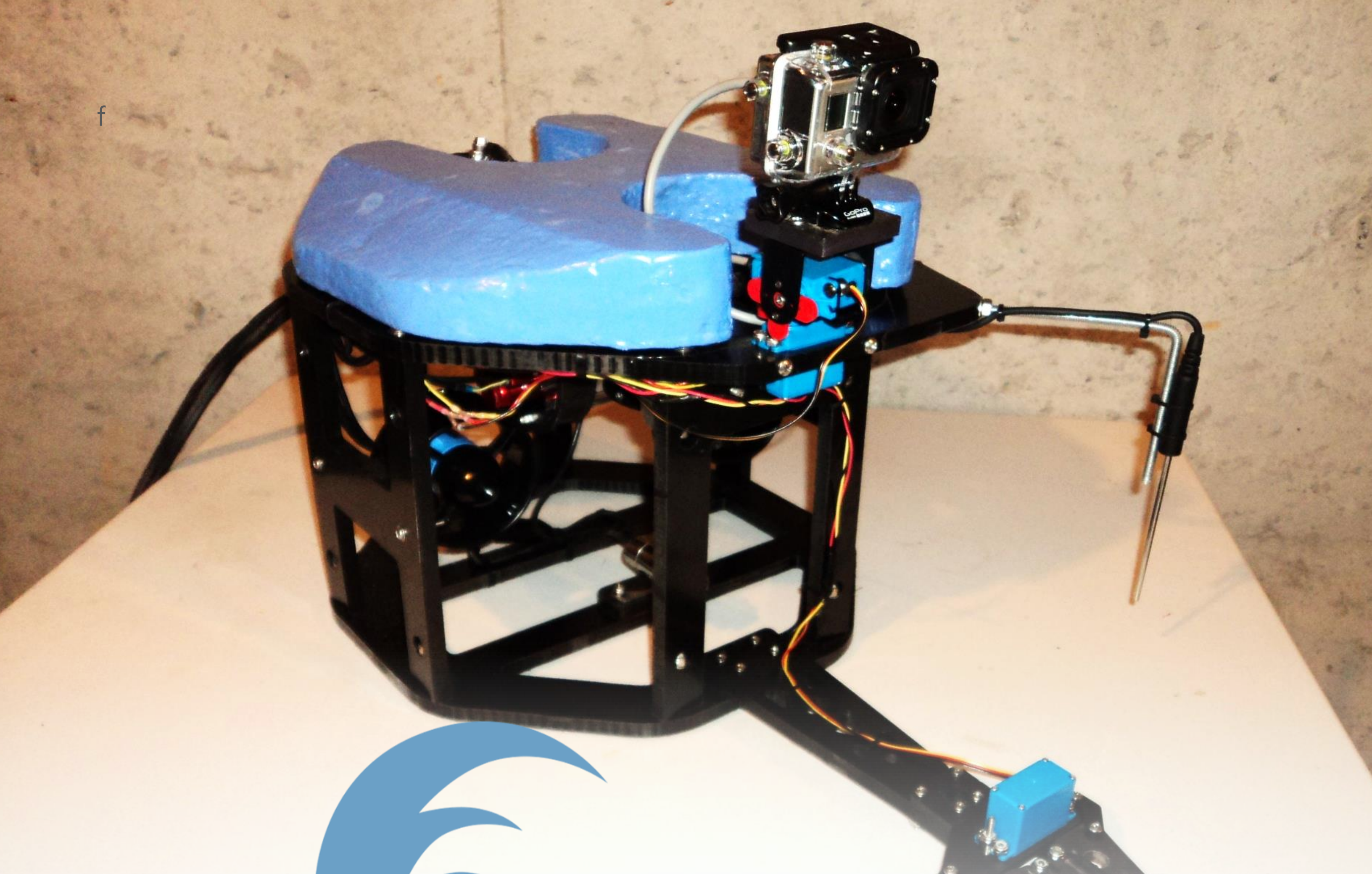

# INNOVOCEAN

## Innovation in Marine Technology

Carrollton High School

Carrollton, Georgia

2016 MATE International ROV Competition, 2016 Gray's Reef Regional ROV Competition

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# Abstract

InnovOcean, an oceaneering company created in 2007, designs, constructs, and operates Remotely Operated Vehicles (ROVs). In response to the Request for Proposals from the NASA Johnson Space Center's Neutral Buoyancy Lab and Oceaneering Space Systems (OSS), InnovOcean has designed and produced the company's most advanced and sophisticated vehicle yet: OTR (Ocean Trans-Galactic Ranger) - the product of months of research, planning, constructing, and testing. The vehicle comes equipped with a rotating and panning camera, a parallel-grip manipulator, temperature sensor, and depth sensor. OTR was built for special equipment recovery, for post oil spill operations, and to travel through outer space for deep sea exploration and analysis.

InnovOcean is at the forefront of ROV development and technology. This year, InnovOcean has gone through many changes such as a transition to a new workshop, many new employees, and a new scheduling system, while maintaining the guarantee of a safe and professional service and work environment. It drastically increased the company's use of advanced technology, such as a CNC router and 3D printer, and advanced software, such as AutoCAD and Inventor. InnovOcean used these resources to create an ROV designed specifically for the mission with the most effective components to date. Such components include a robust manipulator, camera mount, and an HDPE frame. This technical report explains the decision making and development process that makes OTR the best ROV to operate in the demanding environments required by NASA and OSS: deep sea and outer space.

InnovOcean employees

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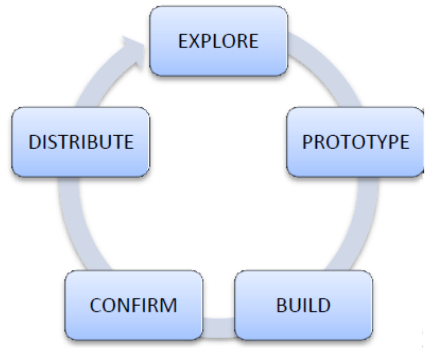
# Design Rationale

## DESIGN CYCLE

InnovOcean places a high priority on following a specific design process throughout vehicle construction and marketing development. Every component of OTR has been designed and tested to achieve optimal functionality and high reliability. To accomplish this, a design cycle was developed that outlines all steps in the creation of its components. At InnovOcean, design begins by brainstorming ideas for each task or component of the ROV. After evaluating each design, the list is narrowed down by asking the following questions:

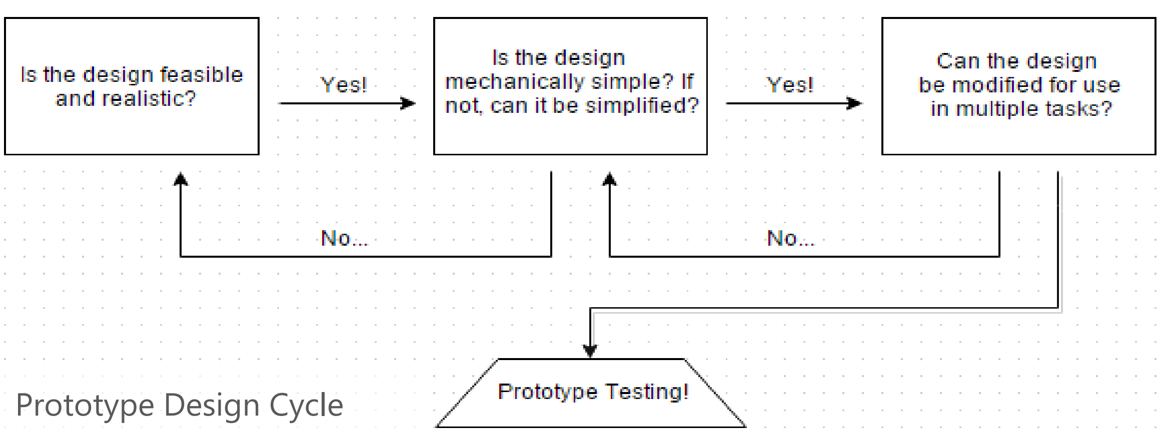



Design Cycle

1. Is the design feasible and realistic?
2. Is the design mechanically simple? If not, can it be simplified?
3. Can the design be modified for use in multiple tasks?

