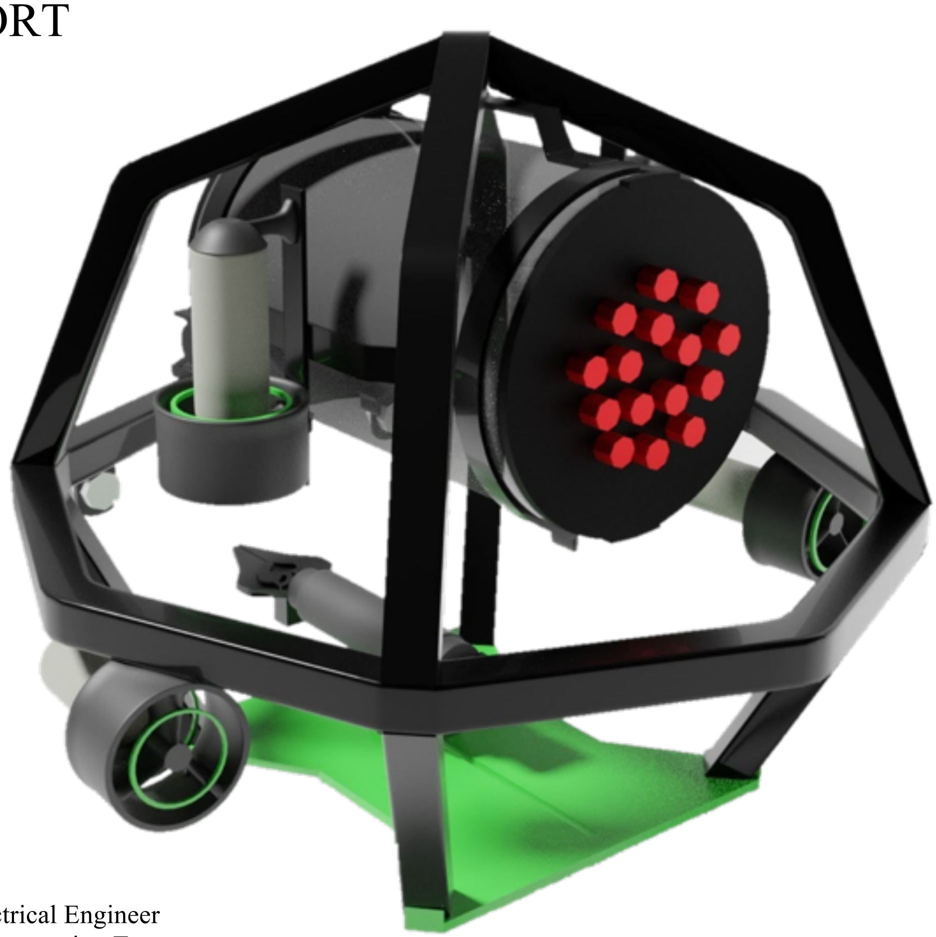
North Paulding Robotics

MATE 2018 Regional Competition
Ranger Class
TECHNICAL REPORT



Company Members

Michael Lees	CEO & Electrical Engineer
Nick Garber	Head of Programming Team
Bryce Rodriguez	Head of Mechanical Team
Glen Lewis	Head of Electrical Team
Nicholas Revelos	Electrical Engineer
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Tanner Highfield	Programming Engineer
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ABSTRACT

North Paulding Robotics specializes in building high quality remotely operated vehicles (ROV) that are durable and meet the highest standards of safety. In response to the Request for Proposal released by The Applied Physics Laboratory (APL) at the University of Washington (UW), the company designed a lightweight, compact ROV that can locate the wreckage of a vintage aircraft and return its engine to the surface, install or recover a seismometer, and lastly install a tidal turbine and instrumentation to monitor the environment. The ROV has a sturdy external frame made from lightweight aluminum to protect the motors, wiring, and cameras while operating in both the fresh and saltwater along the Pacific Northwest. The company focused this year on the onboard electronics by implementing a new onboard control system and an acrylic electronic housing to the ROV so that the team could complete each task in a timely manner. In addition, the ROV was equipped with a rotating manipulator to collect Eelgrass specimens, an upgraded camera system to help identify the missing aircraft, a specimen collector, and a custom airlift bag and inflator to retrieve the aircraft engine and bring collected samples to the surface. Our company upholds the highest level of professionalism and guarantees quality work in a timely manner.

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1. COMPANY PROFILE

North Paulding Robotics was established in 2012 and currently has 15 company members ranging from 9th to 12th grade. To meet the individual needs of our clients, the company's members maintain a wide range of qualifications that allow them to be creative in their build of ROVs. The company strives to expand upon their knowledge and expertise, which allows them to continue to develop high quality and reliable ROVs. The company demonstrates exceptional teamwork and management skills in the completion of this year's build.

North Paulding Robotics 2018 Company Photo

2. MISSION THEME

Ongoing earthquake and volcanic activity has shaped the Pacific Northwest area of Washington and has resulted in beautiful mountain ranges and deep rivers that flow into the neighboring lakes. The continued action of the mudslides, landslides and lahars that accompany this activity have wiped out forested areas and sculpted the terrain. The Pacific Northwest is beautiful and rapidly growing. Seattle is the birthplace of Starbucks, Microsoft, and Boeing, a city commonly referred to as the "Jet City." Due to the rapid expansion of the city and surrounding areas, human impact is a growing concern. Manufacturing and high-tech companies are devising ways to minimize human impact on the environment. One solution is to create renewable energy options and reduce dependence on petroleum. Secondly, there is a desire to restore areas that have been previously impacted and remove invasive species from the area. The innovative use of ROVs can play an important role in helping with the cleanup while maintaining the safety of workers and ocean life. The mission demands are represented by the following tasks:

Task one: **Locating a wreckage of a vintage aircraft and returning its engine to the surface**
Task two: **Installing and recovering a seismometer**
Task three: **Installing a turbine and instrumentation to monitor the environment**

2.1 Task One – Aircraft (80 Points Total)

The company must use flight data to determine the search zone for the wreckage. Once located, the company must identify the aircraft using the tail section. The ROV must then attach an airbag to the debris to move the debris off the engine, and then detach the airbag. The ROV will then attach the airbag to the engine, inflating the bag and returning the engine to the side of the pool. The airbag must be returned to the surface and removed.

2.2 Task Two – Earthquakes (80 Points)

The company will deploy an ocean bottom seismometer (OBS) to the bottom of the pool. The OBS is designed to house a cable connector and a release mechanism. The ROV will disconnect the OBS cable connector from its holder, closing the door of the communication hub, and placing the OBS cable into the OBS. The OBS will then be released from its anchor using an acoustic sensor. The OBS will then be moved to the side of the pool and retrieved.

2.3 Task Three – Energy (100 Points)

The company will use tidal data and nautical charts to determine the optimum location for a tidal turbine set up. Once the optimum location has been calculated, the ROV will install an array of tidal turbine in the optimum location. The ROV will first install the base to the bottom of the pool, then place the array into the base, and secure the array in place by closing the latch. The ROV will then install the Intelligent Adaptable Monitoring Package (I-AMP) to monitor the area. The ROV will transport the I-AMP to its stand and then lock it in place. The ROV will then place a mooring a given distance from the base of the turbine. The ROV will attach an Acoustic Doppler Velocimeter (ADV) at a given height on the mooring line. The ROV will measure the height from the bottom of the pool floor to the ADV. Lastly the ROV will collect two samples of eelgrass from a designated area and then transport two mature samples back to the designated area.

