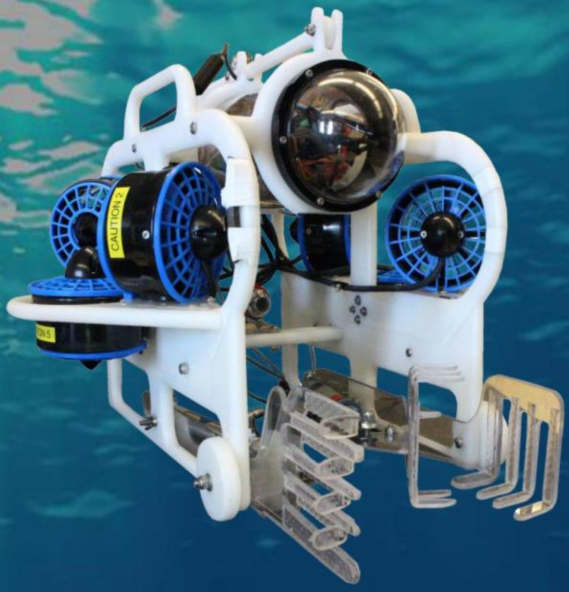
OD-4D

MATE 2018 INTERNATIONAL ROV COMPETITION

MOUNT PEARL, NEWFOUNDLAND

TECHNOLOGY REPORT



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Abstract

OD-4D is a wholly-owned subsidiary of O'Donel High School, in Mount Pearl, Newfoundland, Canada. OD-4D undertakes technological development and fabrication in underwater, sea exploration. All members of OD-4D are well-rounded and worked hard over a period of eight months to make an ROV able to operate along the coast of Seattle and complete all mission tasks. ***ICE*** is the latest Remotely Operated Vehicle from the team at OD-4D. It is optimized in size and weight to ensure it has the agility and compact ability to move smoothly through the water. ICE is equipped with an array of innovative and diverse tools to support the need of ROVs within the conditions of the Pacific Northwest, each designed, fabricated, and tested by following our stepwise design procedure: "Clarify the problem. Explore the ideas. Create a design drawing. Make it. Test it. Modify it. Test it. Problem solved!" ***ICE*** is outfitted with two grippers designed specifically for manipulation of mission props and grasping specialized, detachable tools such as our lift bags, OBS cable connector, and ADV. Each of the tasks presented at this year's MATE competition revolve around the application of ROVs to three, real world sectors within the Pacific Northwest. ROVs aid in locating vintage aircrafts pivotal to their illustrious history, are used by research institutions to study seismic activity, install Ocean Bottom Seismometers along the coast of the Pacific Northwest, and are used in developing and implementing renewable energy systems by installing tidal turbines and monitoring their possible environmental impact.

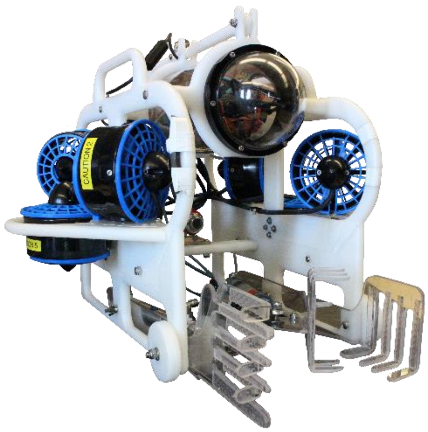


Figure 1: ROV ***ICE*** (Innovative Competition Entry)

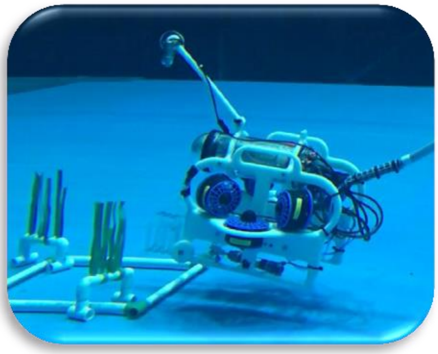


Figure 2: ***ICE*** In Action! Collecting Eel Grass

ROV Specifications

ROV Size
40cm x 30cm x 50cm

ROV Weight
10.9kg

New Materials Cost
$2,130 USD

Recycled Materials Value
$2,643 USD

Total Student Hours
1200

Safety Features
Commercial electrical connectors, rounded frame, no sharp projections, shrouded thrusters, hi-grade electrical components, 25A circuit breaker.

Special Features
Multi-function tools, non-corroding, unique and proprietary, CNC routered floating frame, high maneuverability with by 30° thruster vectoring, multiple POV analog cameras.

Understanding: ROV Scientific Concepts

In the expanding world of technology, robotics, engineering, and underwater exploration, advanced ideologies and mechanics are being introduced all the time. Although these principles may seem far fetched, our award-winning team of technology enthusiasts is up to the challenge of not only comprehending the scientific concepts out there, but also applying them within our ROV and systems.

OD-4D uses a fiber optic tether. This complex science of the transmission of data through light is not something every high school student has the opportunity to learn about and truly grasp. Thanks to our desire to improve and be a competitive entry into the robotics industry, our team has been educated through research and industry professionals on the inner workings of fiber optic cables. Thanks to this new knowledge, we were able to integrate fiber optics into our tether, a feature unique to OD-4D at the regional level.