The design is then modified until all questions are answered with a "yes". After testing a prototype successfully, a final product is built and tested. If the design is found to be effective, the component is implemented in the final ROV for distribution to customers. When InnovOcean employees began brainstorming, a list of focal points was created for the vehicle to operate at optimal efficiency:

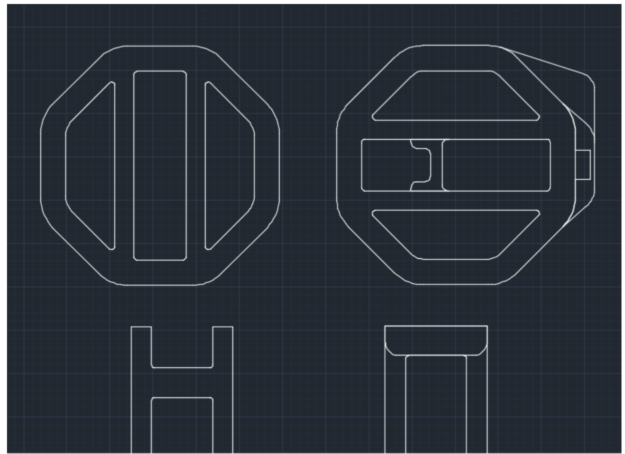
- Practicing performance safety
- Designing for the unique requirements of outer space transport
- Using simple, reliable, and effective payloads to complete all services
- Decreasing non-functional mass while increasing speed, maneuverability, and stability
- Conserving materials and resources whenever possible
- Maintaining a sleek design for appeal to customers



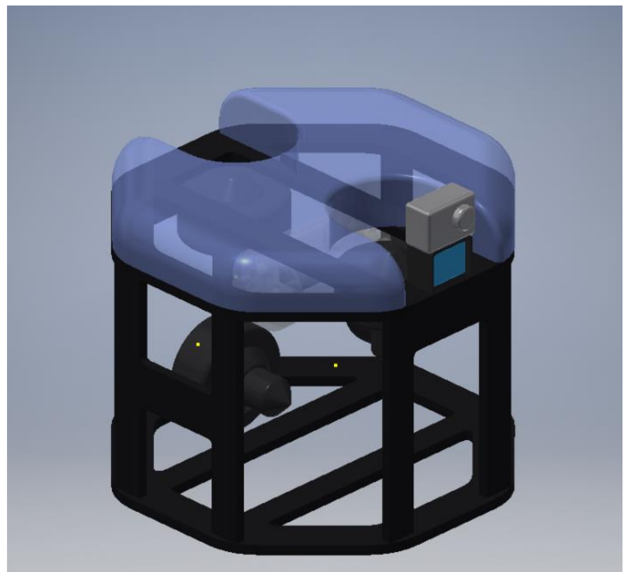

Prototype Design Cycle

# FRAME

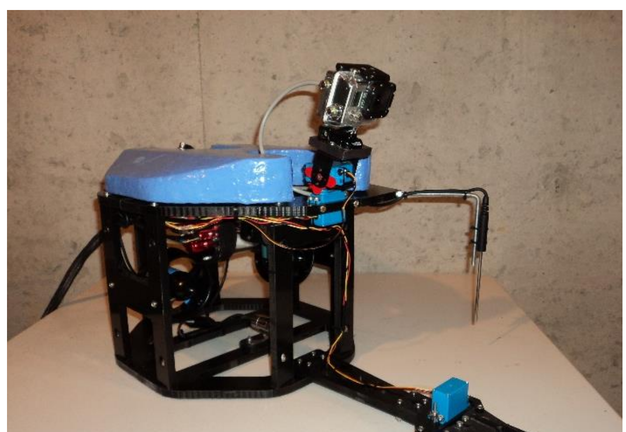
OTR's frame is unique in its design, manufacturing, and assembly. The design process began by analyzing past frames and considering various factors including hydrodynamics, maneuverability, mass, and stability. Previous vehicles featured the common rectangular prism frame design, which increased drag and negatively impacted maneuverability. Eventually, an innovative solution was proposed: an octagonal prism. An octagon has uniform symmetry which allows the vehicle to move and turn freely. Such a shape would allow the ROV to literally "turn on a dime," easily manipulate thruster configuration, and attach payloads at various points of the ROV.



AutoCAD drawing of OTR's frame



Inventor model of OTR



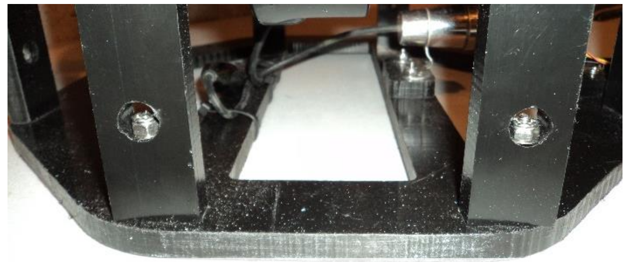
OTR

With the concept and sketch in hand, our engineers finalized the design in AutoCAD 2016 and Inventor 2016. The frame was designed to be compact to accommodate NASA's strict requirements for space cargo dimensions and measures only 24.8 cm tall, 35.6 cm wide, and 35.6 cm long. Stability was considered one of the most important vehicle characteristics to enable precise and efficient operation. This design maximizes stability by keeping the center of buoyancy high and the center of gravity low.

High Density Polyethylene (HDPE) was chosen to construct the frame since it is sturdy, inexpensive, and nearly neutrally buoyant. In the past, the frame was constructed using aluminum; however, it is much heavier and harder to manipulate than 0.65 cm thick sheets of HDPE. The material was also chosen so we could manufacture it in-house using Carrollton High School's CNC router.

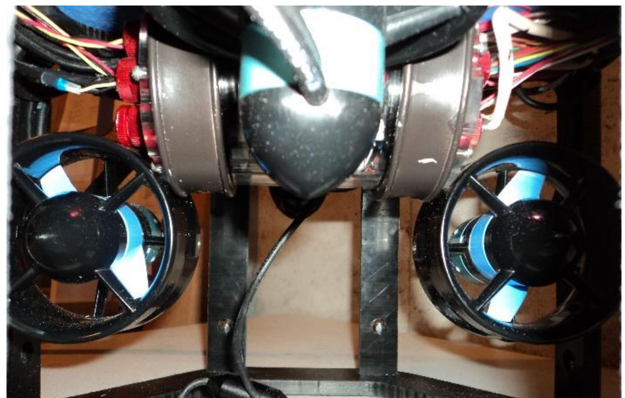
## A. Smart Bolt Assembly

The frame was assembled using a smart bolt design to maintain both safety and sleekness. A hole drilled 3.4 cm from the edge houses a washer and a nylon insert nut attached to a machine screw. HDPE's high compressive strength allows the bolts to be used in this way. This design eliminates the need for angle brackets – which decreases frame mass and increases mounting space – and keeps sharp components out of reach. Like every other metal component on the vehicle, all the bolts, nuts, and washers are stainless steel to eliminate maintenance. This method is used throughout the vehicle.

