MATE 2017 INTERNATIONAL ROV COMPETITION

O'DONEL HIGH - OD4D

TECHNOLOGY REPORT

MOUNT PEARL, NEWFOUNDLAND

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Abstract

OD-4D is a wholly owned subsidiary of O'Donel High School, Mount Pearl, Newfoundland, Canada. OD-4D undertakes technological design, development and fabrication in the underwater environment. ROV ***ICE*** is specifically configured to support the need for ROVs in sea exploration, as well in the confined and precarious conditions of ports and harbors. ***ICE*** is equipped with an array of tools, each designed, fabricated, tested and modified with specific tasks in mind. We followed a stepwise design procedure for each tool. "Clarify the problem. Explore the ideas. Create a design drawing. Make it. Test it. Modify it. Test it. Problem solved!" ***ICE*** is equipped with several innovative and diverse tools. Our gripping ***Claw*** is designed for manipulation of mission props and holding additional, detachable tools such as our Valve Spinner (Mission 2) and Agar Collector (Mission 3). Each of the tasks present at this year's MATE competition relate to application of ROVs to four, major, real world sectors, especially within the Port of Long Beach. First, the use of ROVs in the commerce sector, to further expedite the delivery of goods. Second, in the entertainment sector, to provide maintenance ensuring uninterrupted water and light shows. Finally, ROVs are used for two missions within the health and safety sectors, to protect the people from contaminants and environmental accidents, allowing the port to operate at its full capacity.

ROV SPECS:

ROV name: ***ICE***, Innovative Competition Entry

ROV size: 40cm x 30cm x 50cm

ROV weight: 10.7kg (including tether and tools)

Total cost of New Materials for 2017: $1,505 USD

Value of Recycled Materials on ROV: $3,148 USD

Total Student commitment: 1200 hours

Safety features: Commercial electrical connectors, rounded frame, no sharp projections, shrouded thrusters, labelled, hi-grade electrical and electronics components, 25A circuit breaker at power source.

Special features: All tools are multi-function, non-corroding, unique and proprietary - designed and fabricated in-house, mounted on our CNC router floating frame (Expanded PVC Foam) and tool skid (which can be separated from thruster unit); high maneuverability achieved by 30° thruster vectoring, multiple POV digital video cameras.

Figure 1: ROV ICE (Innovative Competition Entry)

Teamwork

Striving for efficiency, our team has been meeting devotedly throughout the year. During the design, building and testing process the team met on Wednesday afternoons starting in October. We then drafted a structured and individualized development schedule (Table 1, below) allowing our team to 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 including; design ideas of different mission specific tools, ways to modify and improve our frame to achieve a robust and maneuverable model, along with buoyancy, propulsion, electronics, software, and all systems required to develop our fully functioning ROV.

We often dispersed into separate, smaller groups to promote teamwork and achieve goals both quickly and efficiently. Each team member was assigned a different role and focus area based on individual skills set and area of interest. Our team is divided into two primary branches: Engineering and Communications.

Table 1: Staff Development Schedule 2016-2017

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

The Engineering Branch is divided into five sub-departments; ROV Operations, Electronics, Research, Tool Design and Fabrication. The engineering departments are responsible for all electronic components and controls along with software design, programming and all physical structures on the ROV. The team uses i. design software fabrication techniques such as Solidworks™, MasterCAM ™; ii. fabrication techniques which include and CNC (Computer Numerical Control) router operations and 3-D printing in addition to standard electrical and manual tools; and iii. C# programming for electronic remote sensing and control. Our Communications Branch focuses on Technical Writing, Public Relations and Graphic Design. The responsibilities of the team's communications branch include i. composing the team's technical document, ii. researching and supplying information for the marketing display and website, iii. writing press releases, and iv. organizing opportunities for the entire design and fabrication team to participate in various community outreach activities with younger students.

Dividing our group into these two functional Departments facilitated streamlined decision-making and intra-group communications, and allowed each department to primarily focus on the area that best suited the expertise of its employees. This team organization kept our design process and fabrication running smoothly and cooperatively. Many of our new employees moved between the two groups during the first three months (October-December), observing the proceedings, assessing the roles they wished to adopt, contributing whenever they could; learning the ropes and eventually deciding which of the departments they preferred. Each employee became fluent in the focal activities of that Department and joined specific mission teams. Therefore, they became proficient in tasks such as writing technical reports and effectively communicating their work during sales presentations. A core value of our firm is the belief that the most innovative ideas surface when many talented individuals are involved in the creation process. Our firm's track record in designing and the competitive performance of our underwater robotics products over the past several years lends credence to that inclusive approach. Through this system each individual is able to achieve great things, and in turn, our company flourishes.

Figure 2: Staff of OD-4D

Back Row (L-R): T. Galiullin, P. Breen, E. Hurley, C. Rose, R. Murphy, M. Butt, M. Chislett.
Middle Row (L-R): I. O'Rielly, A. Pike, C. Payne, Z. Norman, K. Flynn, J. Edwards, J. Hatcher.
Front Row (L-R): J. Mosher, L. O'Keefe, H. Alway, M. Mosher, M. Glover, I. Parsons, Z. Froude.

Design Rationale

Design Process

In December 2016, before we started the design process for a multi-purpose ROV, the entire staff of OD-4D carefully examined and analyzed the mission tasks involved. This research provided a thorough understanding of the required design features. The process included the entire staff participating in 'role playing' the mission tasks using a mock ROV and tether to accurately visualize and understand them. This comprehension was crucial to guiding the design process and shortened it significantly by reducing the number of design iterations and prototypes required. This shortened the time required to produce not only a highly functional ROV, but the topsides modules and onboard tools. The quest for perfection drives the cycles of technical refinement which has been the hallmark of our continued success. **All** components of our vehicle are designed and built in-house. All components on ***ICE*** were approved only after rigorous testing.