Our programming was done in C# from scratch. This being a versatile coding language used by computer scientists, our staff had to put many hours into not only writing in the language, but simply learning about it. Thanks to the choice to write our coding in C#, ***ICE*** has been made a more universally applicable robot. Our company has produced overwhelmingly proficient employees in the computer sciences simply through the programming of ***ICE***.

Finally, our fabrication team had to wrap their minds around the ideas of vectors and three dimensional movements. Due to our thrusters being fixed and not rotational, we needed to learn about optimum placement, and develop an understanding as in-depth as possible. The same mathematic and scientific principles are applied in the every day work of engineers and technology professionals. Our end result was to vector our main thrusters at 30 degrees to the forward axis, as visualized below in Figure 3.

Ultimately, our team of aspiring engineers, scientists, trades specialists, and technology gurus is able to assuredly venture into unknown territory, exploring notions unbeknownst to many high school students. OD-4D not only strives to be the best team, producing the best ROV on the market, but also strives to be the most scientifically tuned to the endless possibilities the STEM community has to offer.

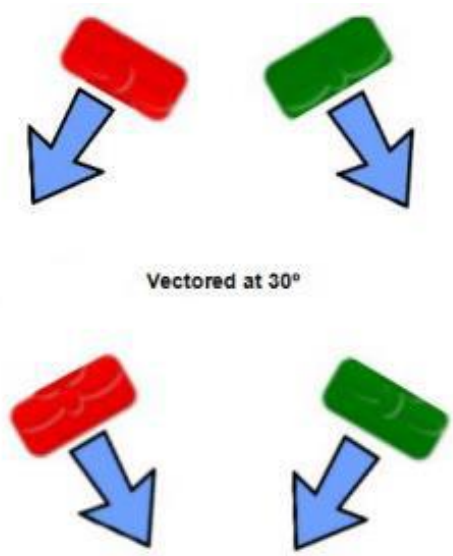


Figure 3: Diagram of thruster orientation

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. Firstly, we wish to thank the First Technology Associates Inc. for their donations of various goods and supplies as well as their continued financial support. Secondly, we would like to thank our mentors for giving of their valuable time, help and guidance needed to exceed all challenges that we faced along with their continued logistical support. Thirdly, we extend our deepest love and gratitude to our parents, who continue to prove just how much they believe in us with their unending moral support. 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 identified below. Finally, we send thanks to the MATE center of Marine Advanced Technology Education for allowing us this phenomenal opportunity. Thank you to all those who make it possible for us to prepare for and participate in this competition allowing us the opportunity to compete at such a prestigious level.

We also wish to send a special thanks out to Solidworks 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 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 2018 Ranger Class. *https://www.marinetech.org/files/marine/files/ROV%20Competition/2018%20competition/Missions/Updated%20manuals/2018%20RANGER%20Manual%20v9_6_3_14_2018_cover.pdf*

Photo Accreditation

Figure 1: Harley Alway

Figure 2: Michael Hopkins

Figure 3: Joel Hatcher

Figure 4: Michael Chislett

Figure 5: Josh O`Keefe

Figure 6: Michael Chislett

Figure 7: Michael Chislett

Figure 8: Michael Chislett

SID: Robin Murphy

Flowchart: Robin Murphy

Fluid Power: Aby Pike

Figure 9: Aby Pike

Figure 10: Michael Chislett

Figure 11: Keeley Flynn

Teamwork

OD-4D began meeting near the end of September and met every Wednesday for 3-4 hours. As we approached the competition, we also began meeting Saturdays for in-pool practice anywhere from 4 to 9 hours weekly and additional Friday afternoon meetings where deemed necessary. In order to make sure our team had plenty of time to complete, improve, and practice with our ROV we implemented a strict attendance policy, making all meetings mandatory (not including absences due to illness or other academic commitments).

Our Board of Directors met numerous times before large team meetings to prepare a baseline list of what things needed to be discussed, fabricated and improved, we then came together in larger team settings to further brainstorm these ideas. At the start of each of these meetings our Board of Directors would put forward the agenda previously discussed, to ensure all members stay on task, complete projects in an efficient and effective manner, and most importantly to see that all members were being productive and no tasks were being unnecessarily repeated. During these large team meetings, members split into small groups (3 to 5 people) based on interest for more focused brainstorming and discussion. Our more senior members of the team took charge in leading these smaller groups, this allowed us to gain innovative ideas from all parties involved, include everyone and allow everyone's voice to be heard.

Teamwork has been the foundation of our team's success in the past and continues to be now. This is why our senior members have taken great pride in mentoring the newer members to ensure they have the necessary skills to achieve success in this competition and beyond. These smaller, more focused brainstorming groups mingled throughout the year so that everyone became involved in multiple aspects of the ROV and it's idea, design and fabrication process. These specialized groups helped us to stay organized and have a clear leader(s) for each section of the ROV. At the end of each meeting all team members met together to share what they accomplished during the meeting, what they wish to accomplish next week and any new ideas they may have.