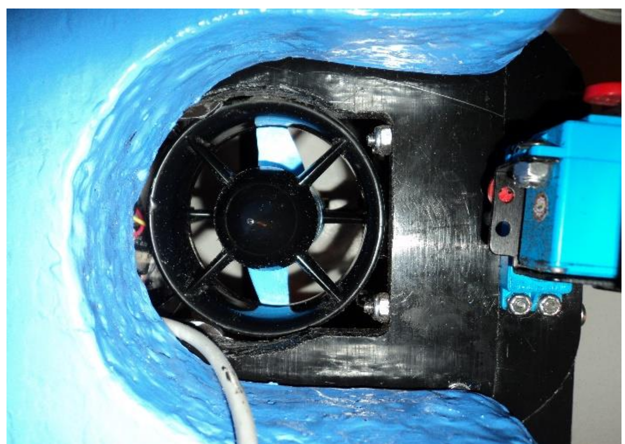

Smart Bolt Assembly

## PROPULSION

Propulsion on the OTR is provided by four T100 thrusters, produced commercially by Blue Robotics. Two thrusters are positioned laterally and two are positioned vertically. The vertical thrusters are at the front and back of the frame, creating an axis that can easily counteract tilting when extra weight is added to the manipulator - a new design feature in InnovOcean's vehicle line. Thrusters are mounted at pre-set positions determined by the frame design to minimize flow interference with the frame and other vehicle accessories.


Lateral thrusters

InnovOcean made the decision to purchase new thrusters to improve the reliability and efficiency of the ROV. Specifically, Blue Robotics' T100 thrusters were chosen because of their reliable brushless motors, near-neutral buoyancy, compact size, and low cost. Last year's thrusters were difficult to waterproof because the ESCs were outside the thruster housing; the new thrusters' ESCs are housed within. They operate at 12V DC and provide OTR with a maximum 23.1 N of forward thrust and 17.8 N of reverse thrust. Each individual thruster draws 6.25 amps of power, well within the power budget set by NASA and OSS.


Front vertical thruster

The T100 thrusters include multiple safety features. Guards on each thruster prevent body parts, vehicle components, and other foreign objects from coming in contact with the propeller. Thrusters were mounted inside the frame for safety and to reduce overall dimensions for outer space transport.

## BALLAST SYSTEM

OTR features one main buoyancy "tank." This tank was cut from a sheet of 5 cm Schlüter KERDI-BOARD. This highly buoyant material was chosen because of its density, success, and reliability in past vehicles. The foam board is a tile substrate and building panel that is commercially used to create bonded waterproofing assemblies with tile coverings. It consists of an extruded polystyrene foam core, with a special reinforcement material on both sides and fleece webbing for adhesion. The foam is closed cell, meaning that all air pockets inside the foam are trapped, forcing any leaks to remain localized, even with physical penetration. Using precise calculations, the appropriate "cut line" was drawn to enclose the vertical thrusters and shaped the foam using a hacksaw. The sides of the buoyancy tank were further shaped using a saw for maximized hydrodynamics when moving in all directions.

Employees sanding buoyancy tank

Furthermore, to resist compression due to hydrostatic pressure, the foam was coated with multiple layers of epoxy. The tank was then sanded to smooth any imperfections and painted it with marine-grade paint. Even if water penetrated through a break in the outer shell, it would fill only the damaged air pockets, without spreading to any others, and allowing the ROV to remain neutrally buoyant. After testing OTR with the main buoyancy tank and the buoyant force of the watertight electrical enclosure, OTR was found to be positively buoyant - a desirable outcome. The extra buoyant force allows the bottom of OTR to be fitted with lead weights (ballast) to maximize the distance between the center of buoyancy and the center of gravity, stabilizing OTR and bringing it to neutral buoyancy.

# CAMERAS

OTR houses two cameras: a reused AquaCam (from Lights Camera Action) and a new Go-Pro Hero 3. The AquaCam was reused because it is light and is of high quality, and a Go-Pro was chosen because it is significantly smaller and lighter than Blu-Vue 700 cameras used in the past.

Go-Pro Rotating/Panning Mount

In the past, a rotating and panning camera has proven to be imperative to the success of the vehicle. Therefore, its development was a priority. The starting point was last year's design: a system consisting of a short single axle connected via gearbox to a VEX servo motor for our main camera. VEX servos are not commercially waterproofed and therefore wear down quickly.

This year's camera mount is comprised of two custom-cut metal connectors operated by two standard-sized, waterproof Hitec HS-5646WP digital servos to ensure maximum precision. The Go-Pro's pre-installed mount allows for a secure connection to OTR's pan/tilt camera mount. InnovOcean's engineers designed and 3D printed a part for the Go-Pro's mount piece to be fitted to the camera mount to ensure minimal wobble and maximum reliability. OTR's camera mount is a significant improvement over past models since it's steadier and more precise. Additionally, the Go-Pro Hero 3 has higher resolution and a wider field of view than the Blue-Vue, decreasing time spent orienting the vehicle or finding objects, shortening mission run times.

The AquaCam camera is mounted on the ROV to provide an alternate view of the manipulator for precise maneuvers. The AquaCam also features six white Light Emitting Diode (LED) lights for enhanced vision on the ocean floor.


AquaCam camera

To capture screenshots from the cameras for coral reef growth analysis, a screen-capture software installed on the laptop is included. This software allows users to quickly and easily save stills from either camera.

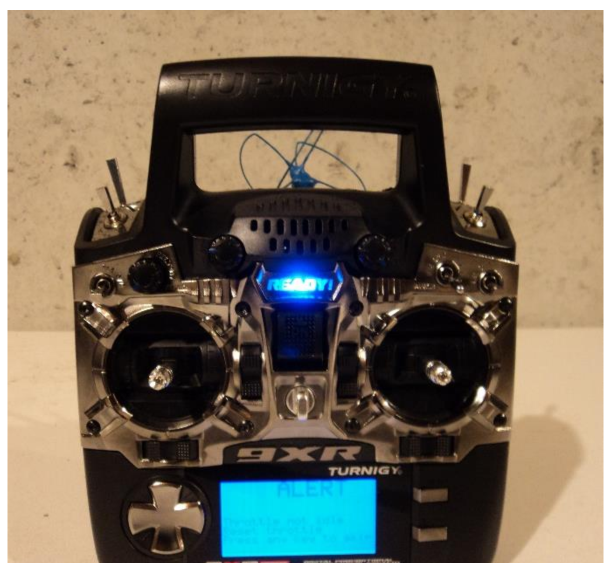
# CONTROL SYSTEM

OTR houses InnovOcean's most advanced control system to date. At the beginning, InnovOcean employed various hardware-based systems that involved little to no software in their design. Such systems were comprised primarily of toggle switches that only allowed for the on/off control of past ROV's thrusters and other systems. As InnovOcean's ROV technology matured, the company recognized the need to develop the controls as well. Eventually, the controls were expanded to encompass an Xbox controller, Arduino, and complex computer programming. This year, the design of the control system has been focused on three main priorities: efficiency, simplicity, and portability.

OTR Control Box

## A. SURFACE CONTROLS

OTR's control box has several important safety features. It features a main power ON/OFF switch, which is both safer and more convenient than connecting or disconnecting from the battery during trial runs. The control box also features a 25 amp fuse on the positive lead less than 5 cm away from the battery connection point, a pair of Anderson powerpole connectors. Wires within the control box are neatly arranged and all terminals are covered to ensure user safety and eliminate unintended failures. Tension relief points on throughout the control box prevent wires from being pulled out of their connections. OTR features two cameras interfaced by an AV switch box to quickly switch between video signals. This switch box connects to a Sony 720p monitor, making for clear and reliable video viewing.




Turnigy 9XR transmitter

Last year's surface control system was problematic for several reasons. The system consisted of a single Turnigy 9XR, a commercially available hobby-grade transmitter, for controlling the thrusters and manipulator and two momentary switches for controlling the pan/tilt camera mount. Thruster control worked extremely well, but manipulator control required the copilot to reach over to the transmitter held by the pilot to turn a knob, which was both inefficient and inelegant, and interfered with the pilot’s operation. Furthermore, momentary switches took up too much space in the control box and made precise control for the camera mount difficult.

InnovOcean wanted to eliminate the need for momentary switches and an extra hand in the pilot’s face, so employees experimented with using a Wii nunchuk for camera mount and manipulator control. However, this system was unreliable (see “Challenges” section) and required the addition of a second Arduino and three more wires to the tether. Because of the inherent unreliability of this setup, two servos were ruined. At that moment, InnovOcean’s engineers fabricated a better solution.

