NORTH PAULDING ROBOTICS

North Paulding High School
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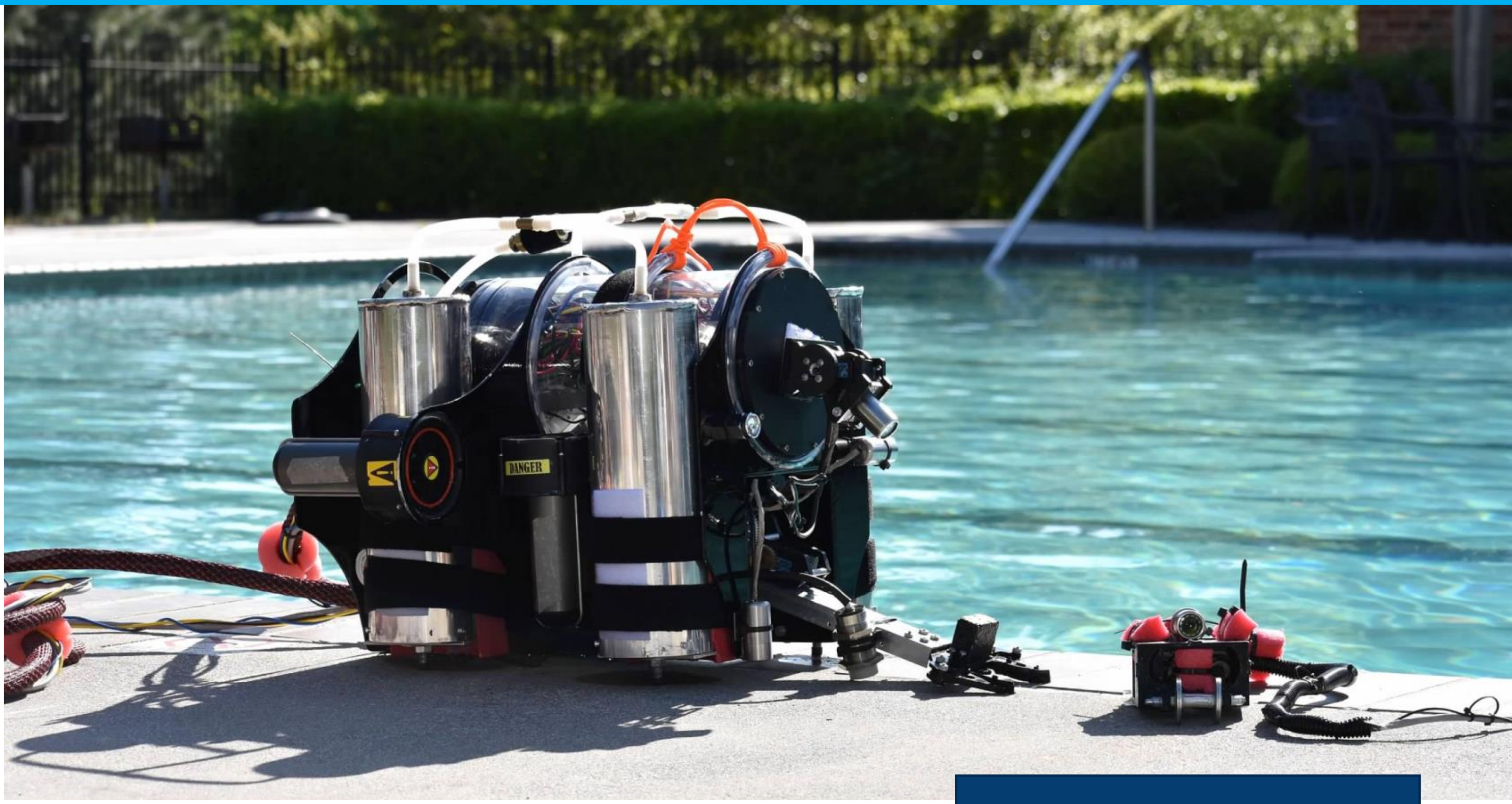

TECHNICAL DOCUMENTATION

2019 MATE
International Competition
Ranger Class

COMPANY MEMBERS

Bryce Rodrigues	CEO & Electrical Engineer
Brighton Allen	Head of Programming Team
Tanner Highfield	Head of Mechanical Team
Glen Lewis	Head of Electrical Team
Ben Buzzelli	Electrical Engineer
Ryan Testino	Mechanical Engineer & Safety Coordinator
Zoe Hood	Mechanical Engineer & Financial Coordinator
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Mentors: Nicola Lees, Geoff Gardener, Mark Lewis, Justin Loomis