As a team, our goal was to have the ROV ready for the pool by mid February, allowing us ample time for in pool practice. Our deck crew has many new members this year so pool time was crucial and used to teach the new members techniques to improve in their roles. More experienced members have been crucial to ensuring the next generation can carry on the successful legacy of OD-4D as well as introducing newer members to our electronic and control systems. We are pleased to say we were able to stick to our original, predicted timeline (Figure 4) and our ROV was fully constructed by this time. However, we unfortunately ran into technical problems with our programming causing a brief delay. We were luckily able to easily overcome this issue as a team, by undergoing extensive group research sessions. As we approached the competition, our practice times began to both increase in length and frequency for troubleshooting and pool practice, as well for presentation practice. Currently, at OD-4D, we are meeting 3 times a week for 3 to 6 hours at a time.

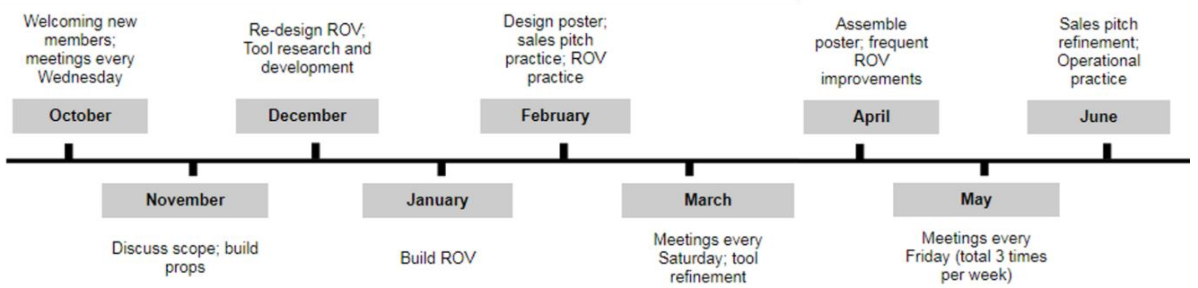


Figure 4: Timeline of team production

Design Rationale

Design Process

In December of 2017, before starting the in-depth 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 participating in “role playing” the mission tasks using a mock ROV and tether to accurately visualize and understand them. This comprehension (with the added benefit of team bonding) was crucial in 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 topside modules and onboard tools. The journey towards perfection drives the cycles of technical refinement which has been the hallmark of our continued success. Most of the components of our vehicle are designed and built in-house by our staff members, and all components on ***ICE*** were approved only after rigorous testing.

Design Specifications:

i. Relatively small size (width and height <60cm) and weight (<12kg).
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 claw.
vi. Multiple high-resolution video camera views.
vii. Tools which are multifunctional.
viii. Adequate thruster force for movement and lifting.
ix. Simple, intuitive ROV controls and payload tools.

The Stepwise to Assure ROV Efficiency:

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, and is agile/efficient;
iv. Vehicle and tool array achieve mission tasks efficiently and quickly;
v. Tools are multi-purpose for effectiveness in completing tasks.

ICE carries six independently controlled 12V Blue Robotics™ T100 brushless thrusters permitting movement in three 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 two multi-purpose pneumatic powered robotic hands or “The Claws” are used in all mission tasks and make up an essential element in our design. Its utility spans all tasks; for example:

i. In Task #1, they manipulate a lift bag to attach to debris
ii. In Task #2, they disconnect an OBS cable connector from the power and communications hub
iii. In Task #3, they collect eel grass samples for research and analysis

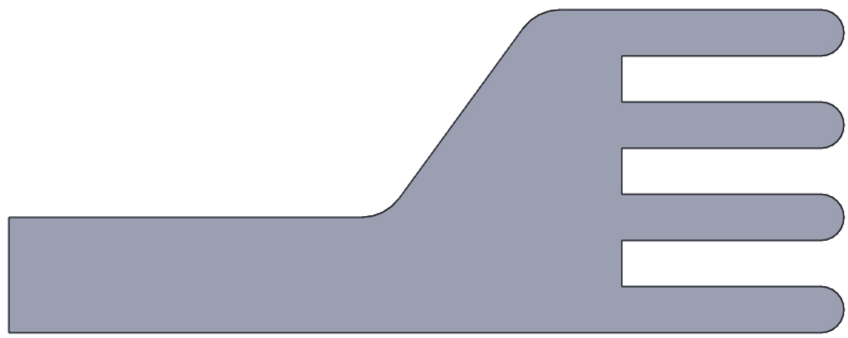


Figure 5: Computer side view drawing of one of “The Claws” (starboard)

The ROV is structured around a rigid, light-weight, HDPE chassis, to which every major component of ***ICE*** is attached, including the waterproof, cylindrical Lexan™ electronics “can”; 6 Blue Robotics™ motors; “The Claw”; two video cameras; and several tools. This overall engineering design makes the ROV compact and maneuverable while maintaining stability, competence, and speed. This design permitted conformity to the dimensions and weight limitations of the missions. 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. However, the terrific product of ***ICE*** was definitely worth the extra research and time.