3. DESIGN RATIONALE

North Paulding Robotics built the ROV in response to the Request for Proposal (RFP) issued by the MATE center in 2018 and The Applied Physics Laboratory at the University of Washington. The request specified that the ROV must be able to operate both in salt and freshwater environments and in the confined spaces of the Pacific Northwest. The requirements set by MATE Center were:

- The vehicle must fit through a 60cm diameter hole.
- The vehicle and tether must weigh less than 12 kg.

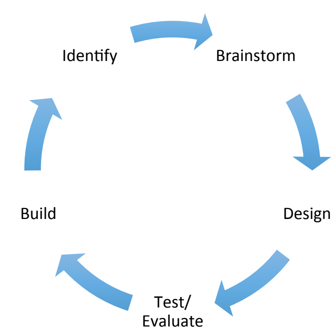

Figure 1 – Design Cycle

3.1 The Design Process and Cycle

The ROV was developed and constructed by following set guidelines established by the company in the first month of the design. Every task, purchase, and decision made to complete the build was thoughtfully planned before any action was taken. Company members developed a clear description of the task, timeframe for completion, and cost by researching what was needed and assigning the most qualified company members to tackle each challenge. The company designed the ROV frame on SolidWorks, consulted with their company leaders and decided the best way to proceed based on time and cost constraints.

The company developed a detailed design plan, which outlined the steps needed during each stage of the ROV build. The company followed a five-step design process, and every component of the ROV underwent the same design process. During the first step, the company brainstormed and researched what was required to complete each mission of the competition. This included material, cost, and responsibility for each task. Prototypes were built, tested and, if necessary, re-designed until the final prototype was developed. The prototype then went into production, was tested, evaluated, and then added to the ROV frame.

In addition, the company followed a detailed timeline and protocols, during each production stage to facilitate the completion of each component in a timely manner. If delays were encountered due to the ordering of parts or components not working, the timeline was modified, and company leaders were informed. The company reused parts and components from last year's build to help improve the overall success of this year's build and to minimize the cost of the ROV build.

3.2 Design Evolution

For our first step, our company considered last year's ROV, evaluating its strengths and weaknesses. The frame from last year was lightweight and made from aluminum sheeting, allowing for easy mounting. At the start of this year, our company debated about the shape of this year's ROV between the octagonal shape, which we ended up choosing, or a square frame. After much contemplation of the pros and cons of the shapes, we ultimately committed to the octagonal shape for its excess of mounting points. This year, the company used the same material as last year to build the ROV frame but modified the shape to house the acrylic electronic housing tube. The company added new features to the frame shape to allow for easy mounting points for thrusters, cameras, and payloads. The same four Seabotix thrusters were reused to save on costs, allowing the company to use devote funds to other materials. The company designed the ROV using SolidWorks and built a prototype. This was presented to all company members for evaluation, allowing for adjustments and improvements before it went into production.

3.3 Mechanical Design

3.3.1 Frame

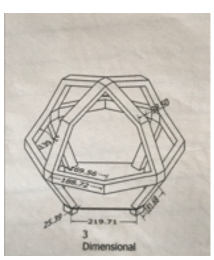

Figure 2- 3D design using Inventor

Figure 3- Wooden Prototype of frame

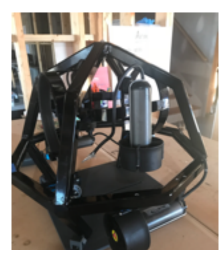

Figure 4- Final ROV Frame

When designing the frame of the ROV this year, we were presented with many new opportunities that we could take advantage of to create an extremely functional design. The addition of an onboard electronic housing was a feature that the company has never tackled before, and it proved to be a challenge to integrate into the design while remaining within the size requirement of 60 cm. The frame was designed using a computer-aided design program, SolidWorks, so the company could create a solution to the issue. In past years, the company has designed ROVs with a simple box-like design to simplify the rest of the assembly; however, due to the addition of the onboard electronic housing, the company had an opportunity to think outside of the box with the design. The company designed an ROV that conforms to the size requirement with more of a spherical shape. Since the ROV is measured around a circle, it makes sense to have a spherical design to maximize space inside and provide multiple mounting points for thrusters and payloads.

After we finalized our design, we created a wooden prototype to preview what the assembly would be like and to have a physical model that we could plan around. The prototype proved to be beneficial because it presented many engineering challenges that we could solve in a wooden structure instead of a final product. Once we had our prototype created and finalized, we were ready to assemble the final product. For our materials, we chose a channeled aluminum to save on weight while retaining strength. The channels also allowed us to better manage our cables and keep them out of sight for better aesthetics. We also custom 3D-printed a baseplate with a mounting slot for the arm. After the frame was welded together by company members, it was powder coated in black and the baseplate was attached. The final frame is a perfect balance among simplicity, efficiency, weight and strength, and is an engineering success. The frame's dimensions measured 55cm in horizontal diameter and 44 cm in height with a weight of 2.7 kg without the tether, electronic housing, and payloads.

3.3.2 Thrusters

Figure 5- Sabot BTD 150 Thruster

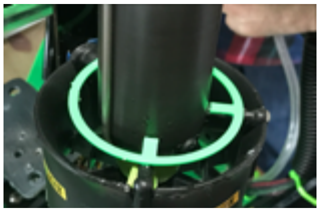

Figure 6- 3D printed guard covers

Figure 7- Testing guard covers

The proposal requested that the ROV must be capable of maneuvering in confined spaces quickly and effectively. The company built an ROV that is equipped with four motors. Four were placed on the inside four corners of the frame of our ROV and securely mounted to the frame using stainless steel machine screws and lock nuts. This balanced the ROV frame and prevented the thrusters from becoming loose during the missions. To meet the specifications of the MATE competition safety requirements, the motors are enclosed inside the frame. The two up/down motors are placed on the top surface of the frame, towards the center, keeping the frame evenly balanced. The company took into consideration that the water had to flow freely in and out of the ROV frame, so the motors were placed to minimize obstruction of water flow. All four thrusters have protective shrouds and custom 3D printed thruster guards to enclose the propellers.

The four BTD150 Seabotix thrusters have a depth range of 150 meters. The continual thrust is an impressive 2.2 kg at only 4.25 amps. Each thruster draws 4 amps of power and provides approximately 28.4 N of thrust. The propellers on the ROV consist of 76mm blades. The dimension for each thruster is

17.3cm x 9.4cm x 8.9cm, with each weighing 350 g in water and operates with a depth rating of 150 meters. They use anti-corroding steel and allow water to flow freely throughout its compact design up to a depth of 3000m (4500 psi). The ROV draws 8 amps of electrical power when all thrusters are in use. The company positioned the thrusters to allow the ROV to move forward, back, up and down.

3.3.3 Cameras

For the 2017 RFP, the company used four underwater waterproof fish finder color cameras with built-in lights. However, after testing the cameras the company found that the feedback to the monitor started to turn yellow on the screen, making it difficult to complete the tasks effectively. In addition, the shape of the camera made it difficult to mount the cameras to the frame.