OTR’s main controls are two Turnigy 9XR transmitters, eliminating the need for any switches in the control box and providing unprecedented reliability. Since such transmitters are typically used for hobby-grade aircraft that require precise control, they function perfectly for ROVs. These transmitters feature large, smooth control sticks as well as a variety of switches and knobs that are fully programmable through an interface on the transmitters themselves. This eliminates the need for tedious software development on a laptop and makes small programming changes quick and easy to perform.


Spektrum AR9020 wireless receiver

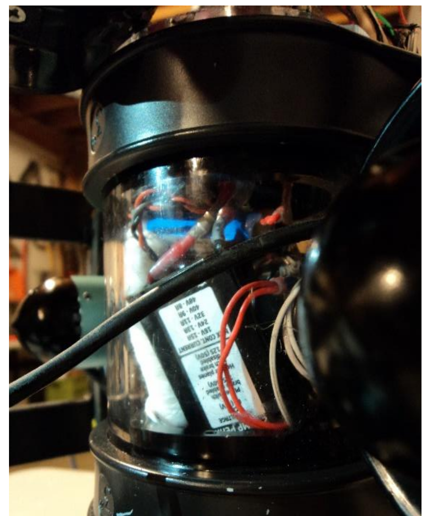
Because OTR utilizes a wireless control system, a secure connection between the receiver and transmitter is essential. Wirelessly transmitting the signal through water to the on-board receiver is extremely unreliable, and a loss of connection could damage both the vehicle and its surroundings. To ensure this doesn’t occur, the control box houses two satellite receivers. These devices receive wireless signals from the first transmitter, and send these signals through a secure wired connection via the tether to the on-board receiver. Because the two satellite receivers are located very close to the transmitter, signal connection is secure and has been confirmed by our testing.

One transmitter, held by the pilot, is used to control OTR’s thrusters. The second, held by the co-pilot, controls the pan/tilt camera mount and manipulator. The two transmitters communicate through a wired connection in the form of an AUX cable. The second transmitter sends signals for the manipulator and camera mount position to the first transmitter. The first transmitter combines these signals with those of the thrusters and sends them over a wireless connection to the satellite receivers. Using two transmitters instead of switches or a Wii nunchuk has proven to be the best solution to date. It gives both the pilot and co-pilot enough personal space, increasing efficiency and accuracy, and allows for more precise control of the camera mount and manipulator than in past configurations.

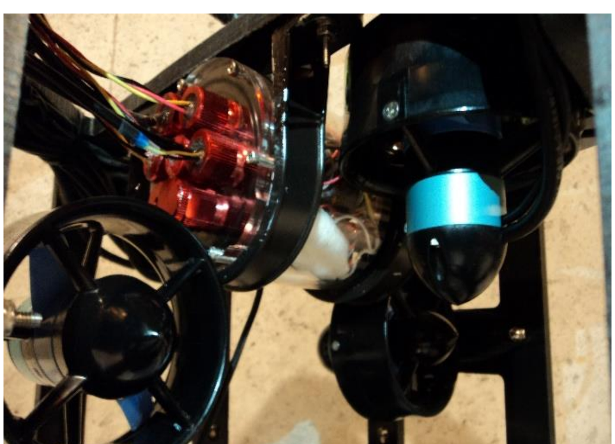
## B. On-Board Controls

OTR's on-board control system is comprised of several sets of components that work together to offer easy and reliable control of the craft. All moving parts, such as the thrusters, manipulator, and camera mount receive control signals from a Spektrum AR9020 wireless receiver mounted inside OTR's watertight enclosure. To avoid signal loss, two satellite receivers are connected to the receiver through the tether and mounted in the control box. These devices receive wireless signal from the transmitter and transmit it through the tether to the receiver resulting in a secure and reliable connection.

In addition to a receiver, OTR features an on-board Arduino Micro used to read and interpret data from the depth sensor. Originally, a USB cable was installed in the tether and used to transmit data between the Arduino Micro in the watertight enclosure and the laptop at the surface. Through testing, the USB was found to be unreliable at distances over 4.5 m, so it was replaced with a CAT5 Ethernet cable to transmit data through the tether instead. The USB signal from this Arduino is converted to CAT5 Ethernet and sent through the tether to the control box, where it is then converted back to USB and connected to a laptop. The temperature sensor connects to a Go! Link connector from Vernier, which then connects to a user interface on the laptop. Both sensors were calibrated and double checked on the laptop, where data from the sensors can also be viewed.


Watertight enclosure (bottom view)

Powering all of OTR's components safely and reliably was a challenge because every component has a unique operating voltage. The wireless receiver operates at a 5.5V, which is provided by a battery eliminator circuit (BEC). A BEC is a small component that is essentially a voltage converter. OTR features two BEC's mounted in its watertight enclosure. As mentioned above, one BEC is set to 5.5V to power the receiver. This BEC also powers the Arduino Micro. The second BEC is set to 6.2V and used to power each of the three high voltage servos on the craft. Last year's vehicle had a receiver and servos that were powered by a single BEC set to 5.5V. This proved to be problematic because the servos were not receiving enough voltage, so they were weak and slow to move, and drew a significant amount of current so power loss on the receiver was frequent. With the addition of a

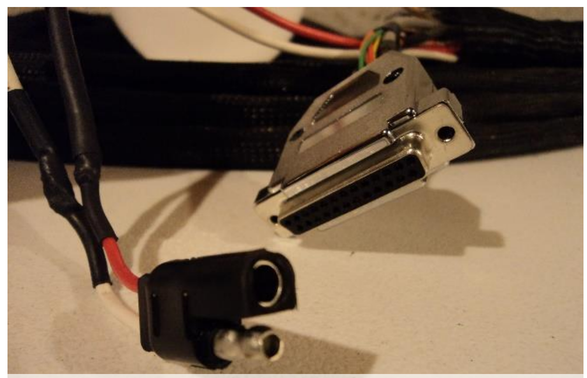

Watertight enclosure (side view)

second BEC used exclusively to power servos, these issues have been completely eliminated.

## C. Watertight Enclosure

Most of OTR's control system is housed on the vehicle itself in a watertight enclosure manufactured by Blue Robotics. Last year, InnovOcean made a watertight enclosure out of PVC and plexiglass sides. This enclosure leaked multiple times since O-rings didn't fit appropriately, ruining electrical components and setting the schedule back several days as engineers waited for replacements. Because of these issues, employees decided to purchase a watertight enclosure kit manufactured by Blue Robotics. This kit was chosen because it's both affordable and commercially tested to be reliable, therefore making it the best solution for OTR's on-board control system. OTR's frame was designed specifically with this enclosure in mind to ensure a perfect fit. Feminine hygiene products and silica gel packets were placed inside the container as an emergency measure.

## D. Tether



Tether connectors

OTR's tether includes 28 leads - two main 10 AWG power leads, two camera cables (3 leads each), a CAT5 cable for the on-board Arduino, six 18 AWG leads for the satellite receivers, and six 18 AWG leads for the temperature sensor - all bundled in an abrasion-resistant tether wrap. The tether has several new features, such as combined power leads for better reliability. Combining all power leads into a central system has also significantly reduced the size of the tether, making OTR easier to handle on the surface and more maneuverable underwater compared to vehicles of past years. The tether is connected to the control box via a D-sub 25 pin connector purchased from RadioShack and a 2 pin power connector. It also features tension relief points on both ends to prevent electrical connections from being pulled on.

The buoyancy of OTR's tether was a difficult design challenge. Engineers wanted to improve on last year's Styrofoam ball system without compromising tether size and ease of handling on the surface.