Our ROV frame went through many brainstorming sessions before arriving at the current design, which was ultimately chosen as (and has proved to be) an improvement from previous designs. This frame allows for even weight distribution, portability, and a spatial increase. It was fabricated using high-density polyethylene, a material known to be cost efficient and durable.

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%. The fiber optics greatly increases the speed and volume of 2-way data transmission.

Our previous ROV's systems of servo motor-powered tools was discarded for pneumatic controls following extensive trial and error based research. This switch was made for the known reliability and power of pneumatic pistons.

Understanding: Mission Scientific Principles

All the Mission Tasks outlined by MATE this year simulate 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 the first task, the advanced locating and recovery of aircraft wreckage will revolutionize how we approach air space fatalities. Through applied scientific calculations, we are able to accurately determine a crash zone from simple flight data. This can further allow for the rescue of aircraft fragments and even vital system components.

Following with the second task, natural disasters are a harsh reality, especially in the Pacific Northwest. Special to this region, earthquakes affect the lives of many. In order to predict, track, and analyze earthquakes, Ocean-Bottom Seismometers effectively record earth movements and trends. An OBS can provide accurate profiling and structural disruption data. Furthermore, in adapting new methods of releasing an OBS through magnetic, Wi-Fi, Bluetooth, or frequency-acoustic means, technical design is brought to a new level.

The third and final task addresses one of the most renewable and long term effective energy sources; hydroelectricity. Using mathematic fundamentals with current tidal flow data, science and engineering specialists can determine the most advantageous location for a tidal turbine, which can then maximize the energy from the highest current. This all in addition to the instillation of an Intelligent Adaptable Monitoring Package and an Acoustic Doppler Velocimeter, both of which monitor and document necessary data on the area and turbine efficiency.

Our oceans are enormous, only 5% of the seawater that surrounds us having been explored. 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 regions never attempted.

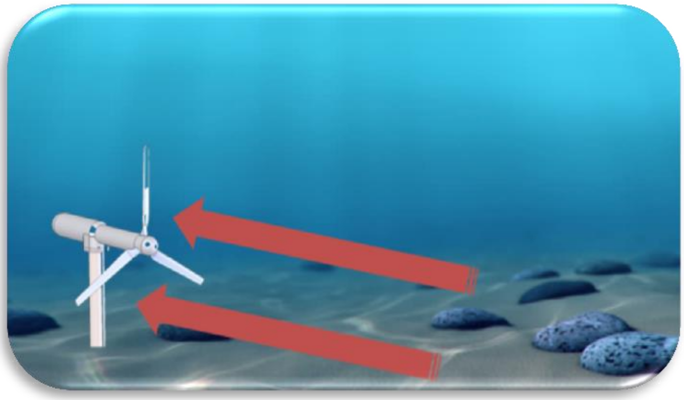


Figure 6: Diagram made by Science Officer Michael to help illustrate to team members tidal turbines

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, control, and programming of the ROV was achieved 90% from within our company.

However, there were a few items that needed to be commercially acquired. External components were purchased only when they were deemed either cost-effective or significantly more efficiently fabricated by other suppliers – not 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. 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 process from a couple reiterations prior, we wanted to ensure that our thrusters were up to par. Purchasing them not only allowed for flexibility in design and function, but afforded more time for the development of mission-specific prototypes of contemporary tools.

OD-4D switched to an Opticis™ fiber optics tether this year, requiring a totally new design. The fiber optics transmission was then converted to USB using a media converter on either end of the tether. We produced this novel tether in-house, by purchasing the individual components of our tether and assembling all components into a final product. 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 optic components/converters, the specialized wiring and electronics, and the flotation materials were purchased, the final product is unique and has exceeded our expectations.

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

Figure 8: Tether Manager Josh with the assistance of Co-Pilot Ian wrapping the tether for transportation

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, and the investment of simple electronic components allowed us to focus on advancing greater functionality in our small ROV.

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, as a rule of thumb, only items we couldn't fabricate ourselves were considered for purchase. All technical and material choices were discussed internally and OD-4D is very pleased to offer one of the best ROVs 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 University of Washington's Applied Physics Laboratory.