This analysis produced the following list of Design Specifications:

i. Small size (width and height <48 cm) light weight (<11kg).
ii. Adequate carrying capacity for tools and materials.
iii. Capable of multi-axis movement and maneuverability.
iv. Capable of low-speed, precision movement.
v. Handling a variety of specialized tools, held by a multi-purpose gripper.
vi. Multiple, high resolution, video-camera views.
vii. Tools which are multifunction.
viii. Adequate thruster force for movement and lifting.
ix. Simple, intuitive ROV controls and payload tools.

The stepwise for the design cycle described below ensures that ***ICE*** is as efficient as possible. This includes:

i. Clarify the problem.
ii. Investigate and Research prior art.
iii. Brainstorm ideas for new designs.
iv. Create multiple independent designs (CAD).
v. Evaluate these potential designs against mission objectives.
vi. Fabricate proof-of-concept prototypes.
vii. Test prototypes on mission tasks and evaluate performance.
viii. Brainstorm improvements.
ix. Test according to mission tasks.
x. Decision on next steps; either approve design or brainstorm more effective ideas.

Through this process, our team was able to create superior final products, capable of completing all tasks safely and complying with all size and weight constraints. All design decisions are viewed as temporary only, and all components of the vehicle are in a continual state of testing and refinement. Our guiding principles in the ROV design process were:

i. Safety and ergonomic design.
ii. Conforms to weight and size limits.
iii. Vehicle performs superbly maneuvers adroitly, is agile and efficient.
iv. Vehicle and tool array achieve mission tasks efficiently and quickly.
v. Tools are multi-purpose for efficiency and above all effective in completing tasks.

ICE carries six (6) independently controlled 12V Blue Robotics™ T100 brushless thrusters permitting movement in six axes. Four thrusters are torqued at 30 degrees to the forward axis, permitting *Surge*, *Sway* and *Rotation* in the horizontal plane and two thrusters in the vertical axis permitting *heave* motion as well as *rotating* around the forward axis and allow three-dimensional movement.

The multi-purpose servo powered robotic hand or '***The Claw***" is used in all mission tasks and is an essential element in our design. Its utility spans all tasks; for example:

i. In Task #1, the claw removes a pin to release the chains holding the frame;
ii. In Task #2, the claw grasps and holds the fountain;
iii. In Task #3 the claw holds the agar suction tool and;
iv. In Task #4 it attaches a buoy marker to the U-bolt on the high-risk cargo container

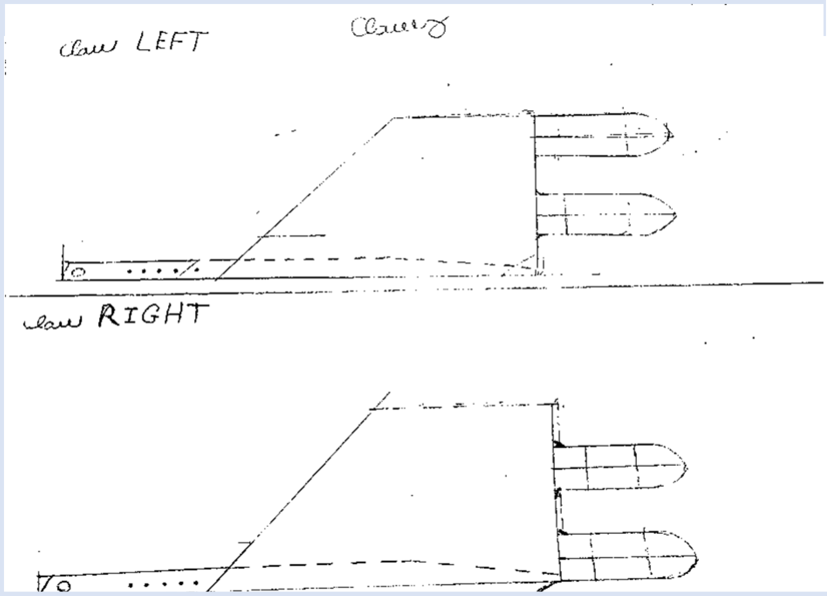


Figure 3: Mechanical Sketch of "The Claw"

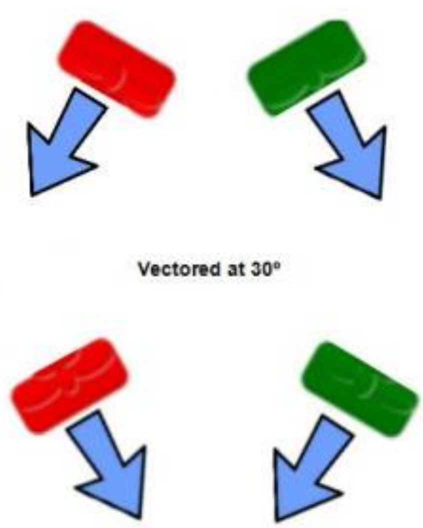


Figure 4: Thruster Orientation
"Vectored at 30⁰ from forward"

The ROV is structured around a rigid, light-weight, buoyant, PVC foam, flat chassis (½ the density of water), to which every major component of ***ICE*** is attached, including the waterproof, cylindrical Lexan™ electronics 'can'; 6 Blue Robotics™; The Claw; two video cameras and several tools. This overall engineering design makes the ROV compact and maneuverable while maintaining stability, efficiency and speed. This design permitted conformity to the dimensions and weight limitations of the missions, but is also crucial for completing Mission Task Two where the ROV must work inside the base of the fountain to disengage the locking mechanism. This totally new ROV design was demanded by the specifications of this year's unique missions. Design is a rather fluid process, and so was our budget. All materials were chosen based on three major criteria: their weight, cost, and functionality. This was often a very difficult tradeoff, and the perfect compromise required a great deal of research, testing and deliberation. The terrific product - ***ICE*** - was worth it!

Our ROV frame went through many sketches and prototypes before arriving at the current design, which was determined to be to be a clever compromise between the size and weight requirements and functionality. It is fabricated using an inexpensive rigid, buoyant, PVC (polyvinyl chloride) foam plastic which was also used for all prototyping and testing, prior to using more expensive plastics like Lexan™ (polycarbonate) or HDPE. Our team has assembled a new tether containing fiber optics for electronic control and sensing which is 4 meters longer than the one used in a previous design, while reducing the weight of the entire ROV system by 25%. It greatly increasing the speed and volume of 2-way data transmission.   Our previous ROV's systems of pneumatic tools was discarded for low voltage servo motor-powered tools following extensive research and testing of alternatives. A single, highly adaptable multi-functional gripping tool was designed for simplicity, weight reduction and reliability.