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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 Eastman, our innovation, the Flying Gibbous, was constructed with a compact frame that can operate in the freshwater environment of Boone Lake, Boone Dam and the South Fork of the Holston River. The ROV is equipped to inspect and repair the hydroelectric dam, monitor water quality and habitat diversity, and restore fish habitats. The ROV has a sturdy external frame made from lightweight aluminum to protect the motors, wiring, and cameras while operating in the freshwater environment. This year the company implemented an onboard control system for improved signal integrity. In addition, the ROV was equipped with a rotating manipulator that can easily maneuver to retrieve and repair a trash rack, remove a degraded rubber tire, install a fish/reef ball, transport and release trout fry, and retrieve a water sample. Our company strives to uphold the highest level of professionalism and guarantees quality work in a timely manner.

COMPANY PROFILE

North Paulding Robotics was established in 2012 and currently has 11 company members ranging from 10th 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 demonstrated exceptional teamwork and management skills in the completion of this year's build.

Figure 1: North Paulding Robotics 2019 Team Photo
Photo Credit: M. Lewis

MISSION THEME

The Great Smoky Mountains located in the Eastern part of Tennessee. They are part of the Appalachian Mountains, and offer tourists multiple outdoor activities including hiking, fishing, and the famous amusement park, Dollywood. Tennessee is a very beautiful place, but unfortunately, this region has some hidden dangers, such as sinkholes. Sinkholes are a common occurrence in Eastern Tennessee, and in October of 2014, a sinkhole was found near the bottom of the Boone Dam. This caused a safety hazard for many and the Tennessee Valley Authority (TVA) had to do a lot to make the dam safer. The mission demands are represented by the following tasks:

- Task one: Dam Inspection and Repair
- Task two: Maintaining Healthy Waterways
- Task three: Preserving History

TASK ONE-DAM INSPECTION AND REPAIR (90 POINTS)

To ensure public safety the company must inspect the foundation of the dam to identify and count the number of cracks. Once the cracks have been identified and counted, the company must map the location of the cracks and then measure the length of the largest crack. Once the crack has been successfully measured, the company must then fill the crack with grout. The ROV must then inspect and repair a trash rack. The damaged screen must be removed and returned to the surface and a new one installed. A micro ROV must then be deployed to inspect the inside of the drain pipe for muddy water which could be the indication of possible dam failure.

TASK TWO-MAINTAINING HEALTHY WATERWAYS (90 POINTS)

The company will use a sensor to determine the temperature of the water near the water sample collection point. The ROV will then retrieve a water sample from the bottom and return it to the surface. The company will then measure the pH and phosphate of the sample. The ROV will determine the benthic diversity underneath a rock using a video image to count and identify the number of each species. All information will be recorded on a data sheet. The company will transport and release trout fry into a designated area, install a new reef/fish ball into a designated area, remove a degraded tire and return it to the surface.

TASK THREE – PRESERVING HISTORY (90 POINTS)

The company will locate and remove a "civil war cannon" from the bottom. The company must calculate the lift capacity of the ROV to lift the cannon. Once calculated, the ROV must retrieve the cannon to the surface. The company will then will examine four objects that may be unexploded cannon shells and deploy a marker indicating which cannon shell is the unexploded cannon shell. Red tees will indicate cannon shells that are metal and black tees for cannon shells that are non-metal.

DESIGN RATIONALE

North Paulding Robotics built the ROV in response to the Request for Proposal (RFP) issued by the MATE center in 2018 and Eastman. The request specified that the ROV must be able to operate freshwater environments like the Boone Lake, Boone Dam, and the South Fork of the Holston River. 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.

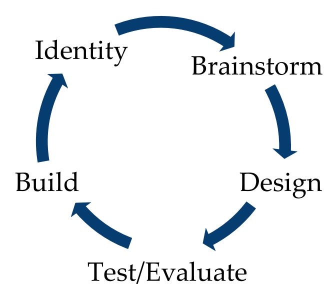


Figure 2: Design Cycle

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, time frame 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.

DESIGN EVOLUTION

The need for reliable, productive and reconfigurable machines working in deep water has led to the continuing evolution of underwater technology. 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. After much contemplation of the pros and cons of the shapes, we ultimately committed to a shape that allowed the team to have excessive of mounting points. This year, the company used a combination of 6061 temper aluminum and abs plastic and 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 devote funds to other materials. The company designed the ROV using SolidWorks. This was presented to all company members for evaluation, allowing for adjustments and improvements before it went into production.