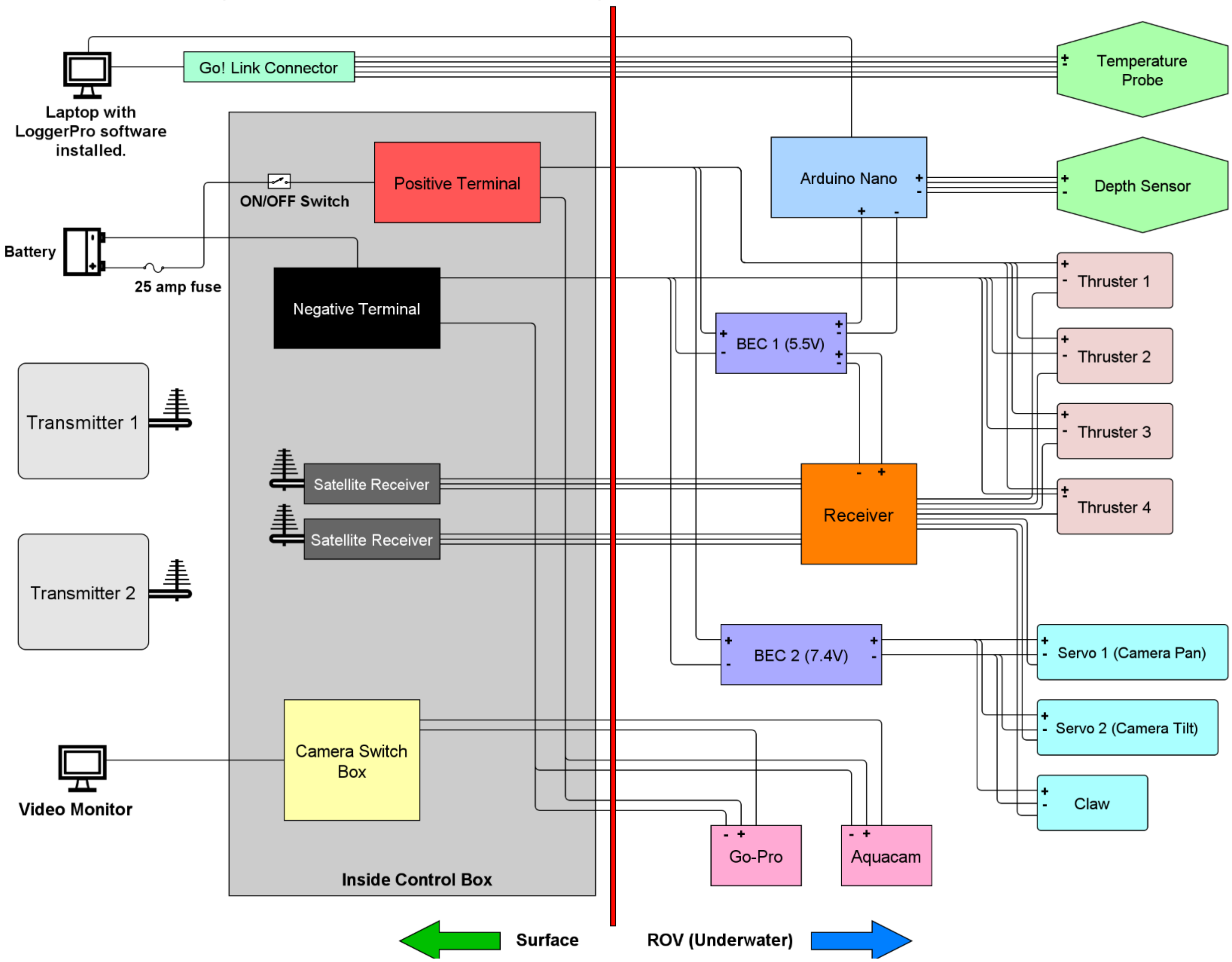
Tether and tether buoyancy

Even though OTR's tether is significantly lighter than tethers on InnovOcean's previous models, it still requires added buoyancy to counteract gravity without compromising the vehicle's maneuverability. Through testing and past observations, it was clear that the ideal position for the tether was for it to remain directly above the vehicle itself during mission maneuvers. To achieve this, InnovOcean engineers implemented a central main buoyancy point, capable of being positioned at variable lengths from the ROV. An affordable and reliable 30 cm Smoothfoam ball was used as center-point floatation.

Even though this system proved to work remarkably well, the entire tether still needed to be neutrally buoyant to ensure absolute zero lateral pressure on the vehicle during operation at intermediate depths. Engineers created a solution consisting of modified 2.5 cm diameter Smoothfoam balls mounted inside the tether jacket. Because the balls are mounted inside the jacket, tangling issues are virtually eliminated and the tether is easy to handle on the surface.

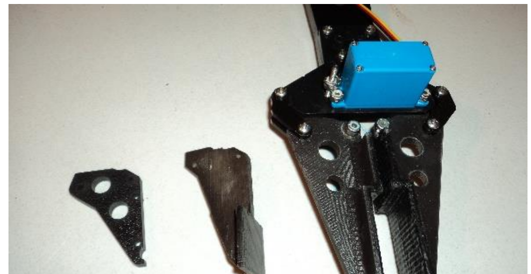
## E. SID and Block Diagram

SID created using AutoCAD software. Block Diagram can be found in Appendix C.



# Mission Specific Tools

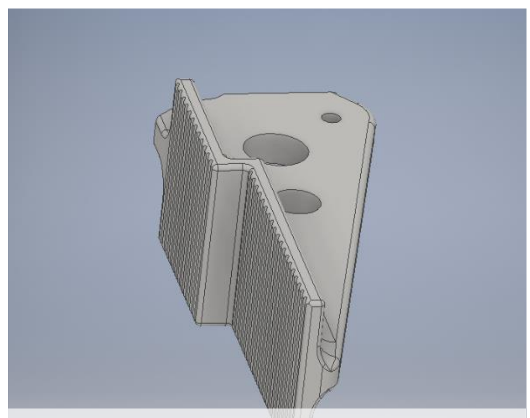
## MANIPULATOR



Evolution of Manipulator Arm

Arguably the most important feature of any ROV is the ability to manipulate its surroundings. In the past, InnovOcean has utilized two- or three-pronged manipulators. Although such manipulators proved useful for previous year's mission tasks, it would inhibit OTR's ability to manipulate the environment in this year's missions, since flat objects would not remain gripped securely. Various manipulator designs were researched and a parallel gripper was selected as the most effective for sampling coral and oil, and manipulating CubeSats and old oil pipelines, given that each features flat and parallel grab points.

InnovOcean purchased a parallel gripper kit from Sparkfun Electronics, with the intention of 3D printing its own gripper arms for maximized efficiency. The original manipulator design had a maximum opening of 7.5 cm; however, the mission – specifically moving and placing flange adapters and oil wellhead caps – required a maximum opening of 10 cm. InnovOcean engineers used AutoCAD to design custom arms with two opening distances: both the maximum and minimum required opening distances. The design was then 3D printed and fitted to OTR's manipulator mount. The arms were designed with a corrugated grip and were plasti-dipped to ensure a secure grasp. A waterproof digital servo (HS-5646WP) from Hitec provides movement to the manipulator, offering improved speed and precision over the analog servos of past models. Engineers also designed and cut HDPE to extend the manipulator out 18 cm so the manipulator "work space" would remain open and clear for precision work.

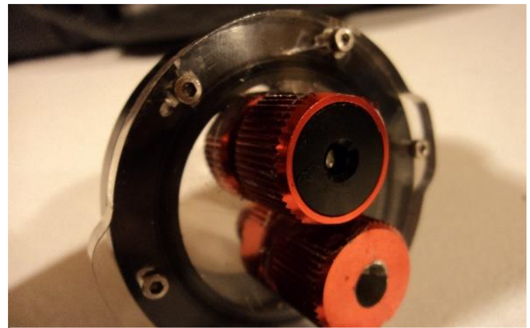


Inventor model of 3D printed manipulator arm

## MEASURING SYSTEM

In the past, vehicle measurement systems have been rather unsophisticated and clumsy, ranging from a physical tape measure to analyzing screenshots in AutoCAD by scaling known measurements.