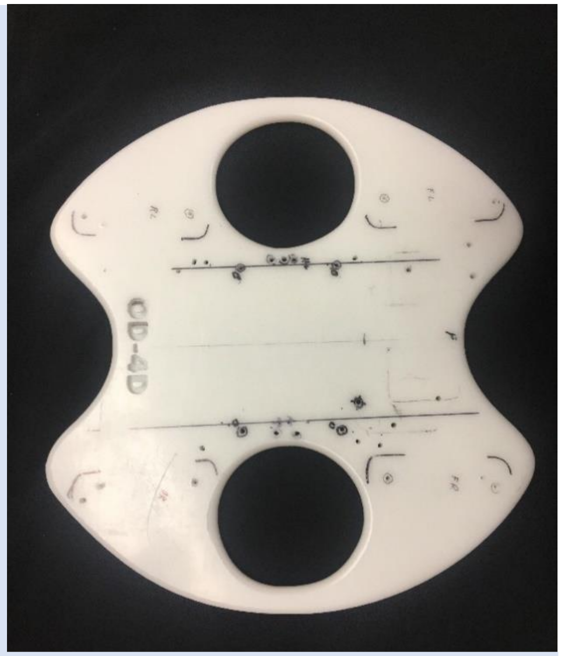


Figure 5: Prototype PVC Foam Frame

Scientific Principles

All the Mission Tasks in MATE's RFP for services this year real world situations entailing highly technical and complex problems. All members of our firm were required to research and understand the science behind the missions prior to designing technical solutions.

In Mission Task One, the Hyperloop will be the first of its kind and will revolutionize how major ports operate. The people of Long Beach have been affected by the pollution of the port for decades. With the Hyperloop, ships can stay further offshore to reduce pollution as well as make room for more ships to discharge cargo. The speed with which cargo can be delivered is also greatly improved with the installation of the Hyperloop. Much of the beautiful coastline is now being used as docks for cargo ships. The Hyperloop will help protect these coastlines from pollution and permit them to be used as parks or green spaces.

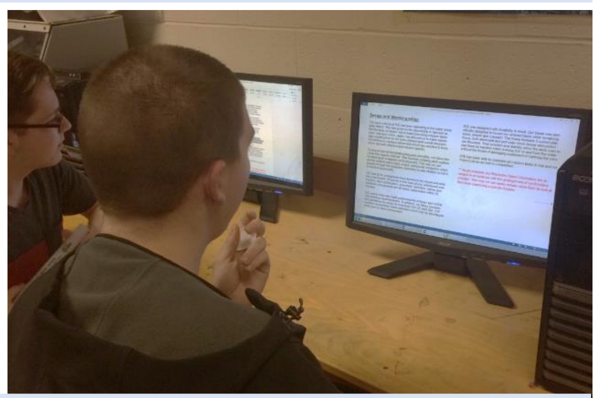


Figure 6: Staff Member Lawrence and Science Officer Clarke conducting vital exploratory research.

The light and water show at the Port of Long Beach is a major tourist attraction. The light display is robust and made to last, but routine maintenance is required. Maneuvering around the display can be a challenge for a crane and expensive for a person, but an ROV can get in the tight areas for little cost. The fountain is designed to be seen from a large distance away. This means the extremely high water pressure on the fountain poses a safety and operational challenge when working on or around it. Using an ROV minimizes the risk associated with that work.

Protecting the waters of our planet is a very important task we all must take part in. Some materials transported ship may contain toxins such as metals, chemicals and other contaminants. This poses a major environmental risk for the port and surrounding waters. While much of the contaminants are contained or recovered, there is legitimate concern that some may still remain. Raman spectroscopy can determine if there are any contaminants still on the seafloor and their nature. It involves shining a laser onto potentially contaminated areas of the seafloor to identify them and reveal the extent of the contamination.

Accidents happen! It is an unfortunate reality of port activity. The serious task of removal and remediation of contaminated areas fells to port officials before lasting damage occurs. Using a GPS (Geographic Positioning System) on our ROV, OD-4D can conduct these analyses much quicker and safer than with other sampling methods. Once detected, a contaminated area, such as from a lost cargo container must be identified, the extent of the problem and the danger level assessed, it must be marked using a buoy or transponder for imminent removal. There are many different contaminants that could wind up on the seafloor. Our ROV can identify the type of contaminant, the distribution of the contaminant, and facilitate its removal.

Our oceans are enormous, we have only explored 5% of the seawater that surrounds us. With the technology in our ROV, the fabrication and planning used, and scientific methods, we have manufactured an ROV with the capability to quickly explore and remediate areas never attempted.

Build vs Buy

Thanks to the expertise brought to the table by individuals at OD-4D, almost everything that is used in the fabrication of our robot is made, in-house, by company specialists. We are expert in the areas of frame, tools, electronics and tool design and fabrication. In conducting the Mission Tasks for this RFP, the design, assembly and control and programming of the ROV ***ICE,*** was achieved 90% in house. External components were purchased only when they were deemed either cost-effective or significantly more efficiently fabricated by other suppliers.

However, there were a few items that needed to be commercially acquired. These purchases were not made simply due to the difficulty of producing these items. The decision to buy our thrusters, tether units, and basic electronic components were all made after well conducted research, to ensure that what we were receiving would meet our standards.

Our thrusters, BlueRobotics™ T100s, were chosen due to their lightweight and sleek design. These are positioned to allow us optimal maneuverability (vectored at 30° on the forward axis). We decided that it would be better to allocate both our time and resources elsewhere, rather than manufacture these parts. As part of our total redesign from last year, we wanted to ensure that our thrusters were *up to par*, and purchasing them not only allowed for flexibility in design and function, but afforded more time for the development of Mission specific prototypes of novel tools.