New VS Used

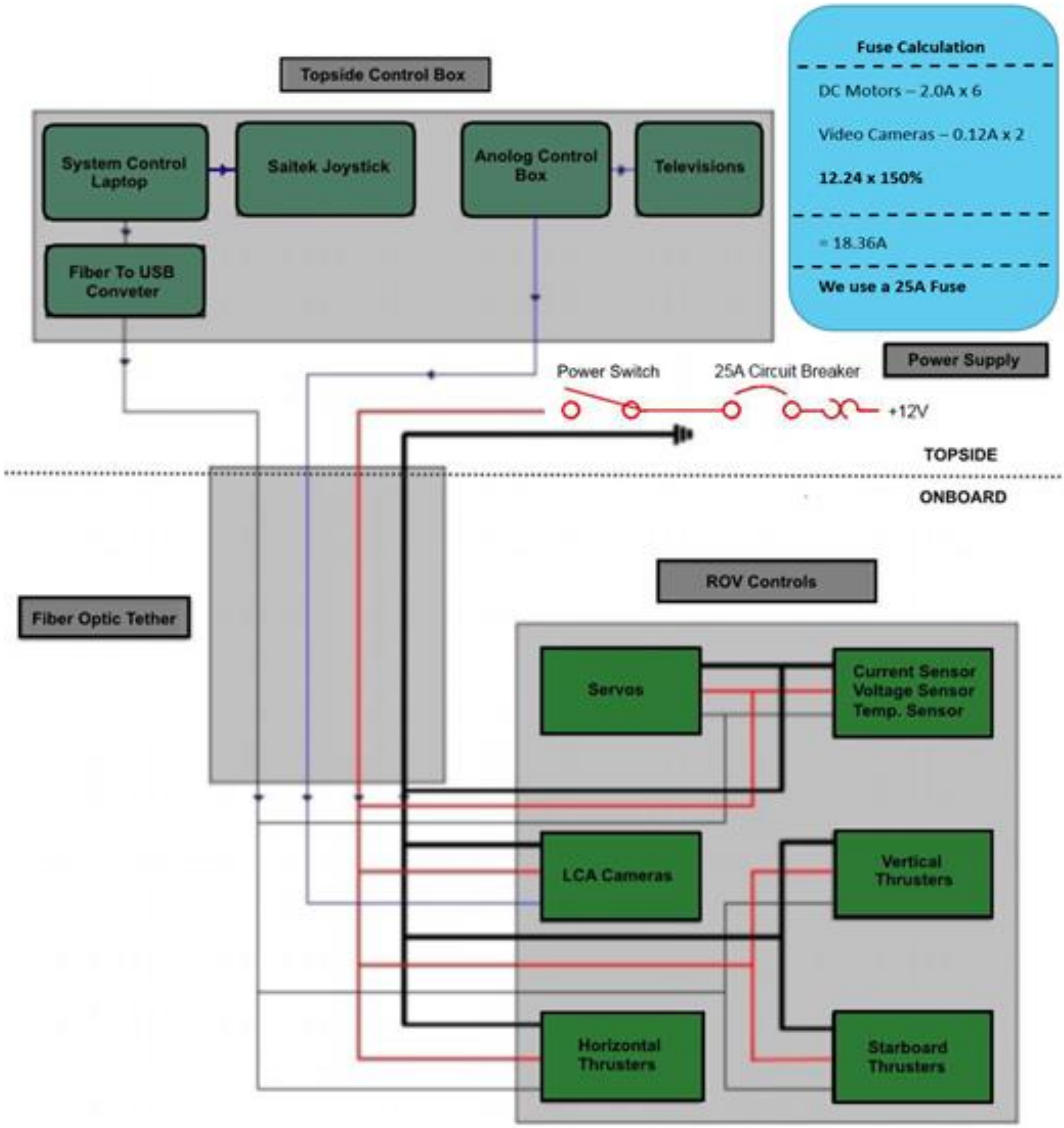
ICE has gone through five models over the past five years. Throughout all these models, our ROV is now a healthy balance of many previously used components. The main pieces reused this year were ***ICE***'s frame, the end caps on our waterproof electronic "can," our two cameras, and our motors. We decided to re-use our frame design from an older model of ***ICE*** with minor modifications because of its manageable size and adaptability. The aft end cap on ***ICE***'s electronics "can" was salvaged from previous years because it had the required penetrator pattern for thrusters and conductors.

In addition to these components, we also use two analog SS Aquacam™ cameras from our previous year's ROV. These have provided superior resolution and also contained LED lighting, A previous attempt to use digital cameras resulted in video latency, an issue solved through the choice to switch to analog cameras. 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.