MECHANICAL DESIGN

FRAME

When designing the ROV frame the company was presented with many new opportunities that allowed the team to build an extremely functional design. Our ROV was primarily designed around the main components such as the thrusters and onboard control box. During phase one, a prototype of the frame was made to decide on basic design, key components, materials, and component locations, such as thrusters, onboard electronic housing, manipulator, cameras and payloads. Materials were selected, and the combination of 6061 temper aluminum and abs plastic allowed for extreme design flexibility. Due to past experiences of components warping during transportation, ABS material was selected for its higher temperature resistance of 105ºC. An essential part of phase one was placing components such as the motors and the waterproof casing for the control box. The waterproof casing was less dense than water, thus making it buoyant. Although the ROV mass counteracted this buoyancy, it was still vital that the casing was positioned in the top half of the frame to keep a proper center of buoyancy. Another necessary component consideration was the placement of the four Seabotix thrusters. Given the MATE specified size requirements and the linear layout of the vehicle, it was not possible to position the thrusters in the exact center of the ROV horizontally without flow interference. Instead the two motors used for X and Y strafing (front-back thrusters) were shifted towards the rear of the vehicle to minimize interference. The front-back thrusters were placed at the center height of the vehicle for maximum maneuverability, and oriented linearly, not on an angel, to maximize the amount of water pulled into thruster. The z-axis thrusters (up-down thrusters) were placed at the center horizontally and at the approximate center of mass vertically for maximum control and stability.

Figure 3: Frame design using SolidWorks

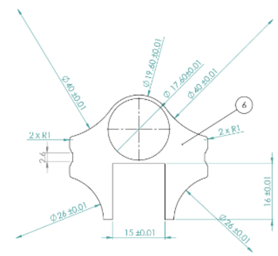


Figure 4: Front dimensions of frame SolidWorks

Phase two of the design was finalizing it in CAD software. SolidWorks software was chosen for its industry standard use, suite of available features both basic and complex, and the flexibility that it offers in an assembly such as that of an ROV. The design consisted of a rigid aluminum body and a 3D printed exterior as well as 3D printed mounting points. This combination resulted in a lighter, modular, and structurally sound frame. The central mounting area spanning the entire length of the ROV, provided enough internal mounting room for much of the payloads such as the manipulator and micro ROV.

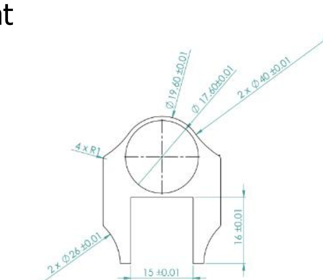


Figure 5: Back dimensions of frame SolidWorks

After the first two phases of the design, the frame could finally be assembled. The aluminum parts were CNC cut, and the team members welded them together to create a structurally, rigid skeleton. The frame was then powder coated in black. Then, components such as mounting brackets and the exterior shell were 3D printed from ABS plastic. The final frame is a perfect balance among simplicity, efficiency, weight and strength, and is an engineering success. The frame's dimensions measured 39.84cm in length, 58cm in width and 35.6cm in height with a weight of 9 kg without the thrusters, tether, electronic housing, and payloads.

Figure 6: Welded frame by team members
Photo credit: N. Lees

THRUSTERS

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. The thrusters were mounted to the ROV so there is the least amount of interference with other payloads on the ROV while also being compact. Two motors mounted vertically just above the center of the ROV to ensure the stability of the ROV while it was ascending and descending. The remaining two motors mounted horizontally giving the ROV four ranges of motion.

Figure 7: BTD 150 Thruster side view
Photo Credit: N. Lees

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.

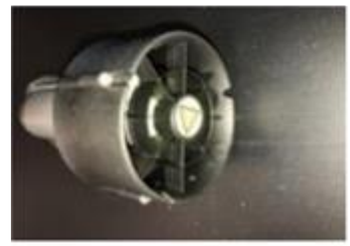


Figure 8: BTD 150 Thruster front view
Photo Credit: N. Lees

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 thrusters 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 3000 m (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.

TETHER

The tether consists of CAT 5e Ethernet cable, three 16 AWG wires, (one main power, ground), three camera wires and a ¼ PVC tube (150 PSI) for the air pump. The tether weighs 2.36kg. 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 9: Tether
Photo Credit: N. Lees

CAMERAS

This year, the specifications require that the ROV must locate and measure the cracks on the dam wall, fix the cracks, repair a trash rack, take temperature, pH and phosphate levels of a sample, determine the benthic diversity, release trout, locate a cannon, and deploy markers. To accommodate the proposal and complete the tasks effectively, the company decided that the ROV needed to be equipped with four underwater waterproof fish finder color cameras with built-in lights. The company chose these cameras for their reliable watertight seal. The camera extension cable length is 50m 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 Savox-1210SG waterproof servo.