For this year's missions, the only necessary measurements were vertical, and therefore it was decided that a depth sensor would best fit that need - creating a simple, accurate, instantaneous, and elegant measurement system.

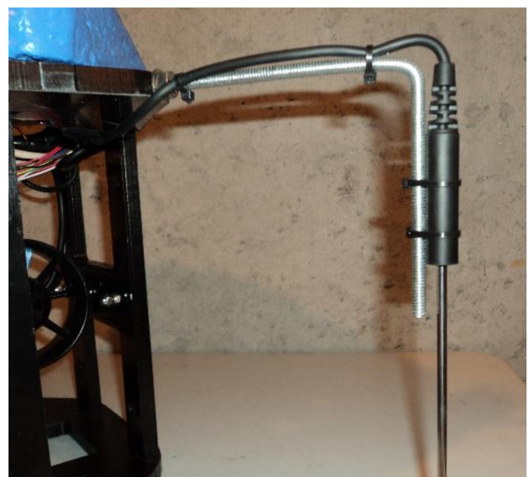


Separated Depth Sensor (top)

OTR features a BlueRobotics Bar30 High-Resolution depth sensor allowing for depth readings with 2 mm accuracy at any time during operation. The sensor can measure up to 30 Bar, or 300 m depths, and is securely mounted to OTR's waterproof casing and is interfaced through an Arduino Mini. Employees are able to analyze the data on the laptop.

## TEMPERATURE SENSOR

OTR also features a stainless steel Vernier temperature sensor with 0.03°C precision. A custom mount for the sensor was fabricated from threaded stainless steel rods and HDPE plastic. The temperature sensor serves two main functions. First, it allows for quick and accurate temperature readings of venting fluid. Second, it serves as a physical guide for depth measurement. Since the temperature sensor and depth sensor are mounted at the same vertical position, the temperature sensor mount can be used to align OTR at the proper depth for accurate reading. Unlike OTR's depth sensor, the temperature sensor connects directly to the laptop through a Go! Link Connector from Vernier. To display and analyze data, the LoggerPro software is included on the laptop.



Temperature Sensor

# Troubleshooting and Testing

Troubleshooting and testing is a constant and dynamic process within InnovOcean. InnovOcean-designed parts are constantly being improved upon, because they are constantly being tested in trial runs. InnovOcean engineers are constantly rethinking designs and improving them. If a critical problem does arise, all company engineers meet to brainstorm and research to find a solution. The reason OTR is so effective is because of the numerous and extensive trial runs that InnovOcean conducts. Every individual component was tested on land and then again in the pool. OTR as a whole was tested in a “dry run” in which the vehicle was powered and tested on a component by component basis. The sensors were calibrated and tested against known measurements before being mounted on the vehicle and the manipulator, while unattached and held by an employee, was tested in a bucket of water by retrieving smaller props. After testing, OTR was moved to a practice pool for a few “trial runs” so our pilot and engineers could fully understand all of its successes and shortcomings. Further action was taken as necessary.

# Safety

Safety is InnovOcean’s greatest priority. This is evident when one inspects InnovOcean’s workshop, each of our vehicles, and employee conduct. With appropriate provisions, all accidents are preventable. In the unfortunate situation that an accident does occur, InnovOcean takes initiative to conduct a root cause analysis to fix the issue. All of our employees deserve and require a safe work environment, which InnovOcean strives to guarantee. Overall, our safety procedures can be summed into three key components: Employee Training, Lab Safety, and Vehicle Safety Features.

## F. Employee Training

New and long-time employees both go through a comprehensive training process every year. First, company leaders give a comprehensive presentation in safety practices. They learn or are reminded of what potential danger to look out for, do’s and don’ts for the workshop, required dress code and personal protection equipment (PPE). Afterwards, veteran engineers host mini programs in which employees practice workshop techniques for skills such as soldering and drilling. Once in the actual workshop, all members are closely watched and constantly reminded by peers of safe practices. Our training process reinforces that safety is a key component of our company’s operations.

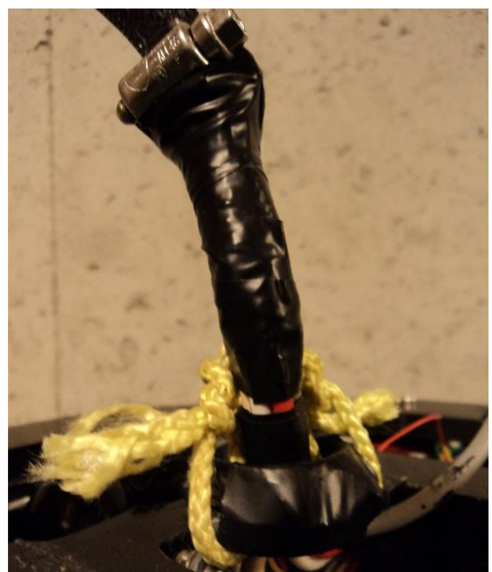
### G. Lab Safety

While constructing OTR, all employees practiced safe habits such as wearing eye protection, wearing closed toed shoes, not wearing baggy clothing, tying back long hair, and wearing gloves or ear plugs when necessary. Additionally, InnovOcean operates in a safe, organized environment. The workshop is cleaned after every meeting in order to ensure a consistently orderly workspace. By keeping our workshop organized, the number of potential safety hazards is decreased. The workshop includes a tool wall for keeping equipment neat and contained, as well as various stations for different tasks. The build station is set-up with power tools, safety gear, clamps, vices, etc., while the electrical station houses all wiring tools and provides a separate area for soldering. The workshop also houses a grinding station. A potential injury of severely scraped hands and injured eyes was avoided here when a member was wearing eye protection and work gloves. The company's safety protocols are listed in Appendix A.


Employee practicing safety protocols

### H. Vehicle Safety Features

Moreover, InnovOcean's dedication to safety is evident in the numerous safety features on OTR. OTR incorporates an array of safety precautions, including a 25 amp fuse to protect the on-board electrical components. Furthermore, all thruster and camera cords are pulled taut around the frame to minimize slack and prevent entanglement with any moving parts. All thrusters are equipped with safety partitions, and the tether is covered in an abrasion-resistant wrap. In addition, OTR's design allows for all moving parts to be confined within the frame. The control box, a water-tight Pelican case, also features safety stickers to warn employees of potential hazards and a plastic sheet that covers all electrical components to further prevent harm. OTR's tether also features tension relief points to prevent electrical connections from being pulled on. Furthermore, the company follows a strict safety checklist before, during, and after all mission runs and testing (See Appendix A). These protocols are enforced in order to protect and guarantee safety for all members from moving parts and "hot" wires.


Tether tension relief point

# Logistics

## SCHEDULE PROJECT MANAGEMENT

InnovOcean sets completion dates for every component of the ROV, technical report, presentation, and marketing display. Usually, projects are distributed to smaller groups of individuals, with which they create their own deadlines for. CEO, Dorothy Szymkiewicz, then approves or modifies deadlines to make ensure that each is reasonable and coincide with all other projects. This ensures that scheduling doesn't hold back OTR's creation. After approval, all deadlines are added to a Google Calendar that all employees can check. The final schedule is also posted in the workshop, and the CEO sends out constant reminders through an app called "Remind." The CEO rotates from group to group, ensuring that projects are finished on time, helping with any problems. In the event that a project is not finished on time, she figures out why it wasn't completed and fixes the issue with other veteran members. Overall, this system has proven incredibly effective and has led to much success.

Google Calendar Schedule of March


## BUDGET AND PROJECT COSTING

At the onset of the work season, we laid out a budget with estimated expenses based on previous year's actual expenses. Income was predicted from fundraisers, employee dues, sponsors, and leftover money from the previous years. Since we are a high school based company, InnovOcean has a very fixed budget that we have to follow. Every month, receipts from items that we have purchased were collected and tracked with the budget. Some of the items on OTR were graciously donated from different sources, while a number of others were built out of purchased materials. A few select parts were also reused from previous years. Budget and Project Costing sheets can be found in Appendix B.