Figure 7: 1 of 6 BlueRobotics™ T100 Thrusters on ***ICE***

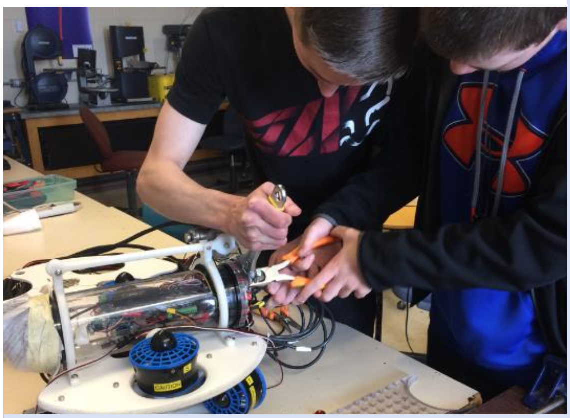


Figure 8: Staff Members Robin and Clarke working on Electronics.

OD-4D switched to USB communications in its tether this year, requiring a totally new design. The USB transmission distance limit was eliminated by using a USB to fiber optic media converters on either end of the tether. We produced this novel tether in-house, by purchasing the individual components of our tether and assembling everything. Some alternations in our C# programming was required for this new system, but it achieved the desired result of reducing the weight and dimensions of our entire ROV. Although the fiber optics components and converters, the specialized wiring and electronics and the flotation materials were purchased, the final product is unique and exceed our expectations.

One could consider the items purchased to be simply stepping stones, which permits the company's own development of more advanced elements. Each decision to purchase was thoroughly researched and only items we couldn't fabricate ourselves were considered for purchase. All technical and material choices were weighed discussed internally and OD-4D is very pleased to offer one of the best ROV's on the market today. ***ICE***'s well balanced mix of commercial and team fabricated items is what makes it a revolutionary and innovative product, effective and efficient in conducting the multi-task missions required by the Long Beach Port Authority.

Our company is very fortunate to have knowledgeable and skilled members in the electronics field. Through the purchase of basic electronic components, a more advanced control and communications system was developed for the ROV. All programming and systems design were completed by employees, in-house, and the investment of simple electronic components allowed us to focus on advancing greater functionality in our small ROV.

New vs Used

ICE has gone through 5 models over the past 5 years. Throughout all these models our ROV is almost entirely revamped. However, a few components have been reused over the years.

The main pieces reused this year were ***ICE***'s frame, our waterproof electronic "can's" end caps, our two cameras, and our motors. We decided to re-use our frame design with minor modifications because its size and shape has helped us to fit within the size limitations specified. In changing the frame material from HDPE to the lighter rigid PVC foam, weight was further reduced this year. We also found that in last year's performance the shape quite effectively. The aft end cap on ***ICE***'s electronics *can* were salvaged from last year because it had the required penetrator pattern for thrusters and conductors. In addition to bringing all these components from our ROV's previous model we brought our current cameras, analog SS Aquacam™, back from our previous year's ROV from two years ago as they provided superior resolution and contained LED lighting. Last year's attempt at digital camera use had slow transmission of the video signal.

Figure 9: SS Aquacam used for Navigation on ***ICE***

We chose to re-use our motors and Electronic Speed Controllers (ESCs) because in addition to being beyond or needs in propulsion the cost of new motors would not be justifiable.

This year, ***ICE's*** new components far outweigh the re-used ones. Our can, electronics, sensors, tether, tools, tool skid and our most important addition; our top-side control panel, known as our "Battle Box" are all completely redesigned. We chose to get a new Lexan™ tube to house our electronics because the thickness and weight of our previous year's acrylic model was unnecessary with no particular benefit. This year we have added an advanced servo controller because we have changed all of our tools operation from pneumatic pistons to small servo motors. This decreased weight and size dramatically.

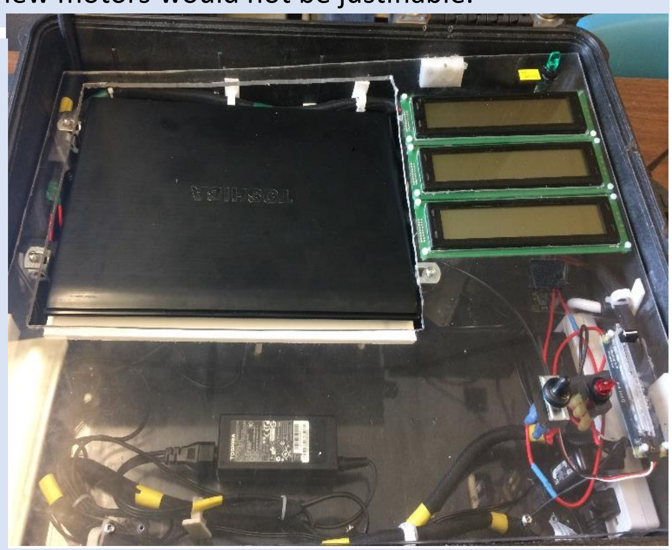


Figure 10: Topside View of the "Battle Box"

This year we added topside and on-board voltage and current sensors. This decision was due to us having power issues at times so we added these to help us fix the problem when it arises. Our tether was completely reengineered to our needs. Again, we found that our tether in our last model was insufficient to our needs. It didn't have the required wires we needed and was very heavy so we designed our own that not only had all the wires we needed but also was a fraction of the weight. Obviously, our tools are brand new this year as result of the missions requiring different tasks. Our agar pump for example was brand new this year to collect the sample of contaminated agar. The lower part of our chassis, the tool skid was fabricated for performance efficiency. Before this addition, we were not able to glide smoothly across the floor which greatly decreased the maneuverability of ***ICE***. We also had difficulty mounting our gripper so to fix this issue we added the tool skid. Finally, our "battle box" as we refer to it is our largest contribution this year. The battle box was made to make on deck set up much easier. Last time, our setup took far too long, often taking time away from our product demonstration.