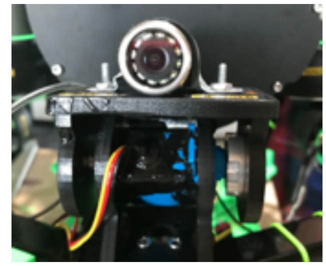

Figure 8- Main camera and tilt mechanism

Figure 9- Multiplexer splitter for cameras

This year, the specifications require that the ROV must locate the wreckage of vintage aircraft, install oceanographic equipment, remove debris and retrieve eelgrass sediments from the ocean floor, and measure the distance from the base plate. To accommodate the proposal and complete the tasks effectively, the company decided that the ROV needed to be equipped with three underwater waterproof fish finder color cameras with built-in lights. The camera extension cable length is 30m long. The camera incorporated a light source of 12 high-power bright white led lights. The cameras offer a field of view angle of 92 degrees. The company selected the best cameras that will provide the best image to the pilot when completing the individual tasks. The camera's dimensions are 2.5cm x 2.5cm x 5cm. The operating temperature of the cameras is 20°C-60°C, allowing the cameras to operate in cold temperatures. One camera was mounted to a DDT500 Tilt system with a built-in HS 5646WP Hitec waterproof servo. The tilt mechanism allows the camera to move up and with a down rotation of 150 degrees to optimize the front view of the ROV during the missions. The remaining cameras were mounted by using hose clamps in specific spots on the frame to help monitor the payloads and to assist in the completion of each task.

The main control box houses a camera multiplexer system which allows our pilots to see multiple camera angles at the same time on a single monitor. The CCTV multiplexer box has a maximum of four input camera signals and one output signal and has multiple viewing modes and combinations. Therefore, the pilots of our ROV can switch between these viewing modes to focus on one camera or view multiple camera angles at once in whichever format they choose. The multiplexer system is extremely useful to our company because this helps our pilots have better viewing angles and will also help increase our levels of efficiency when performing the missions.

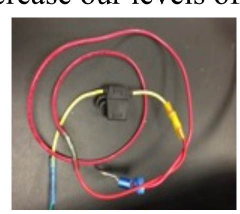

Figure 10- 25 Fuse

3.3.4 Fuse

To meet the safety requirements of the MATE competition the team incorporated a 25amp fuse into the main power line. This small safety device will stop the ROV from working if the electric current exceeds the required amount, preventing fires, electrical shock, and damage to the main control box.

3.3.5 Buoyancy

Figure 11- Additional floatation added to frame

The ROV depends on the acrylic housing in the center of the ROV to act as its main buoyancy. After testing the ROV, we found that the ROV was negatively buoyant. To fix this, 4 strips of closed-cell polyurethane foam were added to the top of the frame to maintain a neutral buoyancy. The floatation was secured with custom 3D printed covers. These covers are not only useful for keeping the flotation devices on, but they also protect the foam from unforeseen damage.

3.3.6 Electronics Housing

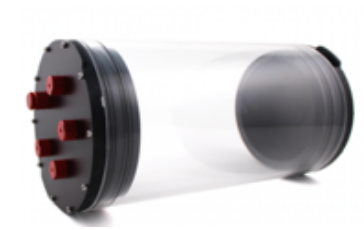

Figure 12 – Electronic housing

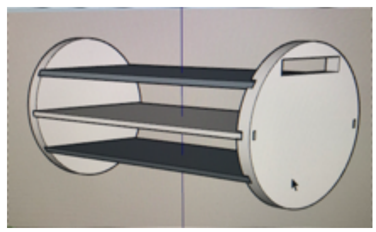

Figure 13 – Custom designed rack for electronics

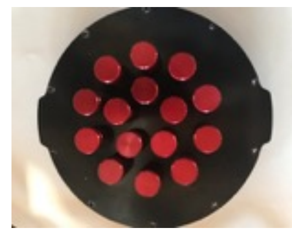

Figure 14 – Aluminum end cap

The control system for the ROV allows for easy transportation and troubleshooting. Contrary to previous years, the control system was placed in a cylindrical waterproof housing and put directly on the ROV. The acrylic housing measures 16.5 cm in diameter and 30.5 cm in height. However, the opening of the acrylic housing is restricted by the watertight seal which reduced the diameter to approximately 13 cm. All the electronic components for the thrusters, manipulator, and lights are housed within the cylinder.

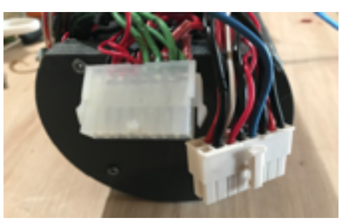

Figure 15 – Connectors to detach tether

Figure 16 – Relay board

Figure 17 – 5V regulator for power

The control system runs via a laptop computer that sends information to an Arduino Mega 2560. This Arduino controls the systems and payloads on the ROV. Within the control system, the Arduino controls the ESCs, the water shut-off, a I 2 C module, and a relay module. A voltage regulator powers any systems that require 6v and a linear voltage regulator converts 12 volts to 5 volts for powering the water shut- off, relay module, and I 2 C module. Two Sabertooth ESCs control both the horizontal and vertical thrusters. These Sabertooth ESCs receive an input from the Arduino and control the polarity and voltage going to the thrusters. A relay module controls two output powers and the polarity of a motor. The I 2 C module controls the Bar 30 Depth/Pressure sensor and sends and receives signals to and from the Arduino.

The water shut-off was custom built with a relay and a transistor to allow for an automatic shutdown of all subsurface systems if water is detected within the waterproof casing. All subsurface components are mounted upon 3D printed shelves that were measured to fit within the casing. On the surface, a camera splitter, power switch, starter button, a voltage regulator, and a laptop are contained inside of an openable box. The laptop is placed on a raised shelf to be flush with the edge of the box. All wires can be disconnected from the surface box to allow for easy transportation of the ROV and components. On the ROV itself, Molex connectors were used to allow for the subsurface control system to be disconnected and maintenance to be performed.

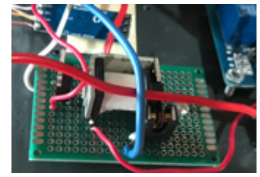

Figure 18 Shut off system

3.3.7 Software and Control

The ROV control system consists of two sections; PC software, and the onboard microcontroller. The PC software is written in Golang, a programming language written by Google. This allows us to quickly import packages for serial and USB communication. The PC software manages input and data from the robot. The second system, an Arduino Mega, gathers information and sends instructions to servos and motors. This is achieved through a virtual COM port over USB. The serial interface was used to simplify the development process, as it did not require us to make a USB class and driver. This design improves stability by utilizing a single microcontroller and using hardware that natively supports the required protocol without any modifications.

The PC improves performance in many aspects. The PC uses USB connections for both the controllers and the tether. This improves simplicity and ultimately reduces the complexity and speed while preparing the control box. The powerful programming language allows us to quickly solve solutions, and compile if the software encounters errors. The software is compatible with all computers running Windows 10. This improves the versatility of the system by eliminating proprietary hardware, allowing the user to use any PC. In addition to compatibility, this reduces the cost of the ROV by removing the need to buy another system to be placed in the box.

The Arduino C wrapper is an important aspect of the control system. It translates the USB protocol from the PC to PWM signals, a language understood by ESCs and servos. We selected the Arduino wrapper for a multitude of reasons and the most important of which was legibility. While Arduino is not the most efficient wrapper, it can be easier for any programmer to use and modify because of its simplicity. This will allow any programmer to configure code to their needs. This can be especially useful if the customer needs to add additional functionality to the robot.

The ROV uses a brand-new control system. Our programming team developed a unique communication method to connect our onboard electronics with our surface PC. At its core, our communication technique uses UART, which is extended through an Ethernet cable. Our novel method for sending commands to the robot consists of data for our motors separated by "." characters. This allows us to offload the complex code to convert input from the joystick to directional data to the motors.

The program flows in multiple steps. First, the PC receives data from the two controllers. The PC breaks these packets down and reformats them into 24-byte packets. These are then sent to the Arduino through a virtual COM port. The Arduino rebuilds the data and parses it into directional data. This is finally sent through a custom algorithm that converts the data into signals to send to the motors and servos.