# Conclusion

## CHALLENGES

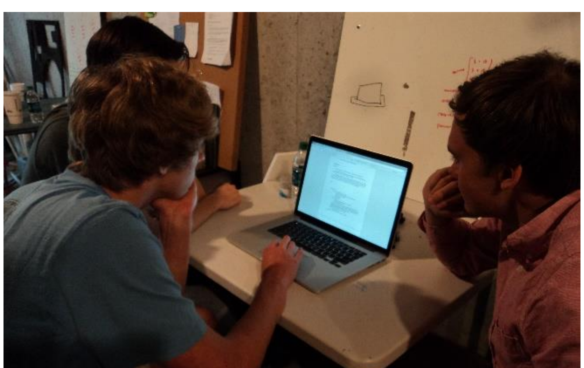
Throughout the duration of this project, InnovOcean experienced various challenges that we had to overcome. We encountered both technical and non-technical obstacles, and sometimes these tasks became overwhelming. However, company members worked together to transcend these challenges and find innovative solutions.

### I. Technical Challenge – Wii Nunchuk Arduino Programming

Originally, OTR's moving camera mount was controlled by a Wii Nunchuk connected to an Arduino that would transmit the proper signals to the servos. After installing and testing the system, it was found to be extremely unreliable - working only about 20% of the time. The signal was traveling long lengths of tether, and we suspected this could cause such unreliability. In response, we mounted the Arduino inside the ROV. However, we encountered the same reliability issues with this setup. After weighing various options and doing additional research, we discovered it would be both easier and more reliable to use a second transmitter to control OTR's moving camera mount and manipulator. This new system works extremely well; however, the trial and error process that led to its implementation lost us a week of time.

### J. Non-technical Challenge – Management

This year the number of employees has almost doubled, with a total of 40 members at the onset of the season. Although an influx of members is beneficial, senior members must spend a lot of time training new employees in safety practices, workshop skills, and critical thinking. Not only was learning how to prioritize a challenge, but learning to manage such a large company was also a demanding. Many times, during meetings, new employees would be without anything to do. At times, even returning members were also idle. Distributing tasks equally and fairly was a challenge. After deliberate scheduling and organization, each member was informed of protocols, schedules, and details of OTR, through spreadsheets with organized jobs and meeting dates. Each member was given the opportunity to participate in groups and work in different fields of the company to expand their skillset.



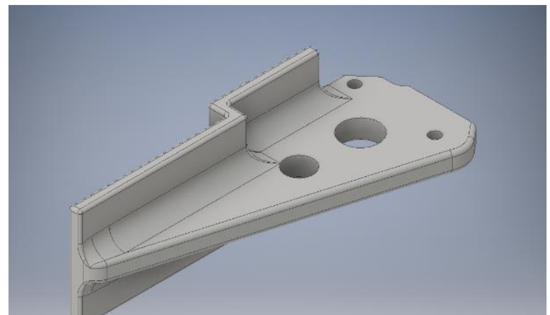
Employees doing delegated research

# LESSONS LEARNED AND SKILLS GAINED

As InnovOcean is a relatively new marine technology company, we recognize that there are many factors that create a successful business. With each ROV that we fabricate, we gain valuable knowledge, experience, and skills that continue to shape our company. These are some of the lessons we learned.

## K. Technical Skill Gained – Use of Advanced Resources

This year, our company used advanced resources such as the CNC Router and a 3D printer to help produce OTR. By using these machines, we made it to where we produced a simple yet cutting-edge ROV. Since we used these machines, we could be as specific to our needs as possible to ensure we obtained every need that we had. Our company had not used these machines before to the extent that we did this year, but because we did, we learned a lot about the use of such machines. Our company now knows how to use these machines proficiently and that has benefited us greatly.



Inventor model of manipulator

## L. Non-technical Lesson Learned – Proper Lab Organization

This year's workshop has been quite an incredible move for the entire company. InnovOcean's past workshop was rather unorganized while this year's is impeccable. InnovOcean's organization structure in the past grew rusty since the company used the same workplace for four years. The new location has none of the same nuances and the move brought a new energy to the company. We designed the new workshop with safety in mind, placing tools and materials in appropriate places, with personal protection equipment (PPE) ready at the entrance. Furthermore, everything is organized into containers with a uniform labeling system for common supplies such as zip ties, PVC, adhesives, hardware, and electrical components. Additionally, the workshop is cleaned after every meeting. This experience has become a lesson learned for many: an organized work space sets new energy and allows members to work with a fresh mind, promoting progress within our company's operations.

InnovOcean Workshop

# REFLECTIONS

This year, reflections were written by a new, returning, and senior InnovOcean employees.

## M. New Member – Leo Ank, Government Regulations

"Within these past couple of months, I have been thrilled to be part of InnovOcean. I have learned so much about engineering and about working within a team. The company has pushed me beyond my comfort zone to think outside the box. I will continue my time with InnovOcean and learn as much as I can. I am proud to say that my fellow team members have quickly become my family."

## N. Returning Member – Jill Fazio, CFO

"InnovOcean is a wonderful outgoing company that I hope to see continue to flourish over the next few years. The amount of growth at InnovOcean over the last two years has astonished me. The company has definitely changed my perspective and the way I think for the better. This year, my knowledge about and experience with engineering and ROVs has grown tremendously. Being a part of this company has been one of the best decisions I have yet to make and would recommend to anyone that would ask."

## O. Senior Member – Dorothy Szymkiewicz, CEO

"Without a doubt, ROV has changed my life for the better. It taught me things that I would have never learned elsewhere: from soldering, presenting, to critical thinking. Most importantly, it has become my family outside of home. With open arms, the upperclassmen from my younger years guided me through high school, all while inspiring in me the engineer that I never realized existed. They taught me that small things in life should be fun, that kindness is key, that hard work will bring pride. As I strive to embody the same unifying spirit I was shown, I am humbled by the fire I see in the eyes of the underclassmen, as I know that my contribution to them is but a transfer of the one the upperclassmen gave me. In them, I see myself - full of undying passion, enthusiasm, and curiosity. I know that ROV was the centerpiece to my future pursuits in engineering at either MIT or Stanford."

# FUTURE IMPROVEMENTS

InnovOcean is constantly looking for ways to advance. There is always room for improvement whether it be in the design, function, and controls of the vehicle or even in the structure of the research branch of our company. This year the consensus is that the following improvements would have benefited us tremendously.

Firstly, InnovOcean is a diverse group of employees: many are also involved in band, sports, school clubs, and other extra-curricular activities. With so many activities, it is always a challenge for everyone to contribute equally at all times. Although it is expected that no one person will make it to every meeting, it is expected that everyone contributes what they can to the best of their abilities. Decreasing student involvement hinders the progress of InnovOcean's operations and services. In the future, we hope to boost morale, possibly by hosting socials, so the company can move forward without any such obstacles.

Secondly, InnovOcean would not be what it is without the help and support the mentors and parents. We appreciate all parent involvement we can get, yet it is not always taken full advantage of. There are currently three parents that help greatly with guidance and organization. In future years, we hope to encourage more parents and mentors to get involved. Such changes would help tremendously, motivating both the company and the individuals within. It is evident that other companies with more parent involvement are progressing quicker than us and have more advanced and sophisticated systems. We are here to learn.

We look to keep parents increasingly involved by starting weekly emails that discuss the operations and accomplishments within the week. Furthermore, we will ask that parents help to provide food for late night meetings and encourage their advice for and critiques of our vehicle and/or operations. InnovOcean will request parent engineers to come in and act as mentors. InnovOcean would have access to more resources and promote more engineering discussions. Greater parent involvement would greatly benefit InnovOcean.