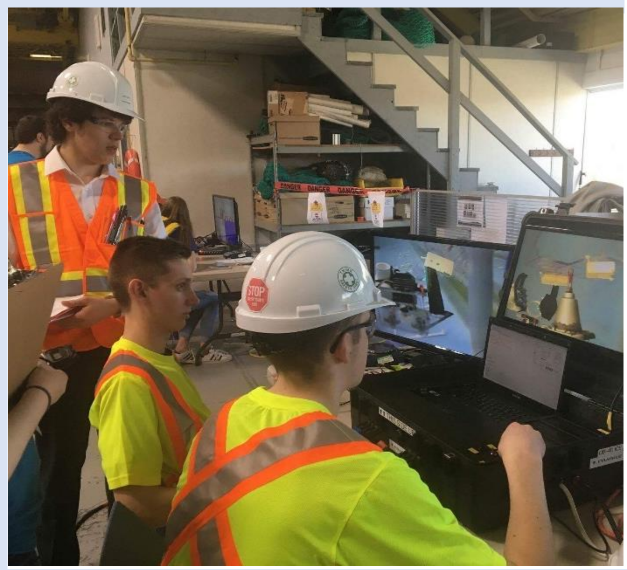
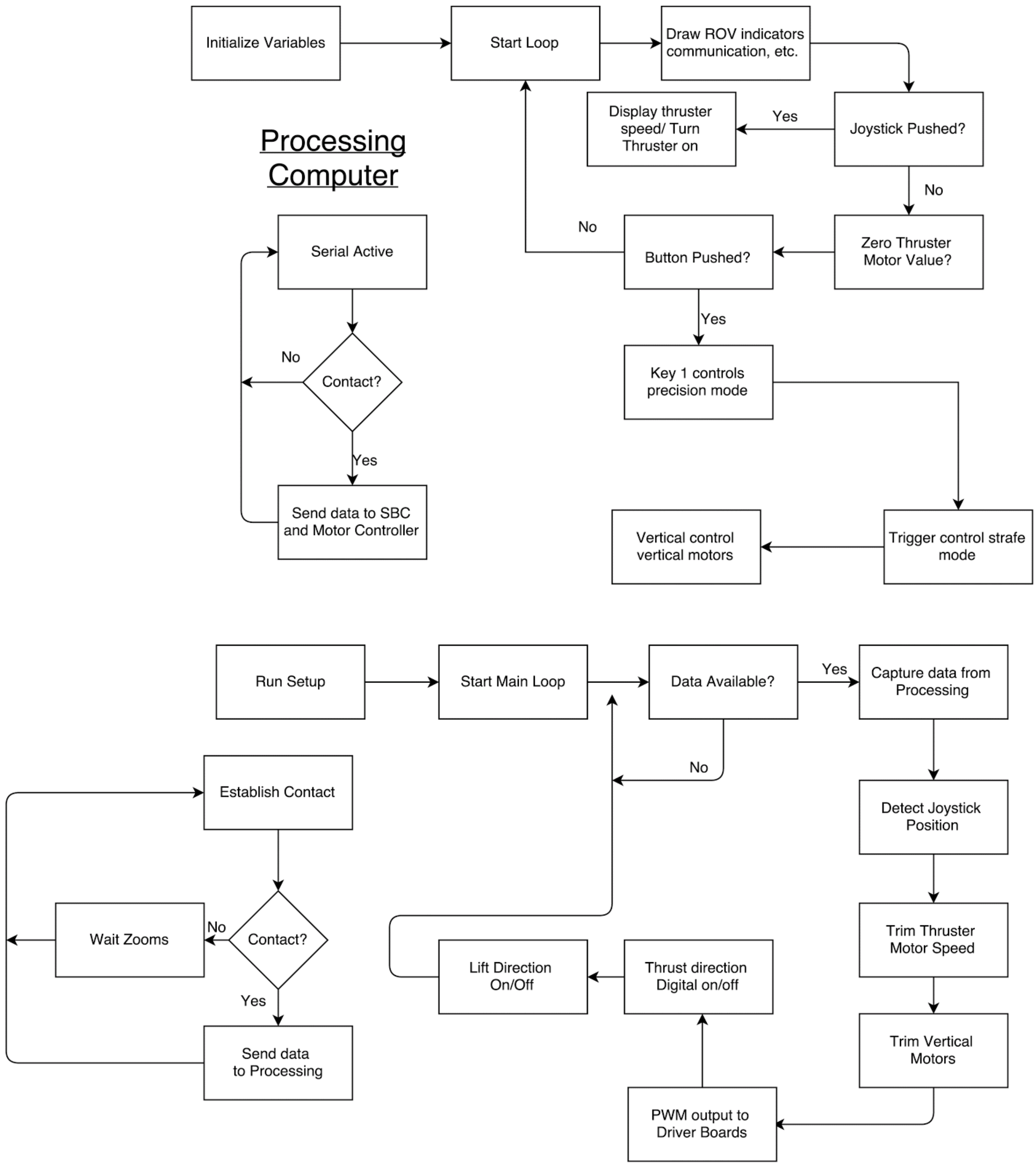