3.3.8 Pilot Control System

A Logitech Extreme 3D Pro flight stick allows the pilot to control the mobility of the 6 motors on the ROV. The manipulator is controlled using a servo joystick. A second Logitech Extreme 3D Pro flight stick allows the teams to control the movement of the manipulator.

Figure 19
3D Pro Joystick

3.3.9 Light

The ROV is equipped with a 6-LED; 9W drain light with waterproof connector. The light is waterproof and is powered from a 12V battery source. The team custom built the camera mount to securely hold the light in place.

Figure 20 - Light

3.3.10 Tether

The tether consists of CAT 6 Ethernet wire, one main power and ground, a starter wire for the power relay, 3 camera wires and a tube for the air pump. The tether has a total length of 15 meters. The tether allows the ROV to communicate with the main control system and the pilots.

Figure 21- 3D Pro Joystick

4. MISSION SPECIFIC TOOLS

The company researched what payloads would be needed to reliably complete specific tasks during each mission. These payloads would allow the company to complete the following missions: locating the wreckage of a vintage aircraft and returning its engine to the surface; installing or recovering a seismometer; installing a tidal turbine and instrumentation to monitor the environment.

The ROV can perform these missions by implementing special features that will help improve the mobility, offer multiple mounting options for payloads, and improve the electronics and programming. The payloads and their tasks are as follows:

4.1 Manipulator

Figure 22 – Shaft that rotates the arm

Figure 23 – Wheel piece with bearings

Figure 24 – casing for manipulator

The ROV is equipped with a custom-built manipulator that incorporates special features that allow the manipulator to rotate 360-degree, it is lightweight, and compact size. The Manipulator consists of four major components: Rotational system, Outer Tube, The Claw, and a Tilt Mechanism. We built the Manipulator for Task 1,2, and 3 to attach the lift bag to the debris, disconnecting the OBS cable, returning the OBS to the surface, placing a mooring device, and attaching a velocimeter to the mooring device.

The rotational system is responsible for a 360 rotation. It is made up of a 140mm threaded rod that is cut into two pieces combined with a metal coupling. It is connected to a Savöx waterproof SW-121056 servo. On the other side of the threaded rod, there is a custom 3D printed wheel piece that acts as part of a ball bearing system and a slot for the claw. The wheel is measured at a diameter of 38mm and a total height of 52mm. In the top of the circular wheel, there is an 8mm width, 37mm length, and a 33mm depth slot for the claw. The claw is tightly secured by two nuts and bolts. 5mm from the bottom of the wheel is a 3mm deep and 6mm high indention for the 6mm ball bearings to sit in. The wheel is epoxied to the threaded rod.

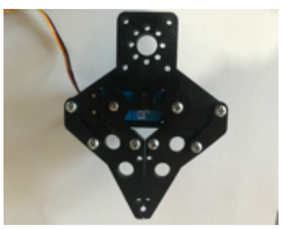

Figure 25 - Claw

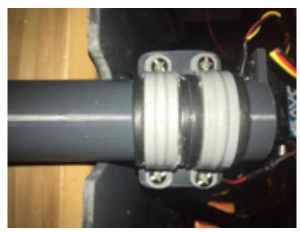

Figure 26 – Mount bracket to frame

Figure 27 – Assembled manipulator

The outer tube's function is to create a stable enclosure for the rotational system. It also serves as a mounting point for the arm. The outer tube has a length of 175mm and a diameter of 24mm with a thickness of 2mm. On one side of the tube, there is a servo-mounting slot. This slot is 40mm by 22mm with a thickness of 8mm and note that this section hangs off by (20mm). The claw's function is to grab objects. We bought a parallel gripper kit from ServoCity that has the dimensions of 127mm by 104.14mm with a maximum width of 71.12mm.

The company decided to use an SPT 400 Tilt System from ServoCity, which is used to move our arm vertically. It has a 135-degree range of motion. The base of the tilt mechanism is 76.2mm by 57.15mm. The height of the overall mechanism is 82.04mm and the overall length is 115.57mm at its standard position. The SPT 400 takes a Hitec HS-5646WP Servo. We mounted the tilt mechanism onto our frame where it can slide forward and backward inside the ROV.

4.2 Measuring Tool

The mission requires the ROV to place a mooring a given distance from the base of the tidal turbine. To accomplish this the ROV is equipped with a fabricated measuring device. The company mounted a metal bracket to a small, lightweight tape measure. The tape measure will allow the company to hook the metal bracket onto the container and once attached, the ROV will reverse extending the tape measure until it can measure the distance of the one container to the other. A camera is mounted to allow the company to see the measurement on the tape measure. A company member will then be able to read the measurement and use the information to place a mooring a given distance from the base of the tidal turbine. The second measurement requires the ROV to measure the height of the Acoustic Doppler Velocimeter (ADV) that is placed on the mooring line. To accomplish this task, the ROV is equipped with a waterproof depth sensor, capable of measuring depths of up to 300m. We built the measuring tool specifically for Task 3 to know where we place the mooring device and place the velocimeter at the given height from the mooring device.

Figure 28 – Measuring device

4.3 Air Bag and Inflator Tool

Figure 29 – Airbag to remove debris

Figure 30 – Air bag inflator and camera

For task one, the ROV uses a lift bag to remove debris off the engine located on the ocean floor. Once the debris is off the engine, the lift bag must detach from the debris and reattach to the engine, lifting it to the surface. To construct the lift bag, one-gallon plastic bottle was modified with a hook to allow for easy attachment.

4.4. Ocean Bottom Seismometer (OBS)

The Ocean Bottom Seismometer (OBS) is used to observe acoustic and seismic events on the sea floor. For a Remotely Operated Vehicle to retrieve the data from the OBS, the OBS must be able to be released from the sea floor. The OBS can be released via an acoustic release, a manual pin release, magnetic reed switch, or Bluetooth/WIFI release. North Paulding Robotics opted to use an acoustic release with a magnetic reed switch as a backup for our release mechanism. The system is controlled via an Arduino Pro Mini 5V which is located on the surface. The Arduino Pro Mini has two modes to accommodate our two systems. The first mode is for the acoustic release, while the second mode is for the magnetic reed switch. The Arduino detects whether the switch is on or off and chooses between the two modes based off those readings.

Figure 31 – Ocean Bottom Seismometer

Our Magnetic Reed Switch release utilizes a reed switch that is triggered by the presence of a magnet. When our ROV brings the magnet, that is attached to the manipulator, in close enough proximity the switch is put into a high position and the Arduino triggers the release mechanism.

The Arduino controls a Savox SW-0241MG servo which acts as our release mechanism for the two systems. Both release modes use this servo to release our OBS to the surface. The Savox SW-0241MG servo offers plenty of torque to securely hold the OBS to the anchor.

4.5. Acoustic Doppler Velocimeter (ADV)

The Acoustic Doppler Velocimeter serves as a device that will register the inflow and turbulence around vertical axis turbines. The task requires the ROV to attach a ADV at a given height on the mooring line. To accomplish this task the company constructed a simple device from half inch PVC with a T-connection and metal hook for easy attachment to the mooring line. The ROV will deploy the ADV down to the mooring line and attach it to the U-bolt.

Figure 32 – Ocean Bottom Seismometer

4.6. Collection Basket

The company decided to modify a basket so that it could be deployed to the bottom of the pool as the missions starts. The Eelgrass samples will be returned to the surface via the basket. The basket has a five-meter rope attached to it. One company member will pull the basket to the surface at the end of the missions. The basket dimensions are 25 cm in diameter and weighs 450g.

