new ROV design was demanded by the specifications of this year’s unique missions. As design is a rather fluid process, so was the budget. New components in the 2016 budget included structural frame, thrusters, electronics, tether, buoyancy/ electronics containers, and of course a totally new array of tools. Enhancements in all these components were needed as the testing and redesign process proceeded.

9.0 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. We were introduced to not only a variety of useful technical skills, but also to a new way of looking at the world.

Some of the more 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.

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 even the exciting potential in outer space
ii. We have learned that learning by the book is but one way, and that the problem solving approach to learning is an excellent preparation for dealing with the issues of an adult world
iii. We have come to realize that the essential skills of planning and organizing require time and management. This comes into play in other aspects of life as well, specifically for those preparing for post-secondary and future careers

10.0 FUTURE IMPROVEMENT

In the future, OD4D would like to improve our weight and reliability. There is currently an excess of weight on the ROV's frame. This weight is caused by the necessary tools on the ROV frame. Our company has been looking into materials that are lighter weight and also more durable than our current materials. Our company has not yet found a material that fits these two categories but our researchers will continue to look for new ways to improve our ROV.

Reliability has been a problem with some of our company's electronics, mostly due to the major changes that our company's ROV has undergone this year. Changing brands for electronics was risky but was a necessary evil to push our ROV ahead. In the future our company will work these bugs out and ensure trust and reliability in our company's products.

11.0 TEAMWORK

The team has been meeting devotedly throughout the year. We drafted a development schedule (Appendix A) so that we would stay on track. Extra meetings were scheduled when we found our progress was slow and 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.

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. Many of our new members fluctuated from one group to another to see where their skills would be put to the best use.

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

Figure 10: Team members during a group discussion

One section of the company focused on the payload tools and overall functionality of the ROV, another keyed in on electronics and software, and one group worked on graphic design and presentation. 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. The three teams worked jointly to create a final product which all staff members are extremely pleased with.

12.0 REFLECTIONS

Our company has made many significant accomplishments over the past year. Some of these include our growth as individuals and as a team, the standards we have met and exceeded, the knowledge we have gained and the knowledge we will pass on to future robotics teams. We have made significant advancements on our ROV, and most notably, we have earned the opportunity to compete on an international level for the sixth 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. The skills and knowledge that we have gained through this experience will undoubtedly contribute to our individual career paths, as many of our senior members plan to pursue studies in STEM areas.

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.

13.0 ACKNOWLEDGEMENTS AND SOURCES

13.1 Financial Contributors and Donations in Kind

OD-4D’s success would not have been made possible without the continuous support of numerous bodies. We would like to start by sending our thanks to our generous sponsors identified in Table 6. We would also like to thank our mentors for contributing their personal time and knowledge to help us conquer all challenges, as well as supporting us in all we do.

We thank the many volunteers, along with the MATE center for making this competition possible. The practical skills and knowledge we have gained from this experience will stay with us for the rest of our lives.