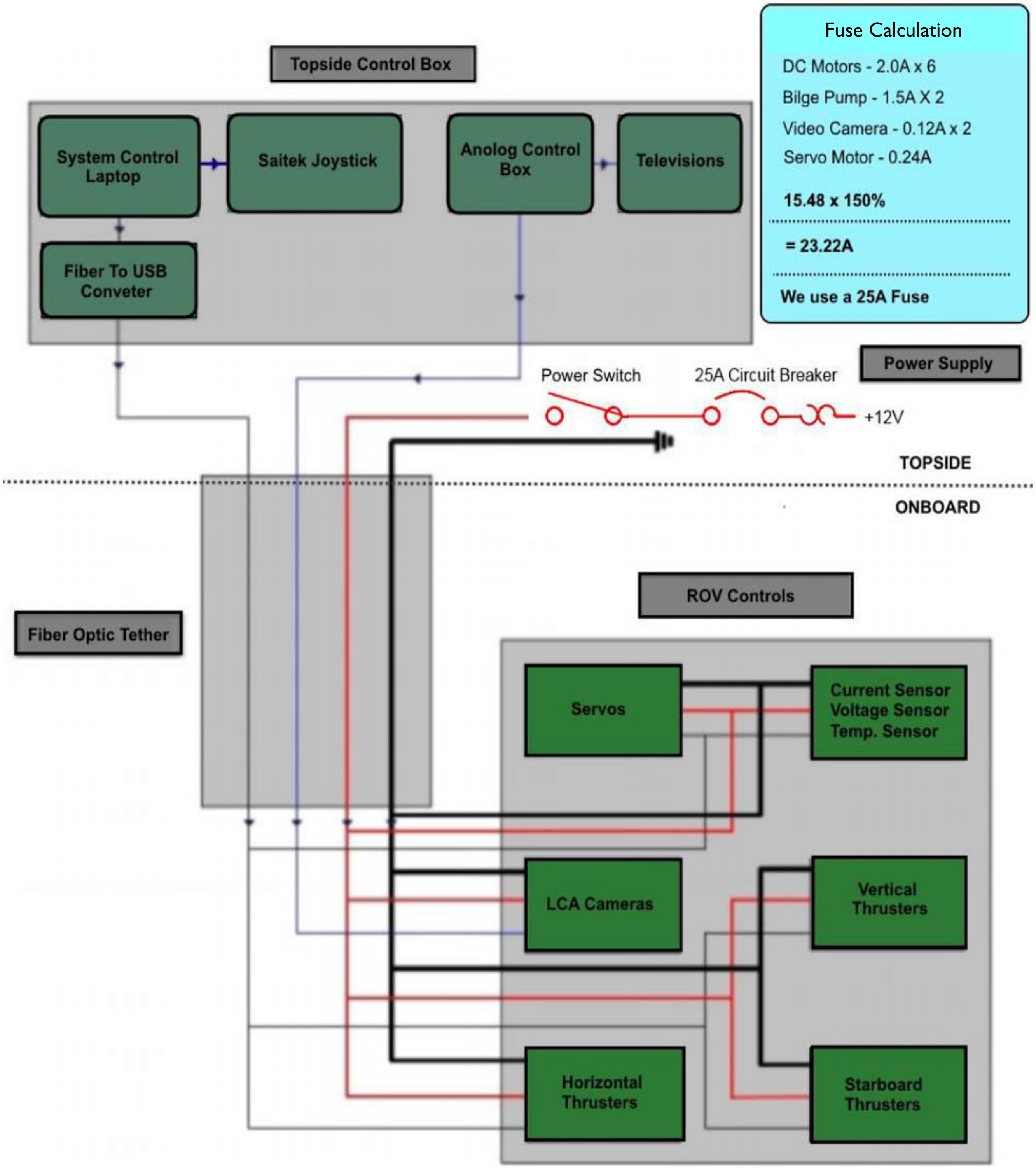
Figure 11: (Left) All New and Used Components on ROV ***ICE***

Figure 12: (Right) Deck Crew Members Joel, Robin and Matt in practice runs.

Software Flowchart



Systems Integration Diagram



Safety

Content

Safety is always our team's top priority. We like to say, "prepare and prevent, don't repair and repent." This reminds us that if we do not take proper precautions, we will have to face the repercussions of our actions. It is through this attitude that our company is able to ensure the safest product possible is produced, and that our employees always feel safe while working at OD-4D.

ICE is also designed with a number of safety features to ensure safety. These include:

i. Grates and Cowlings on thrusters
ii. Fasteners fitted so they don't snag skin or lines.
iii. Curved and rounded edges on the ROV frame.
iv. Warning labels on each of our six thrusters, and Servo motor
v. Electrical materials are enclosed within water tight containers
vi. 25A fuse to prevent electrical issues
vii. Kill switch in the event of emergency

Figure 13: Thruster #3 complete with warning labels.

ICE is continuously operated and tested with safety in mind. Every design decision on ***ICE*** is made with safety as the **first** priority, and our company always errs on the side of caution in every situation. All components of ***ICE*** have been meticulously examined to ensure they meet all safety criteria. We designed ***ICE*** to follow all safety protocols set out by the MATE center. We tested the current draw from our cameras, thrusters, and tools, and equipped ***ICE*** with a 25A fuse. ***ICE*** is designed to connect using Anderson Powerpole connections. ***ICE*** does not use battery power and has been stringently checked to ensure it has no loose connections or exposed wiring. We equipped our topside control console with a kill switch in case of any electrical emergencies. This topside control system has been designed in an organized manner, keeping wiring neat, and DC wiring separated from and easily distinguishable from AC wiring. All wires entering and leaving this system have proper strain relief. ***ICE*** does not use lasers or fluid power.

Procedures

Our company is proud to create a constant atmosphere and philosophy of safety through our strict adherence to safety protocols. We follow strict safety rules during all company meetings to ensure safety for all team members, such as:

i. Wearing close-toed shoes while in the workshop

ii. Tying back long hair while using tools

iii. Use of proper safety equipment like guards and safety glasses in the workshop

iv. Use of life jackets on the pool deck

All new company members are required to be properly instructed and observed by a more senior team member prior to using any tools. We also have an absolute rule of "NO HANDS" when power is on, which is strongly enforced for everyone handling and operating the vehicle. OD-4D uses several checklists to ensure all tasks are done with safety in mind, and all potential safety hazards are being dealt with accordingly.

Our Job Safety Analysis (JSA) is used to evaluate all tasks undertaken by our staff. It outlines the potential safety hazards posed by each, and the safety protocols that are strictly followed to prevent these hazards.

Table 2: Job Safety Analysis

Task	Safety Hazard	Safety Precaution
Carry ROV/Place in water	Tangled feet in tether	Strict tether management protocol
	Drop ROV on feet	Wearing close-toed shoes
	Back injury from improper lifting	Follow proper lifting technique Use of a trolley for transport
Testing ROV thrusters	Hands caught in thrusters	Proper Warning labels, cowlings, and grates Rule of "Hands off" when power on
Use of tools	Injury from sharp edges/ blades	Proper training prior to using tools. Use correct tools for tasks Use of proper protective equipment
Soldering	Inhalation of fumes	Solder in a properly ventilated area
	Risk of burning skin	Wear proper protective equipment Proper instruction prior to soldering
CNC Routering	Hearing Damage	Use ear plugs
	Eye damage	Always wear safety glasses Always close door when operating
	Cuts from spinning bit	Ensure bit has stopped spinning prior to opening door
Electronic Testing	Shock or Electrocution	Proper fuse No electronic testing around water

We also developed and use a pre-drive checklist. This highlights the steps that must be undertaken prior to any operation of the ROV in the water to ensure it is safe in every way. This checklist is followed closely, and any potential hazards are dealt with accordingly prior to the vehicle entering the water.