Figure 33 – Ocean Bottom Seismometer

5. TESTING AND TROUBLESHOOTING

5.1 Control Box Troubleshooting

One of the most difficult tasks that we had to accomplish was figuring out how to fix our control box into such a small form factor acrylic housing. Our control box has approximately a 16.5 cm diameter and 1 ft. height. However, the opening of the acrylic housing is restricted by the water tight seal which reduced the diameter to approximately 5 inches. This caused us to have to fit an entire control box into a small 12.7 cm diameter hole, which also reduced the amount of space we had to fit all the needed electronics for the ROV to operate properly. How we managed to overcome this was to reprint the whole shelving and redesign the positioning of all the electronics. We also had to remove one of our relay switches to free up space on the shelving. To make up for the removed relay switch, we replaced all relay switches with one long, eight output switches, which was sufficient for our needs to have a properly working control box.

5.2 Manipulator Troubleshooting

The arm was a challenge to engineer because of the complex design and all the small and minuscule parts of the arm. During the printing process, the inner tube of the arm was not completely smooth which affected the rotational ability of the arm. To eliminate the problem, the inner part of the tube was sanded down, so that the manipulator could rotate smoothly.

Another problem that we ran into was the mounting plate was not strong enough to support the arm. Originally the mounting plate was made from a 3D printed platform, but when it was attached and screwed in, the plate would bend to the shape of the arm slightly. To troubleshoot, we removed the plate and placed a piece of aluminum metal bar to the platform and mounted the arm directly to the metal. With this new addition to the mount the piece did not deform to the shape of the arm and was stiff and would be no problem later down the road.

Figure 34 – Corroded wires due to rotating mechanism

During pool testing, the manipulator rotation stopped working. This problem was caused by the twisting or rotation mechanism of the arm. As the manipulator rotated the coiled wires in the shaft were caught up in the end part of the shaft. The bolt that allows the shaft to rotate, eroded the protective coating on the wires, exposing the copper wire, resulting in a short, which caused the manipulator to stop working. The company 3D printed a new shaft, that allowed the wires to be housed outside of the shaft away from the rotating bolt, allowing the manipulator to work more efficiently.

6. SAFETY

6.1 Company Safety Philosophy

North Paulding Robotics is a company committed to the highest standards of safety performance. The company has developed an organized and effective safety program for every phase of the build. We continuously evaluate risks inherent in every activity performed daily. Creating a safe working environment is every employee’s responsibility and the company’s priority.

This year we took safety very seriously, and put in place various safety measures, along with reinstating all the procedures from last year. The company maintained a clean working environment, returning tools and equipment to their correct places at the end of each meeting, eliminating clutter, tripping hazards or loss of equipment. The company is constantly evaluating the safety procedures and weekly meetings are held to discuss modifications of safety procedures or to discuss concerns.

6.2 Procedural Safety

During the build and design of the ROV, company members are required to wear appropriate clothing when working in the workshop area, including no open-toed shoes and no loose-fitting attire. While working with chemicals such as adhesives, company members are required to wear gloves and safety goggles. In addition, safe working practice dictates that personnel should not work alone when dealing with power tools. Company members are required to have an adult present when working with any large machinery. Lastly, all members are expected to conduct themselves in a professional manner, so no horseplay is permitted in the ROV work area.

6.3 Electrical Safety

When members are working with electrical wiring, batteries, or power tools, safety protocol measures are in place for their protection. In case of electrical shock, members are trained to help a company member in distress. A separate soldering station is distanced from the main work area and all electrical wiring and equipment are packed away at the end of each workday.

The ROV is designed to meet the safety guidelines provided by the MATE competition manual. This included three major criteria:

- Mechanical features: The ROV frame has no sharp edges that could cause injury during the deployment and transportation of the ROV. The ROV thrusters are housed within the aluminum frame. This prevents objects from contacting the propellers, ensuring the safety of the thrusters and the surrounding marine environment. Safety labels are placed on the surrounding casing of the thrusters, indicating that the moving propellers could cause harm. The control box is clearly labeled to prevent wires from being switched or connected incorrectly.

- Electrical features: All cables inside the frame are secured away from the moving propellers. A fuse is attached to prevent the ROV from exceeding the maximum operation value of 25 amps. All connections are waterproofed with liquid tape. The control system is constructed from watertight six-inch acrylic tube with watertight end caps.
- Environmental concerns: The ROV is free from any chemical substances or pollutants that may affect or harm the marine environment.

All members operating the ROV follow the safety checklist thoroughly before operating the ROV. A visual inspection before the operation of the ROV would indicate any potential issues that may need to be addressed before the operation of the ROV in the water. In addition, company members follow a deck command list when testing the ROV in the pool, to ensure both the safety of the company members and to minimize damage to the ROV.

During Construction Checklist:

Check √	Initial/ Date:
	Eye and ear protection worn when working with power tools
	No loose clothing is worn when working with machinery or moving parts of ROV
	Long hair tied back
	No open toed shoes
	All work with power tools performed under proper adult supervision
	Rubber gloves and dust masks/ respirators when sanding or handling epoxy/ fumes
	Proper workshop behavior (No running or horseplay in the workshop.)
	Proper training on ALL power tools

Pre- Mission Checklist

Check √	Initial/ Date:
Mechanical	
	All cables are fastened
	Ensure all cable connections are good
	All screws, nuts and bolts are fastened tightly
	All thrusters are secure
	Hazardous areas of the ROV have warning labels
	All parts of the ROV are securely attached to the base
	Propellers are enclosed inside the frame of the ROV
	Thrusters have custom front and back shroud covering to prevent anything from encountering the propellers.
	Tether is secularly attached to ROV

	Tether is secularly attached to control box with clamp
	Tether is neatly bundled and protected to prevent injury
Electrical	
	No copper wire is exposed
	No cables are damaged
	Installed fuse within 30 cm of attachment point
	No loose wires are detected
	All soldering joints in the tether are covered in heat shrink
	Single attachment points to power source
	All soldering joints in the tether are covered in liquid tape
	Servos liquid dipped as a precaution

Table 1 – Safety Checklist

The company had numerous opportunities this year to test the ROV in the pool. At the beginning of each pool session, the main pilot follows the checklist to ensure the safety of each company member. The following deck commands are also used:

Hands Clear – The pilot(s) are ready to turn on the control box and all company members on the site of operations will remove their hands from the area of the moving propellers.
Going Hot – The pilot(s) is going to connect the ROV control box to the power source
Going Cold – ROV powered off and connections removed from power source
Tether –Company members on the site of operations are to roll up the tether before all company members leave the area of operation to avoid company members from tripping and getting hurt.

7. LOGISTICS

7.1 Company Structure and Teamwork

North Paulding Robotics showed exceptional teamwork throughout the building process and the preparation for the competition. At the beginning of the year, we split the company up into four different segments to work on the different key parts of the ROV. This allowed the company to finish the designated jobs at a much higher level of efficiency.

Company members were assigned roles based on their understanding of the tasks, as well as the strengths, skill-level, experience, and interests of each company member. The division leaders collaborated with the CEO and voiced their individual divisions, keeping the CEO on track and aware of any potential delays or changes in the build to ensure a successful construction of the ROV.