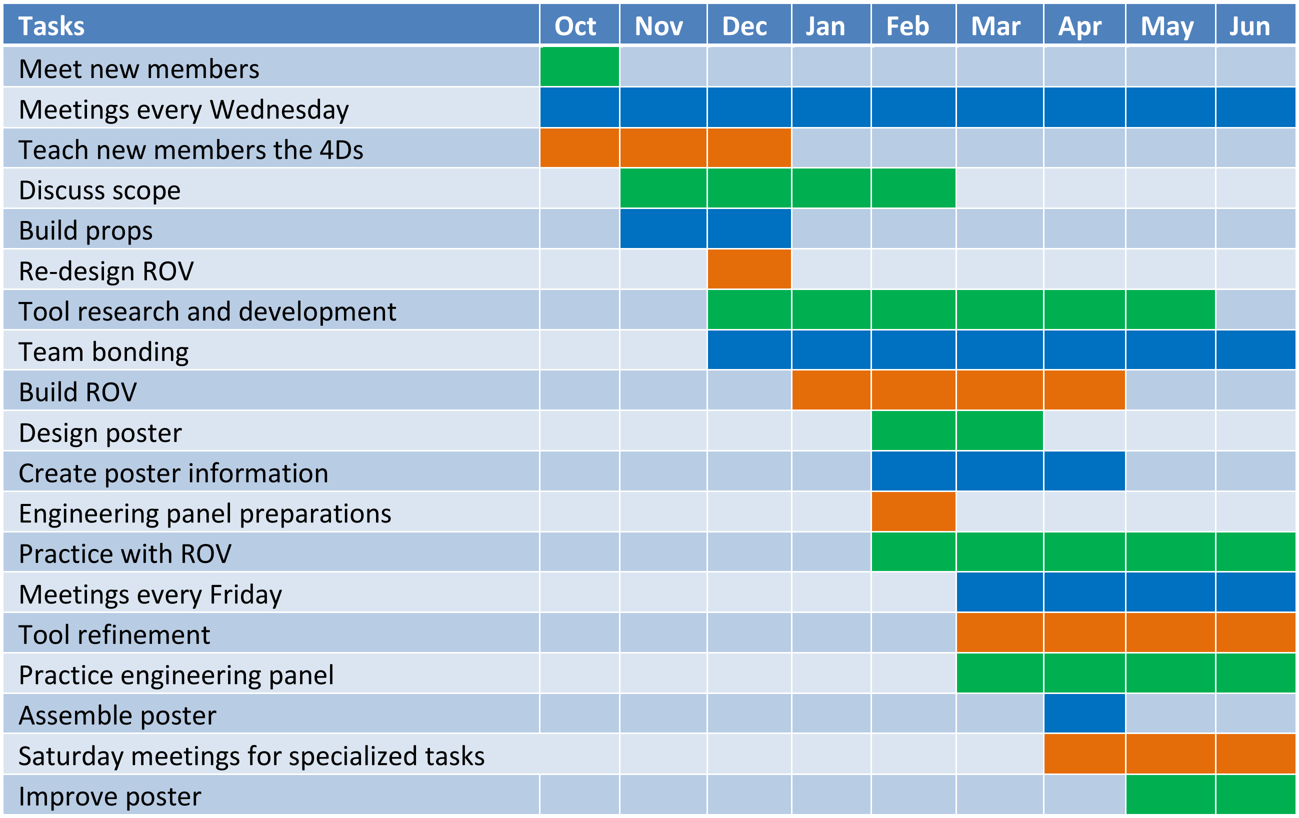
Table 6: Contributors and Supporters

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)**

13.2 Sources

www.marinetech.org
wolfcs.net/ssaquacam.php
https://www.bluerobotics.com/store/thrusters/t100-thruster/
http://www.phidgets.com/
Anderson, T. (2004). C# in Easy Steps. United Kingdom: Computer Step.

APPENDIX A: OD-4D DEVELOPMENT SCHEDULE



APPENDIX B: ROV OPERATIONS SAFETY CHECKLIST

Pre-mission preperation:

- 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"***

APPENDIX C: 2015-2016 BUDGET

OD-4D is an experienced company in the field of underwater robotics. Through research and our prior knowledge, we were able to create a realistic budget to plan our financial expenses for the project. Of course, the company chose to reuse some components from last year which helped lower the cost. Our plan to reuse was considered when creating our budget. Since we are a school-based company, our funding is generally limited. We committed to following this guideline to ensure that we did not spend an unreasonable amount of money.

Table 7: 2015-2016 budget

	Item	Expected Amount ($US)
Expenses	ROV components	2000.00
	Competition entry fee	100.00
	Travel Costs ($750 each)	11 250.00
	Competition accommodations	8500.00
	Expenses	**21 850.00**
Income	Staff fundraising	2000.00
	Marine institute regional winner contribution	15 000.00
	Individual contributions	4500.00
	Income	**21 500.00**
	Total Expenses	***350.00***