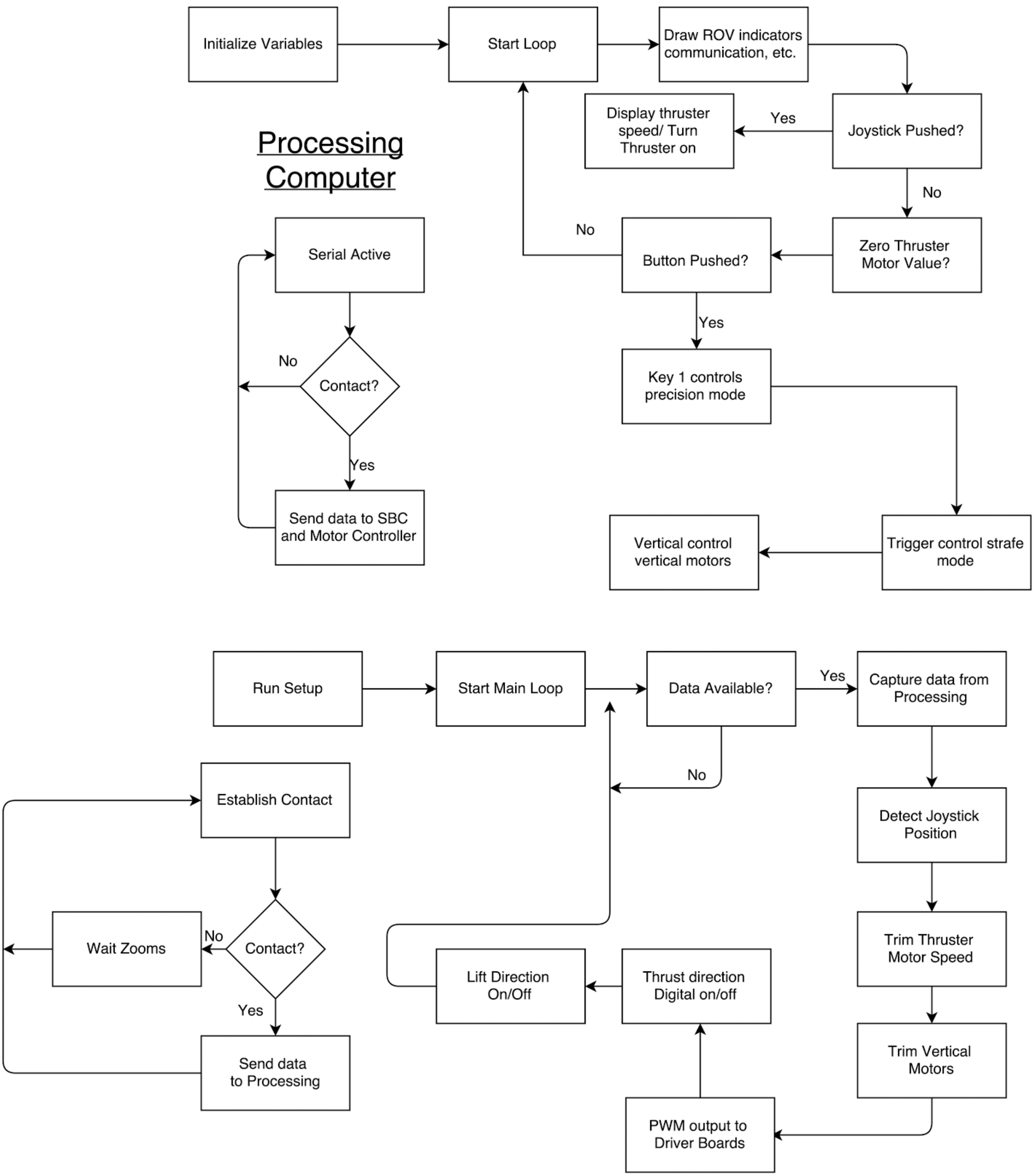
ICE's electronics, sensors, tether, tools, tool skid and our most important addition; our top-side control panel, known as our "Battle Box," are all valued components brought forward from last year. The "Battle Box" was made to make on deck set up much easier, and seen as a trusted contribution from previous years, and a necessity moving forward. However, new this year is the "can" itself; a Lexan™ tube to house our electronics. The thickness and weight of our previous year's acrylic model was unnecessary with no particular benefit. Another reason for this new tube was for it to be longer to house all of our electronics with plenty of space.

Last 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 tools are brand new this year as result of the missions requiring different tasks. Our portside claw, for example, was specifically designed to transport lift bags with ease.