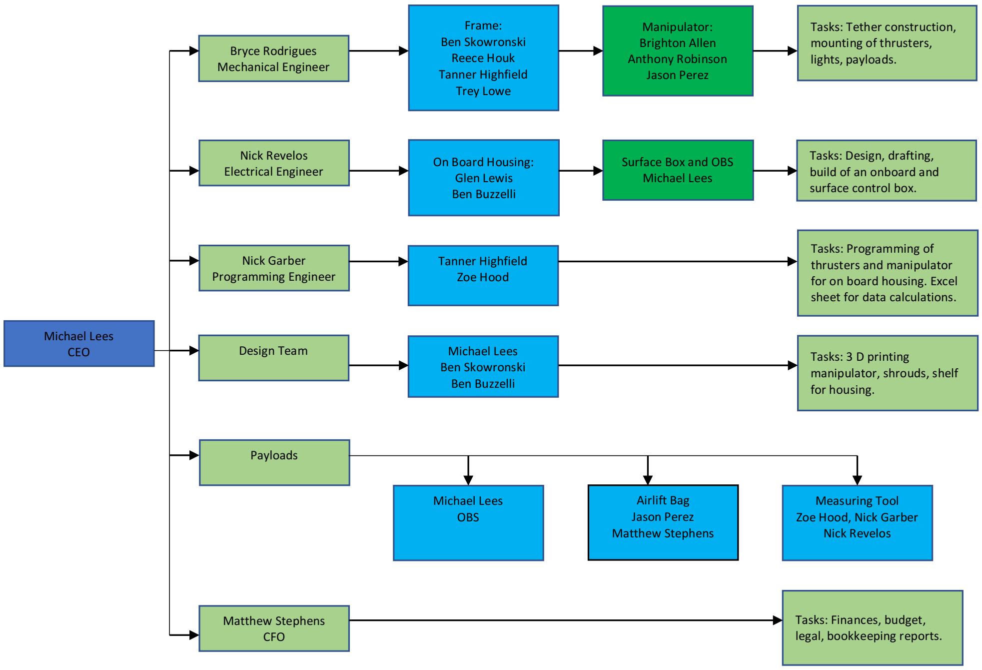

Figure 35 – Company organizational structure.

7.2 Project Management

Our company met together after the 2017 International competition and decided to take on a new and unique idea for our ROV design. The company laid out a Gantt chart that would allow them to complete the ROV build in a timely manner, allowing more time for testing, debugging and modifications. The company dedicated a minimum of 4 weeks for ROV testing and practicing of pool missions.

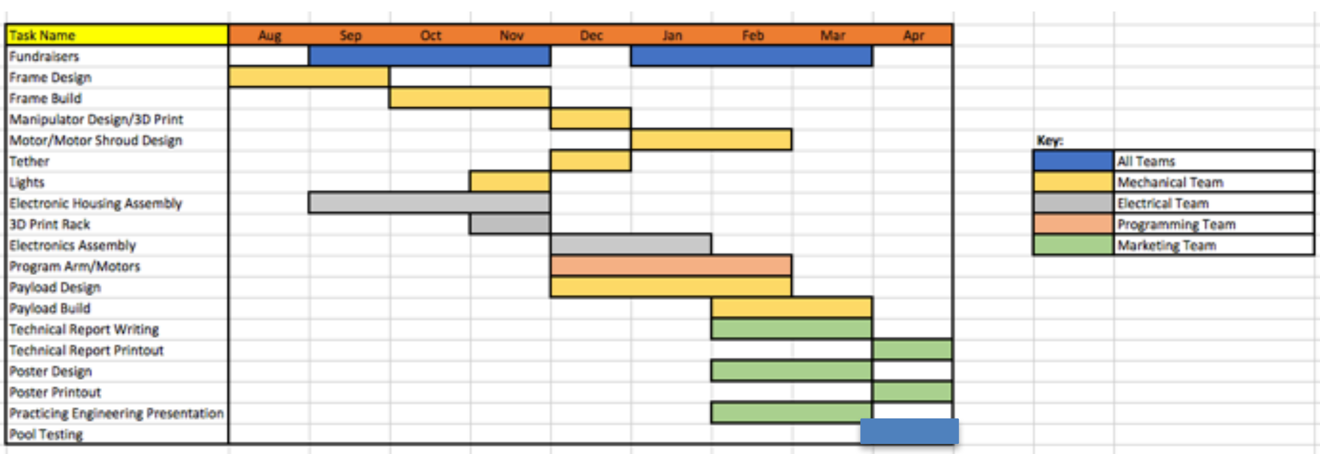

Figure 36 - A Gantt chart to assist with project management by providing a schedule with deadlines for different components

7.3 Project Plan

North Paulding Robotics laid the groundwork for this year's build by making a list of what needed to be done. We used knowledge from past years to make a Gantt chart and set goals for when we needed to finish each objective. The idea was that the build would compound upon itself. We started with one thing which, when finished, allowed us to do two more things and so on. Planning the ROV construction this way and splitting up the members into divisions gave each division something to be for which to be responsible. Each person knew what they were supposed to be doing and when they needed to be finished. We also prepared for the release of the mission specs. The schedule allowed us to maximize our efficiency until they were released. For example, the frame and box could be worked on and then added to later once we knew what needed to be added. The mechanical and programming divisions knew what was going to be reused. At the same time, the divisions were also planning to add things later. Electrical and mechanical made sure to leave extra wires and space respectively so that payloads could be put on the ROV and so that they could be powered. Using proper planning the entire company worked more effectively than any of the previous years.

7.4 Budget and Project Costing

Our company proposed a budget for new vehicle development after reviewing the requirements for the 2018 MATE competition and the expenses incurred from previous builds. The company decided they would manufacture a new frame and onboard control system. The only component that would be reused would be the motors. We decided to reuse the motors because they are reliable, and our company has had great experience working with Seabotix over the years. We wanted to have a fresh start with a new frame, as well as a new onboard control system. The company pledged $3,000.00 for vehicle development and $5000.00 for operating expenses including travel and accommodation. Actual vehicle development costs totaled $3329.66 and operating expenses totaled $5179.00. This overage was offset by an actual income of $8500.00 which exceeded our initial estimates, resulting in a nominal overage of $8.00. Budget and costing sheets can be found in Table 2 and 3.

Operating Income 2017-2018		
Fees	Company member's fees ($300 per company members, total 16 members)	$4800.00
Donations	STEM day/ donations	$3200.00
Sold Items	4 T200 Blue Robotics Thrusters with ESCs	$500.00
	Total Operating Income	$8500.00
Operating Costs 2017-2018		
Travel	Hotel costs, Transport and food for 16 members	$4864.00
Registration Fees		$215.00
Shipping Costs		$100.00
	Total Operating Costs	$5179.00
	Balance	$3321.00

Table 2: Operating Income and Costs for 2017- 2018 ROV Build

Project Costs 2017-2018						
Item		**Notes**	**Type**	**Amount**	**Quantity**	**Total**
Mechanical	Assembling Components	Bolts, screws, zip ties	Purchased	$30.00	1	$30.00
	O-Rings	To seal enclosures	Purchased	$29.99	2	$59.98
	3D Printing	Filament for OBS printing, thruster shrouds, camera and manipulator mounts	Purchased	$35.00	4	$140.00
Thrusters	Seabotix Thrusters	2 up/down, 2 forward/reverse	Reused	$200.00	4	$800.00
	3D Printed Guards	Guards to protect propellers	Printed	$30.00	4	$120.00