Table 3: Pre-Drive Checklist

Pre-mission preparations:	ROV Team In-transit:
• **All fasteners are tested and tightened**	• **Use a wheeled cart**
• **Electronics can is tested and tightened**	• **Secure equipment on wheeled cart**
• **Electronics booting up normally**	• **Wear safety vests for visibility.**
• **25A fuse installed inline**	• **Wear Safety Glasses at all times**
• **No exposed wires**	
• **All thrusters shrouded completely**	
• **Thrusters and tools functioning properly**	
• **Safety equipment available:** • **safety glasses** • ***fluorescent* vests and life jackets**	
• **Loose clothing removed**	

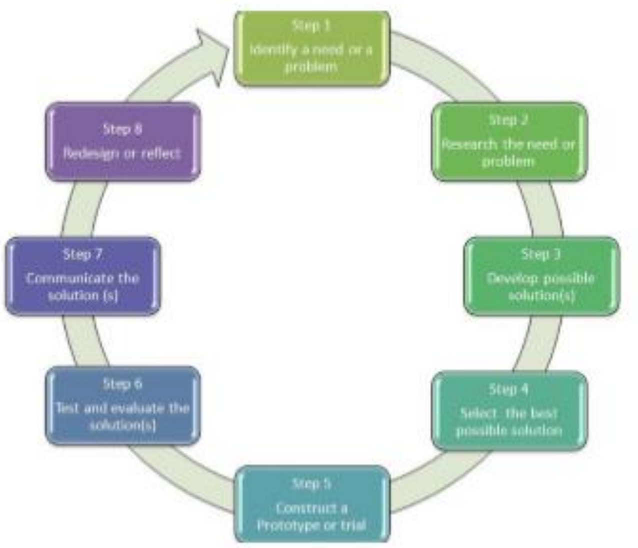
Figure 14: (Left) Staff Member following Safety Protocol after being instructed on power tools.

Figure 15: (Right) Deck Crew prepared with all pieces of safety equipment prior to mission tasks.

Testing and Troubleshooting

As soon as ***ICE*** was mission ready, we tested ***ICE*** and its capabilities in the Acoustics Tank available to us at local facilities. 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 Battle Box 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. Our first step was ensuring all thrusters and electronics functioned properly, and that neutral buoyancy was achieved. 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 can 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.

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 and a non-or poorly responsive thruster suggests blockage or entanglement. Fortunately, our experienced deck team has encountered most of the potential difficulties we may face and know how to recognize and correct them.



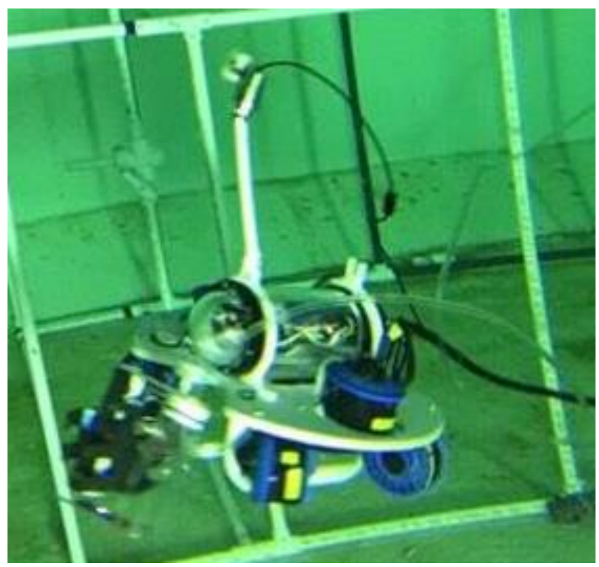


Figure 16: (Left) "Circle the Wagons" Troubleshooting process.

Figure 17: (Right) ROV ***ICE*** during practice trials in the Acoustics Tank.

Challenges

At OD-4D we believe that no tool is ever the best model, there is always a further advanced or more efficient model out there to try. We are constantly improving and redesigning to maximize our chance of success. One technical challenge we encountered this year was designing a claw usable in each unique mission task or to equip other tools. We went through many variations, changing grip, design, servos, and size. We finally settled on a model we believe can adequately perform all tasks, and perfectly complements our ROV design. A more unique issue we had to face this year was competing with a much larger group. With the addition of so many new members, we had to organize ourselves accordingly so that everyone has a task and purpose, and work is being completed as efficiently as possible. It took presentations, practice, and lots of work, but everybody has been given a role that they find interesting and engaging, and is also beneficial to the team. We aim to make sure every member has a basic understanding of each component of our ROV, with some specializing in certain areas.

Lessons Learned

Throughout the preparation, we have learned many new lessons on how to operate our team. When it comes to tool design, the tool should be tailored to the final ROV's design and fitted accordingly, not the other way around. This ensures we have base parameters for a tool to work on the ROV, so no major changes need to be made on the frame itself. We've learned that each member has a role to play, and proper guidance and instruction from senior members is key to running a safe and efficient team. We have all progressed from the beginning of the year and learned so much in every aspect of ROV development, and how to properly manage a team.

Exceptional Software

All ROV programming is original and made by our company. Our ROV was programmed in C# by our team members over the course of a few weeks. Our code is sensible, efficient and logical so that all team members are able to understand and contribute improvements.

Our ROV tool is designed to close an optimal amount to correctly apply pressure customized to each mission prop and tool. Our ROV pilot can open and close the claw manually via a slider. If our ROV senses a major increase in pressure inside our electronics can, our upward thrusters automatically activate to avoid water damage.