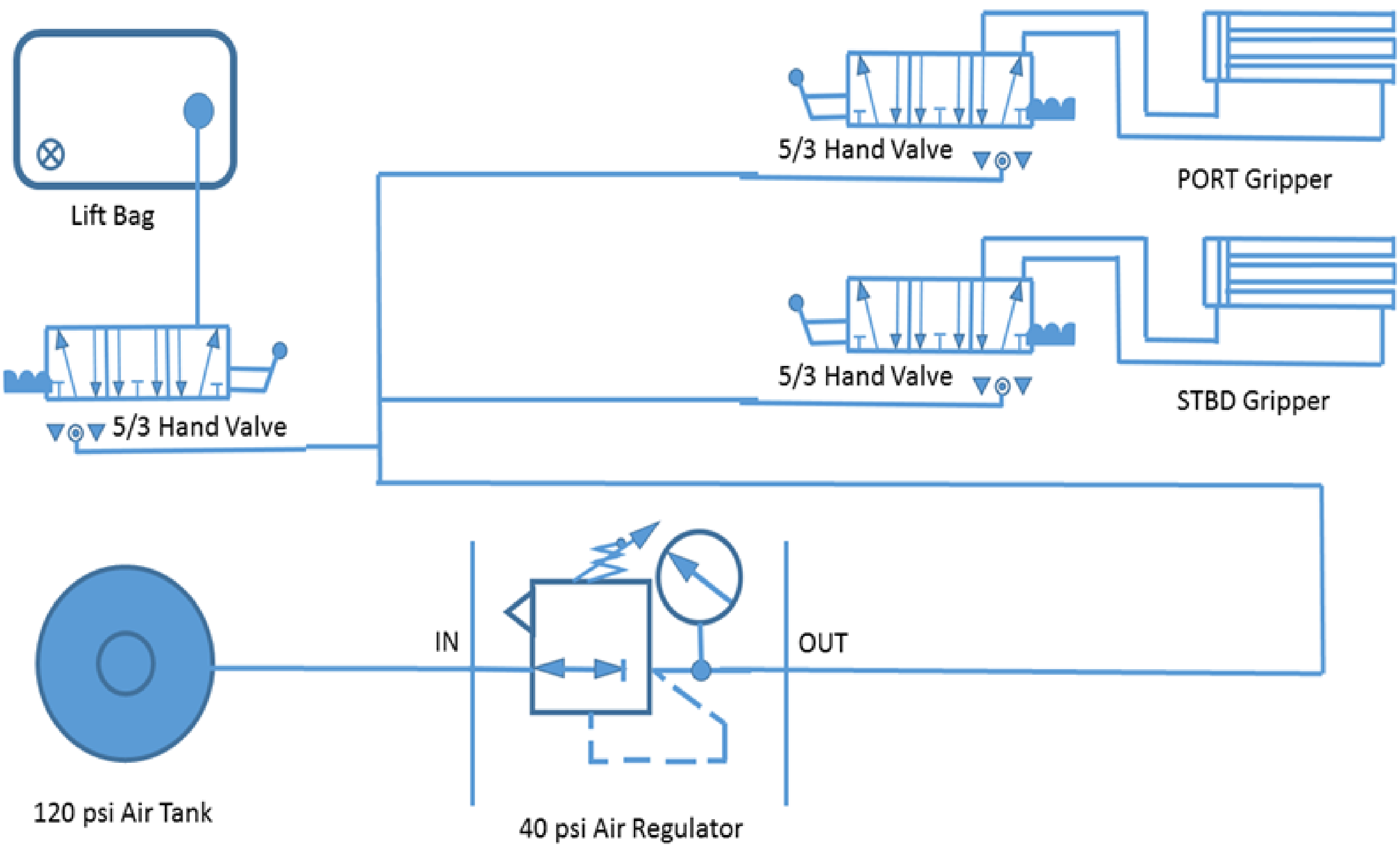
System Integration Diagram



Software Flowchart



Fluid Power Diagram



Safety

Features

ICE is equipped with a number of key safety features, including:

i. Curved edges and fitted fasteners on the ROV's frame added to ensure company members are not injured while handling ***ICE***;

ii. Proper casings and shrouds for all six thrusters;

iii. Proportional control of thrusters (meaning they are not always using their full power force) preventing unnecessarily high thruster outputs;

iv. A 25A circuit breaker, which acts as a kill switch for all of ***ICE***'s electronics;

v. Waterproof casings for all electronic components onboard the ROV, to prevent water leakage leading to any electronic device short circuiting;

vi. Appropriate warning labels on each of our six thrusters, servo motors and tools which may present any possible pinch hazards.

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, located at a distance greater than 30cm away from the connection point. ***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 and easily distinguishable from AC wiring. This is done through a colour coated convention, where we have labeled all AC wires in yellow, all DC wires in green and any additional USB cables are indicated in black.

All wires entering and leaving this system have proper strain relief secured in tension waterproof adapters. ***ICE*** uses pneumatic powered pistons to control all of our tools, controlled by 5/3 Hand Valve. We have 3 ethylene tubes, to send compressed air from the surface down our tether, we use a 120 psi air tank, monitored by a 40 psi air regulator to ensure we do not exceed the maximum amount of air, alloted to us by the MATE center specifications. Our onboard electronics can has been tested in a pressure chamber able to withstand pressure up to and at 18.3 meters.

Philosophy

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 precautions, we will have to face the repercussions of our actions. We first identify all possible risks present in mission tasks, we then take the necessary precautions to ensure we have a 100% safety guarantee. In order to maintain this safety guarantee, we have put in place a strict set of protocols and procedures which must be precisely followed by team members at all times, both in-house and poolside.

First and foremost, team members are required to wear close-toed shoes and have long hair tied back at all times. Second, anytime team members enter the workshop, they are required to wear safety glasses and hand protection at all times. Proper safety equipment, such as guards and clamps, must be used while operating any type of power tools. Before operating any power tools for the first time we require all team members receive the proper training, instruction and supervision on how to safely operate the needed tool. Our team is focused on providing the safest work environment possible, allowing all members a secure atmosphere to work at all times. This is achieved through our strict adherence to all safety protocols including our "No Hands" rule while power is on, enforced to all members while handling and operating the vehicle. Our team's attention to detail also spans outside the workshop. While team members are on deck, they are always required to wear life jackets, while still following all previously mentioned protocols such as, having long hair tied back, wearing close-toed shoes and safety glasses.

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

Table 1: Our Job Safety Analysis, used to evaluate all tasks undertaken by our staff

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**	

Table 2: Our Pre-Drive Checklist highlighting steps that must be taken prior to operation of the ROV

Critical Analysis

Testing and Troubleshooting

As soon as ***ICE*** was mission ready, we used a very thorough testing process to ensure each component of our ROV is capable of being utilized to its full potential during competition. We began by testing ***ICE*** and its capabilities as a whole in the Acoustics Tank available to us at local facilities before we began testing individual components.

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

Challenges

At OD-4D we believe that no tool is ever the best model, but rather 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 that was also able to equip and grasp additional, detachable tools.