	Screws	Screws for mounting	Purchased	$30.00	1	$30.00
Arm	Savox Servo	Turning mechanism	Purchased	$81.99	2	$163.98
	HS 646 WP waterproof servo	Tilt mechanism servo	Purchased	$62.99	3	$188.97
Tether	Tech Flex covering	Encloses and protects tether wires	Purchased	$14.79	1	$14.79
	Conductor wire	16 meters 16 AWG 2 - wire	Purchased	$19.99	1	$19.99
	CAT 6 cable	16 meters	Purchased	$47.99	1	$47.99
Electronic Housing	Cast Acrylic Tube	housing for electrical components	Purchased	$90.00	1	$90.00
	Aluminum End Cap	15 holes, 6 inches, seals the caps	Purchased	$44.00	2	$88.00
	O-Ring Flange	6 Inches diameter, waterproofing	Purchased	$59.00	2	$118.00
	Cable Penetrator	Entrance points for all wiring to components	Purchased	$4.00	4	$16.00
	Raspberry Pi 3 module		Purchased	$34.99	1	$34.99
	mega 2560 R3 Arduino	Ximico arduino	Purchased	$10.99	1	$10.99
	Relay module	Jbtek 4 channel DC SV	Purchased	$6.99	4	$27.96
	DROK mini voltage converter		Purchased	$18.86	4	$75.44
	TP Link S- Port Switch		Purchased	$9.95	1	$9.95
	Sabertooth Dual 12 A Motor Driver		Purchased	$65.99	2	$131.98
	Element 14 T90N SD12-15		Purchased	$13.30	1	$13.30
	Daoki 50 piece		Purchased	$13.88	1	$13.88
	Adafruit Bluetooth		Purchased	$17.01	1	$17.01
	Arduino Stackable Header Kit		Purchased	$5.70	2	$11.40
Box	Black tool box	Housing for pool side components			1	$35.99
	Laptop	Coding	Re-used	$200.00	1	$200.00
Cameras	Cameras	High Definition cameras	Purchased	$79.00	3	$237.00
	Tilting Mounting Bracket		Purchased	$24.99	1	$24.99
	Video Quad Splitter Multiplexer Processor		Purchased	$50.49	1	$50.49
	HS 646 WP Waterproof Servo		Purchased	$62.99	1	$62.99
Control	Logitech 3D Pro Flight Stick	Control the ROV	Reused	$72.50	2	$145.00
	Acer 60 cm Computer Monitor	View from 3 cameras	Reused	$298.00	1	$298.00
					Total Project Cost	$3329.66

Balance Sheet 2017-2018	
Operating Income	$8500.00
Operating Costs	$5179.00
Project Costs	$3329.66
Balance	($8.00)

Table 3: Project Costing Sheet for 2017-2018 ROV Build

8. SYSTEM DECISIONS

8.1 Build vs. Buy

At North Paulding Robotics we custom build the majority of our ROV components, but some tasks only seemed logical to be completed using a premade/bought component. Much of the outboard control box was purchased. Some of those items include USB connectors, wires, the electronic housing itself. The tether casing and the tether was also bought. Two factors were considered when purchasing major components for the ROV and the control box, number one, can we make the same part for the same price or less and of the same quality and secondly, can we build the part in a timely manner and of the same quality. Some of these components are simply unrealistic to attempt to make ourselves due to cost or time.

8.2 New vs. Reused

This year the company decided to start with a fresh build, new frame and design. Allowing the company to innovate and develop and more effective ROV than previous builds. The company decided to reuse the four Seabotix thrusters. The thrusters have been reliable in the past and were our largest purchase three years ago. Other components reused were the Joysticks, and Computer Monitors.

Our largest hurdle this year was the innovative design of the ROV frame. The company decided to create a unique design from Aluminum metal and had the opportunity of welding the frame themselves. The decision to design and build a new frame, instead of reusing the frame like the years before, was that the company wanted to have more space for payload mounts. Lasts years frame did not provide enough space for mounting. As the material was donated, the cost did not impact the budget for build year.

The manipulator was custom built for the ROV this year, as the company wanted to be creative and design the claw to rotate 360 degrees. The mounts, casing and brackets for the manipulator were custom designed and 3D printed onsite by the company members. The company decided to 3D print the components for the manipulator, instead of purchasing the parts as they were able to reuse components found in the workshop, modify and manipulate old parts in redesigning the brackets, the rotator for the claw and modifying and old servo to work as a motor. These modifications again allowed the company to use the funds in other areas of the build.

In the previous builds the company has purchased security cameras and attempted to waterproof them in PVC housing. Unfortunately, this router has proven unsuccessful and lead to water seeping into the cameras and resulting in the loss of our "eyes" during the missions. To avoid this the company purchased three underwater fish finder cameras, although this was an added expense, it freed up time as they just needed to be installed onto the ROV and the company could then focus more time on other aspects of the ROV build.

9. CHALLENGES

9.1 Technical Challenges

This year we embarked on a completely new build that incorporated an onboard electronic system. With these changes came new obstacles. Moving the previously large box into a much smaller canister was one of these. The old box contained many electronic parts that all need to be protected and kept away from water. It was decided that an acrylic canister with metal seals and sealable holes for wiring would be the best. The next problem was how to place the electronics in the canister, but still have them accessible so that if we needed to add things to fix something, we could. We designed a housing that would be removable. The housing was 3D printed to fit the canister perfectly. We also designed the housing to be multilayer so that we could have multiple layers of electronics as opposed to one layer like the previous box. Due to the old frame having been used for multiple years it was in a state of degradation. This year it was decided that we create a new frame. After weeks of designing, we decided upon a more spherical frame. This frame took advantage of the circular size which was needed because of the inclusion of onboard electronics. The problem was that the frame didn't allow for much space for the arm of payloads. The frame was then redesigned, and the bottom was flattened out. This design was the result of the entire company's input and meets each division's requirements. The last challenge was the manipulator. The manipulator from lasts years ROV was relatively weak and required a counterbalance to function. The company designed a new manipulator lighter in weight and capable of rotating in either direction. We 3D printed the arm so that we could place a continuous servo at the base of the shaft of the arm. This arm is the result of many years of experience and is anticipated to be extremely effective.

Also, in April, team members accidentally left the ROV next to an indoor pool heater vent, resulting in slight damage to our 3D printed parts on the ROV. The baseplate did not melt, however, but it did change shape and warp significantly. This cost the team money and time by having to reprint and mount all the parts that were damaged in the accident.

9.2 Non-Technical Challenges

A major challenge for us this year was the integration of the Sammy McClure Middle School team and new members into the high school team. As a result, there was a major communication divide between the returning high school members and the new members. Over the course of the year, the team could merge efficiently, and all members could effectively communicate with everyone.

Time management has been a huge obstacle for the company this year. Due to the struggle with the onboard control box, the company members spent countless hours and late nights troubleshooting the problems that occurred within the housing. However, with patience and determination the members found a solution to fix the bugs within the box. With the loss of pool practice time, the members met over Spring Break to ensure that they were ready for the MATE competition.

10. LESSONS LEARNED

10.1 Technical lesson

This year, one of our goals was to make an ROV that contained all its components within its frame, allowing the ROV to be compact and easy to transport in and out of the water. Company members decided that they would to be responsible for the building of the entire frame, instead of outsourcing for the welding. To accomplish this company members had the opportunity to spend weekends at Stage Left Fabrication, where they were taught how to weld correctly and safely before they embarked on welding their own frame.

Although the frame needed extensive sanding, the company members had the satisfaction that they designed, built and welded the frame themselves.

10.2 Interpersonal lesson

Our company has grown rapidly since last year, learning to communicate and be open to listen to each other opinion was a struggle at the start. It's exciting to see the increased interest, but it comes with many challenges. With a larger group, we've had to be more structured in our coordination and decision-making processes. We've also had to create a training partnership between new and experienced team members for skill building. We have learned so much in such a short period of time. As the year progressed, company members learned how to communicate effectively and when stress levels grew, to walk away and take a break. Through this process members could complete the work in a timely manner and find ways to successfully troubleshoot as problems occurred. Members learned from each other through collaboration and ultimately trust them with complex challenging tasks during the build.