Thirdly, we would like to improve our tether buoyancy system while decreasing the size of the tether. We are also working on a rotating thruster design, with the use of servo motors, which would not only eliminate two thrusters, but would also decrease the weight of the vehicle and decrease the size of the tether. All these improvements will allow for a better and more efficient ROV and oceaneering company. InnovOcean looks forward to applying these improvements next year.

InnovOcean Employees and Future Recruits (from CMS and CJHS)

## ACKNOWLEDGEMENTS

InnovOcean would like to recognize several sponsors and individuals for their support and help throughout this year. Carrollton High School has allowed us to use the STEM lab equipment, specifically the 3D printer and CNC router, to create many of OTR's components. We thank Advanced Precision Manufacturing for advice on frame design and material choice. We would also like to thank the school for their generous donations and ongoing support. We appreciate the support of Sunset Hills Country Club and Lakeshore Recreation Center for permitting us to utilize their pools for practice. We would also like to thank Ozier Apparel for providing us with custom embroidered polos. Additionally, we would like to give a special thanks to our parents and families for their advice, inspiration, and encouragement as we take on new challenging endeavors. Mrs. Jane Hornsby and Mr. Paul Szymkiewicz, in particular, have gone out of their way to make this year possible. Mrs. Jane has offered the team her basement as a meeting space where we collaborate and construct while Mr. Paul has served as a guiding hand, giving us useful advice and tips as we progress through the year. Without the support of our beloved mentor, Mrs. Kristie Bradford, none of our accomplishments would have been possible. She has ensured that we stay organized, has guided us along the way, and has never stopped believing in us. We appreciate all that these individuals and organizations have done! Finally, InnovOcean would like to acknowledge Gray's Reef National Marine Sanctuary and MATE for giving us the opportunity to participate in such an amazing experience.

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# Appendices

## APPENDIX A – SAFETY CHECKLIST

Mission Preparations

- Area clear/safe (no tripping hazards or items in the way)
- Verify power switches and circuit breakers on Control Box are off
- Tether laid out on deck
- Tether connected to Control Box
- Electronics housings sealed – no leaks inside
- Nuts tight on electronics housings and ROV components
- Thrusters free from obstructions
- Power source connected to Control Box

Going Hot

- Control Box receiving 12V DC
- Laptop up and running
- Ensure team members are attentive
- Call out, "Going Hot"
- Power on Control Box
- Call out, "Performing test"
- Perform test - verify thrusters and other servos are working properly
- Verify video feeds

Start-Up

- Load accessories
- Call out, "Prepare to go"
- Deck crew members handling ROV call out "Ready"
- Call out, "Ready"
- Maintain hand hold, wait for release order
- Call out, "Launch" and launch ROV

In Water

- Check for bubbles
- If there are large bubbles, pull to surface immediately
- Wait 5 minutes, then check leak detector
- Engage thrusters and begin mission

ROV Retrieval

- Pilot calls "ROV surfacing"
- Deck crew calls "ROV on surface"
- "ROV captured", kill thrusters
- Co-pilot powers down Control Box
- Co-pilot calls out "We're Cold"
- After securing the ROV on deck, deck crew calls out "ROV on deck"

Loss of Connection

- Turn off/on Control Box to reboot ROV
- If no communication, power down ROV and retrieve via tether
- If communication restored, confirm there are no leaks and resume mission

Leak Detection Protocol

- Surface immediately
- Power down Control Box
- Inspect (May require removal of watertight enclosure)

## APPENDIX B – BUDGET & PROJECT COSTING

| Project Costing | | | |
|---|---|---|---|
| **Deposits** | | | |
| **Description** | **Vendor** | **Amount** | **Balance** |
| 2014-2015 ROV Balance | ROV Account | $3,430.32 | $5,930.32 |
| Poinsettia Fundraiser | Coweta Greenhouses | $2,200.00 | $8,130.32 |
| ROV Dues | ROV Members | $2,800.00 | $10,930.32 |
| **Expenditures** | | | |
| **Description** | **Source** | **Value** | **Balance** |
| **Payloads** | | | |
| SparkFun Parallel Gripper | Purchased | $57.49 | $10,872.83 |
| HiTech Waterproof Servos 5456 | Purchased | $270.00 | $10,602.83 |
| Go!Link Connector | Purchased | $61.85 | $10,540.98 |
| Depth Sensor | Purchased | $68.00 | $10,472.98 |
| Manipulator Base | Purchased | $13.47 | $10,459.51 |
| Threaded Rod | Purchased | $8.98 | $10,450.53 |
| Stainless Steel Screws, Nuts, and Washers | Purchased | $60.30 | $10,390.23 |
| Vernier Stainless Steel Temperature Sensor | Donated | $29.00 | $10,390.23 |

| Budget | |
|---|---|
| **Category** | **Amount to Spend** |
| Payloads | $600.00 |
| Camera | $950.00 |
| Frame | $100.00 |
| Tether | $300.00 |
| Control | $750.00 |
| Hardware | $300.00 |
| Safety Equipment | $50.00 |
| Propulsion | $700.00 |
| Supplies/Props | $600.00 |
| Buoyancy | $200.00 |
| **Total Budget** | $4,550.00 |

| | | | |
|---|---|---|---|
| **Camera** | | | |
| GoPro and Casing | Donated | $450.00 | $10,390.23 |
| AquaCam | Re-Used | $495.00 | $10,390.23 |
| **Frame** | | | |
| HDPE Plastic | Donated | $80.00 | $10,390.23 |
| **Tether** | | | |
| Wires | Purchased | $176.43 | $10,213.80 |
| Wrap | Re-Used | $82.50 | $10,213.80 |
| **Control** | | | |
| Connectors | Purchased | $30.13 | $10,183.67 |
| Recievers | Purchased | $130.00 | $10,053.67 |
| New Transmitter | Purchased | $120.00 | $9,933.67 |
| Anderson Powerpole Connectors | Purchased | $10.71 | $9,922.96 |
| Transmitter Lithium Battery | Purchased | $40.07 | $9,9882.89 |
| Waterproof Enclosure Kit | Purchased | $199.99 | $9,682.90 |
| Box | Re-Used | $90.57 | $9,682.90 |
| Transmitter | Re-Used | $120.00 | $9,682.90 |
| **Hardware** | | | |
| Power Tools | Purchased | $150.00 | $9,532.90 |
| Hand Tools | Purchased | $60.00 | $9,472.90 |
| Wire Stripper/Crimper | Purchased | $15.00 | $9,457.90 |
| Drill Bits | Purchased | $20.00 | $9,437.90 |

| | | | |
|---|---|---|---|
| **Safety Equipment** | | | |
| Gloves | Purchased | $12.90 | $9,425.00 |
| Glasses | Purchased | $10.81 | $9,414.19 |
| Masks | Purchased | $6.20 | $9,407.99 |
| **Propulsion** | | | |
| T100 Thrusters w/ BlueESCs | Donated | $796.00 | $9,407.99 |
| **Supplies/Props** | | | |
| Props | Purchased | $423.13 | $8,984.86 |
| Tape | Purchased | $15.23 | $8,969.63 |
| Epoxy | Purchased | $17.80 | $8,951.83 |
| Misc. | Purchased | $50.00 | $8,901.83 |
| **Buoyancy** | | | |
| Epoxy | Purchased | $32.98 | $8,868.85 |
| Paint | Purchased | $4.95 | $8,863.90 |
| Schluter Foam Board | Donated | $80.00 | $8,863.90 |
| | | | |
| **TOTAL** | | **$4,260.46** | $8,863.90 |
| **Total Amount Spent This Year** | | **$2,066.42** | |
| | | | |
| **Total Value of Donated Items** | | **$1435.00** | |
| **Total Value of Re-used Items** | | **$788.07** | |
| **Total Value of ROV** | | **$3,541.45** | |

# APPENDIX C – BLOCK DIAGRAM (ARDUINO MICRO)