We went through many variations, changing grip, design, servos, and size before finally settling on a model we believe can adequately perform all tasks, and perfectly complements our ROV design. Overcoming these challenges has allowed us to work together as a team, through many extensive group research sessions which resulted in us improving original ideas for our ROV. This experience has also taught us that simple solutions can sometimes be more effective than complicated ones and pursing complex solutions can often use valuable time and resources for a less than satisfactory result.

A more unique, organizational 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, we have learned the tool should be tailored to the final ROV's design and fitted accordingly. All tools are tested until perfect, and we never settle on the first draft. We have learned over the years that there is always room for improvement. 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.

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, 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. After the experiences over the past year, we hope to work more efficiently earlier on in the competition year, to prevent the small, last minute rush we have experienced to some extent. This will allow for more testing, prototyping and refinement of all aspects of the ROV, leading to an overall greater success rate.

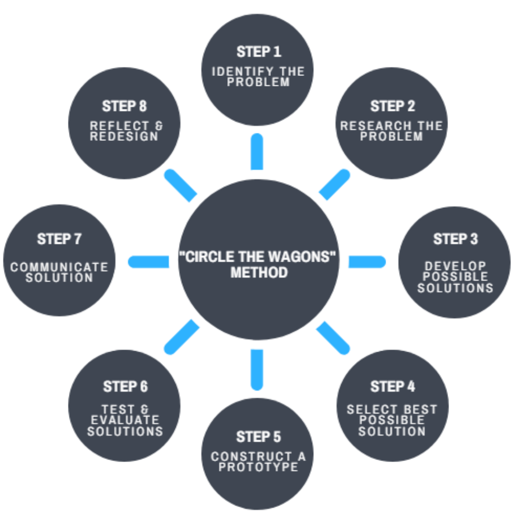


Figure 9: The Circle of Wagons method for troubleshooting

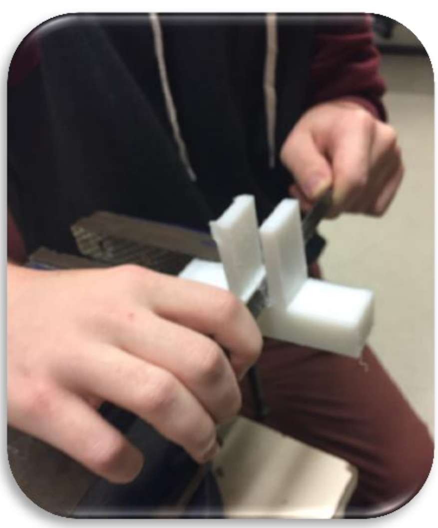


Figure 10: Tether Manager and General Technician Josh working on a fifth improvement of a pivot piece for the frame

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 $2,974.00 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.

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 3: Total cost of materials and travel to MATE Internationals 2018

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

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

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. Our ROV is equipped with humidity temperature, depth, and pressure sensors. It has a unique feature whereby if the internal humidity sensor temperature passes 100 degrees Celsius or if our ROV senses a major increase in pressure inside our electronics can, the programming sends a signal to our upward thrusters to automatically activate, send the ROV to the surface and kill all power to the ROV to prevent overheating and avoid water damage.

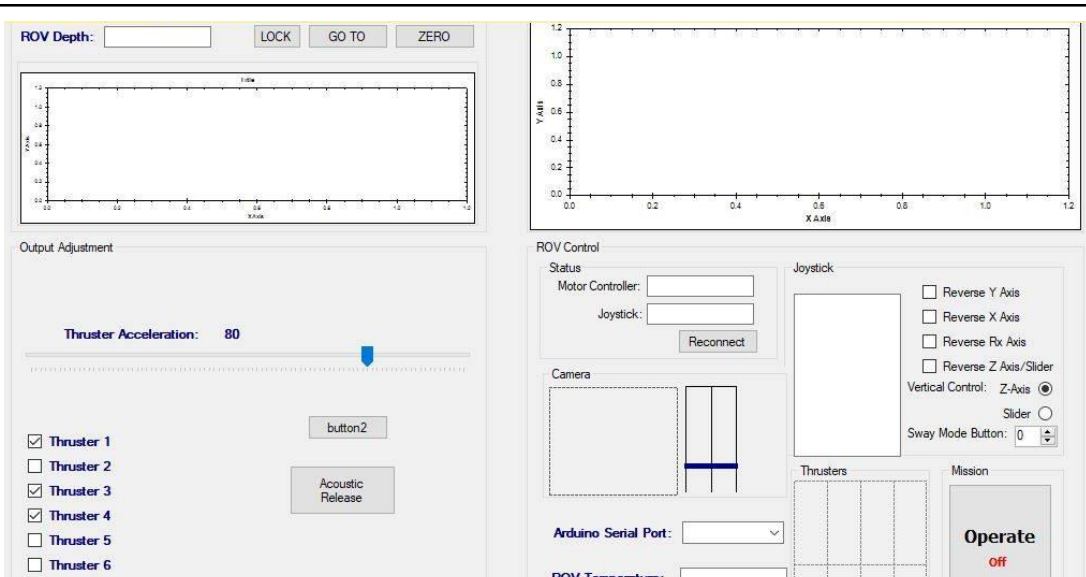


Figure 11: Main interface of programming when commencing ROV operations