11. REFLECTIONS

North Paulding Robotics has an increased amount of people in the company this year, which makes teamwork and collaboration even more critical than it was in previous years. All employees have elevated their skills in both planning and problem solving to streamline the ROV building process. This year our reflections are written by a senior member, advancing member, and a new member.

Nick Garber - Senior member

"ROV has taught me many important lessons and skills. Throughout the year, I have accomplished many new aspects of designing and building the robot. Our team decided to implement underwater electronic systems, changing the way the program would operate. This forced me to abandon the concept of using a microcontroller as a user interface, in exchange for a PC application, a field I had not explored until this year. This new structure changed the way I needed to look at issues and communicated with teammates when issues arose. When an issue was found, I needed to communicate with my team in a different manner to find where the problem was located. This year in the ROV program enhanced my knowledge and team communication skills, improving my skills in a future workplace."

Jason Perez - Advancing member (from middle school team to the high school team)

"I have learned a lot in this year of ROV, including how to be part of a team and act as a team member and not an individual. Being part of this team teaches you it's not about anyone individually, but what can be accomplished when every works together. I've also learned how to work my way around a workshop and how to handle myself there, which can be extremely useful later in life."

Ben Skowronski - New member

"Being new to the North Paulding robotics team this year, I learned a lot of valuable things. One of the many things I learned was how to properly overcome a challenge. Given the difficult nature of the frame we had many unforeseen challenges that we had to learn how to conquer without stress and in the proper manner. Robotics also helped me meet new people and develop new engineering skills."

12. FUTURE IMPROVEMENTS

This year in ROV there were many obstacles that developed during the construction process. The company completely redesigned the robot for this year's competition. We believe we rose to the challenge and built an ROV capable of performing and completing the missions set forth by the 2018 MATE challenge. However, moving forward, the company would like to successfully master the use of lasers for measuring the distance from the base to place the mooring and to suspend the Acoustic Doppler Velocimeter (ADV) at a given height as required in task three. The lasers purchased this year did not meet the MATE specifications, so the company moved onto plan B, a measuring device that utilizes a tape measure. Next year, more time will be focused on understanding how to make the lasers work effectively.

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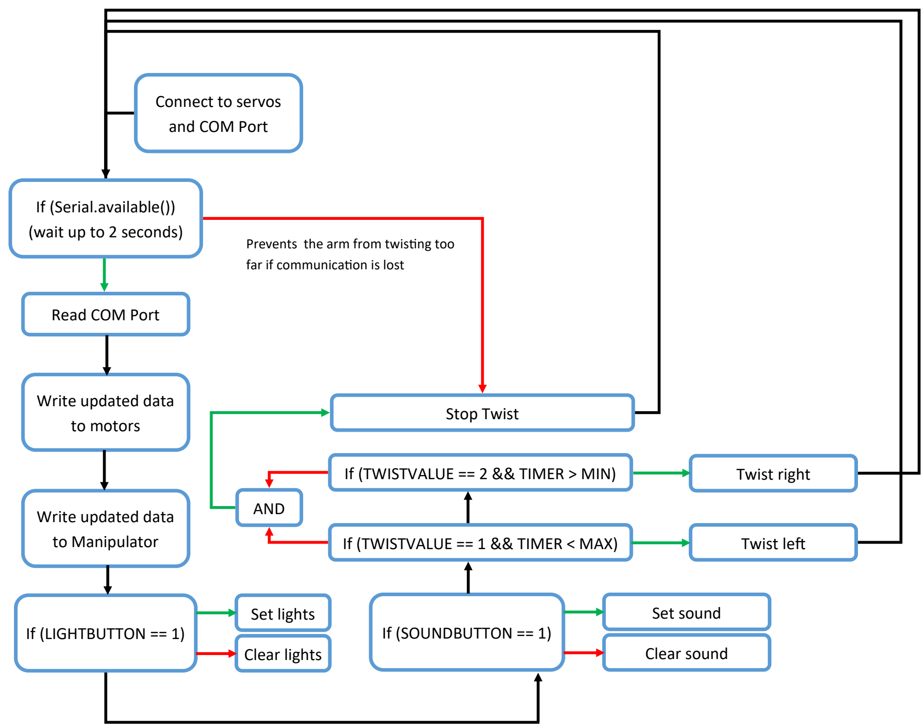
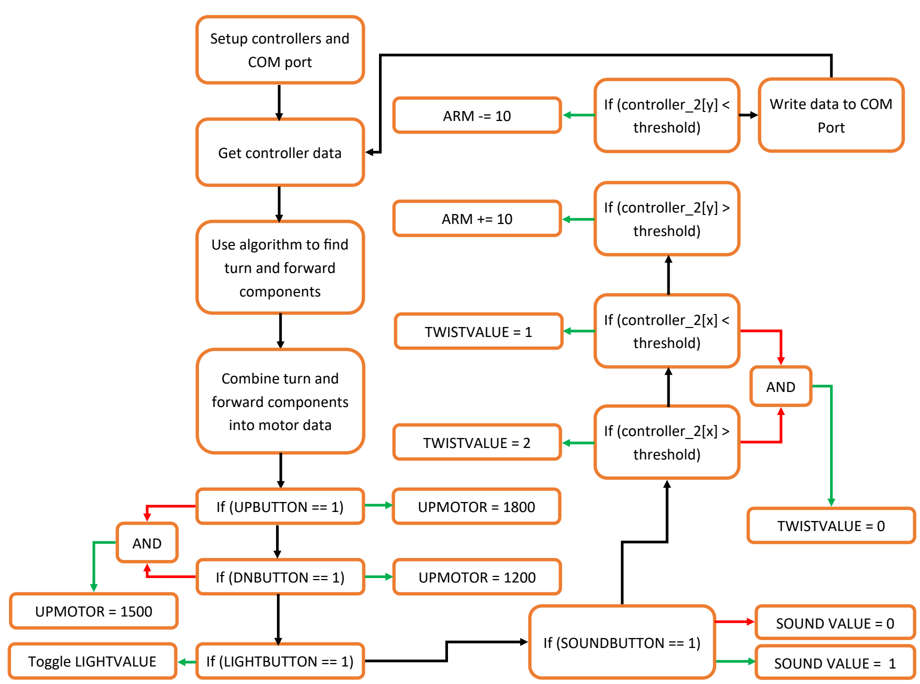
14. ACKNOWLEDGEMENTS

North Paulding Robotics would like to recognize several sponsors and individuals for their continuous support and help throughout the year.

- MATE Center and Gray's Reef National Sanctuary for creating the 2018 missions and organizing the competitions
- University of Washington for hosting the event
- Governors Towne Club for allowing us the use of their pool to practice for the event
- Longhorn Steakhouse for allowing us to host two fundraisers throughout the year
- Stage Left Engineering for helping us weld the frame
- Interstate All State Batteries for sponsoring our team shirts
- Parents of company members for transporting us to meetings and pool practices and for the wonderful snacks and treats during our meetings.
- Mrs. Lees, Mr. Gardener, Mr. Lewis and Mr. Lees for the continuous help and support throughout the year.
- MATE sponsors (Marine Technology Society, Marine Technology Society ROV Committee, National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), Oceaneering, University of Washington, Marine Technology Society.
- Special thanks to the following businesses for sponsoring our club.

Appendix A – Software Embedded Flow Chart





Appendix B- SID