Future Improvements

Based on a value of continual improvement and innovation, OD-4D is already planning the next model of ***ICE*** and working to improve the company dynamic. In the future, the firm would like to improve communication skills, divide tasks more effectively, reduce the weight and equilibrium issues associated with the valve rotating tool, and reduce the overall weight and size.

The company previously experienced a lack of productivity due to an ineffective division of assignments in the initial months of work. This often leads to staff losing valuable time that could be better used to accelerate development progress and meet approaching deadlines. To accomplish this goal, the company will implement its current system of task assignment, which is based on individual skills and surveys of interest, at the immediate onset of the year. Effective communication has the ability to greatly improve OD-4D's overall efficiency and, therefore, greatly increase the productivity of the company.

OD-4D will also work to improve its valve rotating tool. The current model can effectively perform three rotations of a submerged valve, but is disproportionately heavy and lowers the front corner of the ROV. Consequently, ***ICE*** becomes difficult to maneuver while this tool is attached. The company will design and test several iterations of the tool, using more lightweight materials and motors to address this problem.

In addition, OD-4D will strive to reduce the weight and size of future models of ***ICE***, even though our current model is less than 11kg, while remaining robust, reliable, and able to complete all mission tasks with ease.

Accounting

OD-4D is a school-based company and therefore, our funding is limited to that which the school offers. We had to plan our funds management very carefully to ensure we stayed within our budget. When looking to purchase tools and materials, we compared several different brands, looked at each individual cost, and chose the one that was the most budget-friendly. We were fortunate to have been donated products to assist with ROV production such as the 2 SS Aquacam™ composite video-cameras and the joystick used to pilot our ROV. For products that had to be purchased, we used funds raised by O'Donel's recycling team, which totals to about $2974.00 USD. With such a large team, travel expenses were greatly eased by a donation of $14,870.00 USD from Marine Institute of Memorial University. The Newfoundland provincial government also graciously donated $371.75 USD. This ensured the minimal amount coming out of student pockets. Table 4 outlines material costs and the list of financial contributors can be found in table 5.

Table 4: Total Cost of Materials and Travel to MATE Internationals 2017

Type	Date of Investment	Expense	Amount ($US)		Running Balance ($US)
			Spent	Donated	
Re-Used	05/2016	ESCs, Servo controls		1,530.00	
		SS Aquacam™ composite video camera (two)		448.00	
		PC Netbook (HP™)		699.00	
		Joystick (USB)	76. 00		
		Fasteners, CNC bits, drill bits, glues	70.00		
Purchased New this Year	09/2016	BlueRobotics™ T100 Thrusters (6)	951.00		
	10/2016	Buoyancy /Electronics Can Lexan™ pipe (10.2 cm ID)	135.00		
		Acrylic Dome and End caps BlueRobotics™	464.00		
		PVC Rigid Foam	65.00		
	01/2017	LED TV (HD) Samsung™	210.00		
	09/2017	High Density Polyethylene (HDPE)	40.00		
Parts Donated this Year	10/2016	Tether (components, power cables, USB to fiber optic converters.		265.00	
Cash Donated		Travel Funds	32,560.00		
		General Cash Donation		14,870.00	
Total Expenses				17,632.00	37,333.00

Table 5: OD-4D contributors (financial and in-kind)

Contributor	Item Donated	Value ($US)
Opticis™ Inc.	Tether	265.00
Private & Gov't of NL via Marine Institute, MUN (Regional Winner)	Travel Funds	14,870.00
Provincial Government of Newfoundland and Labrador	Travel Funds	371.75
Eastern Valve	Travel Funds	148.70

Acknowledgements

This year OD-4D came first in our regional competition. OD-4D's success would not have been made possible without the continuous support of numerous bodies. We extend our deepest love and gratitude to our parents, who proved time and time again just how much they truly love and support us. As well, we would like to thank our mentors for the giving of their valuable time along with their help and guidance needed to meet and exceed all challenges that we faced. We also thank the many outstanding volunteers who help to make this competition possible and we acknowledge the generous support of each and every one of our sponsors. Finally, we send thanks to the MATE center of Marine Advanced Technology Education, along with many other schools and organizations for giving us the opportunity to compete at a regional and international level. As well we wish to thank all parties which make it possible for us to prepare for and compete at this prestigious level

Special thanks to Solid Works 2010 and Master Cam, without the use of their program, we would not have been able to design the necessary components used in the fabrication of ***ICE*** as efficiently or effectively as possible. We also acknowledge Statoil and Memorial University for sponsoring our school and giving us the resources needed to purchase many necessary components, and contributing to our endeavors at both regional and international competition. We also extend our deepest gratitude to Opticis™ for supplying components of our new tether, and Phidgets™ for all materials we were able to purchase from them. These materials were crucial in the design of ***ICE*** and in the completing of all mission tasks.

Lastly, we thank our school O'Donel High for all their support. The practical skills and knowledge we gained from this experience will stay with each one of us for the rest of our lives, and for those of us who do continue on into the fields of Ocean Science Exploration and Development, the MATE competition will be our launching platform into this fascinating career field filled with endless possibilities.

References

MATE - Marine Advanced Technology Education, International Competition Manual 2017 Ranger Class. *https://www.marinetech.org/files/marine/files/ROV%20Competition/2017%20competition/Missions/2017%20RANGER%20Manual%20FINAL_3_8_2017_cover.pdf*

Photo Accreditation

Cover Photo: Abygail Pike

Figure 1: Abygail Pike

Figure 2: James Hickman

Figure 3: Abygail Pike

Figure 4: Joel Hatcher

Figure 5: Joel Hatcher

Figure 6: Ian Parsons

Figure 7: Joel Hatcher

Figure 8: Harley Alway

Figure 9: Harley Alway

Figure 10: Ian Parsons

Figure 11: Ian Parsons

Figure 12: Clarke Payne

Software Flowchart: Robin Murphy

SID: Robin Murphy

Figure 13: Joel Hatcher

Figure 14: Harley Alway

Figure 15: Joseph Santos

Figure 16 : Abygail Pike

Figure 17 : Clarke Payne

OD-4D