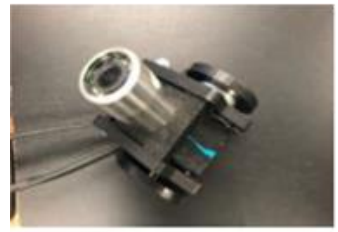


Figure 10: Camera with tilt
Photo Credit: N. Lees

The tilt mechanism allows the camera to move up and with a down rotation of 150 degrees that optimizes the front view of the ROV during the missions. The remaining cameras were mounted by using mounting brackets in specific spots on the frame to help monitor the payloads and to assist in the completion of each task.

Figure 11: Camera connectors into surface
Photo Credit: N. Lees

The main control box houses a camera multiplexer system that 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 12: Camera Multiplexer splitter
Photo Credit: N. Lees

LIGHTS

The ROV is equipped with two 9W drain lights to improve visibility and to assist with the image recognition software. The light is waterproof and powered from a 12V battery source. The team mounted the light directly onto the frame.

Figure 13: LED Lights
Photo Credit: N. Lees

BOUYANCY

The Buoyancy designed this year has two main functions. The first is to provide an adjustable means of keeping the ROV neutrally buoyant. We achieve this by using a piston style ballast that can be adjusted by moving the plug or piston up and down. The main rod is threaded and, by using a nut and a piece of aluminum, we can find and lock our desired position into place. The tanks are also open to the air via a ¼" OD LLDPE (Linear low-density polyethylene) tube that runs to all four ballast canisters. The tube can handle a maximum of 214 psi. The ballast canisters are four, thirty-centimeter-long, aluminum pipes with a ten-centimeter OD and a nine and a half centimeter ID. They have two and a half millimeter thick walls. With the piston removed, they can hold maximum of 2.13 L of air and each can lift about 2.18 Kg. They can each provide 21.38 N of buoyant force. The

Figure 14: Solidworks design showing placement of buoyancy tanks

second function of the ballast is its use as a built-in lift bag. By pumping air with a hand pump into the tube, we can move the pistons out and lift the ROV up. To keep the pistons from popping out we have three screws in the end that keep them from moving too far. This does not mess with the settings of the pistons and by sucking air back in with the hand pump we can return the tanks to their original locations and continue the mission. The hand pump itself provides a tested maximum of 9 psi, which means that the tanks are never pressurized beyond an unsafe level. At no point are the operators under any level of danger. This dual system saves space and time by removing the need for a separate lift bag. It is also more resilient than regular foam and resist wear and tear. Overall, it is a vast improvement from last year's pool noodle design and separate lift bag.

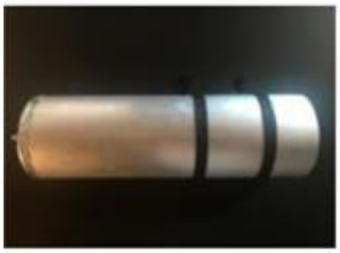


Figure 15: Buoyancy tank
Photo Credit: N. Lees

Figure 16: Valve to connect air hose
Photo Credit: N. Lees

Figure 17: Custom molded tank insert plugs
Photo Credit: N. Lees

ELECTRICAL DESIGN

ELECTRICAL HOUSING

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

Figure 18: Waterproof electronic housing
Photo Credit: BlueRobotics

ELECTRICAL SYSTEMS

The electronics systems are designed to be reliable and quick throughout its use. The ROV is controlled using an Arduino Mega running the atmega2560 8-bit microcontroller. This microcontroller gives us the freedom of using multiple serial communication channels, multiple timers were used to the control PWM (Pulse Width Modulation) signals, and a large selection of GPIO (General Purpose Input Output) pins. The main communication with the surface laptop is done using serial communication that is converted to an ethernet cable to ensure better signal strength through the tether and then converted back underwater to communicate effectively.

Figure 19: Electronic components platform
Photo Credit: N. Lees

The Motors of our ROV are controlled using two Sabertooth 2x12s and one Sabertooth 2x5. These Electronic Speed Controllers allow us to control the speed and direction of our motors by sending a pwm signal. By having accurate control over our thrusters, we can efficiently complete our mission tasks. The Servos on our ROV that are used to control things such as the manipulator and the tilt of our main camera are also controlled using a PWM signal that is sent to the Servo and is then interpreted into an angular measurement. To save components in the event of the acrylic housing, we have designed and implemented a Water Shut-off system that cuts power to the ROV if water is detected.

Our waterproof housing is a Blue Robotics 6-inch series watertight enclosure with 16 accessibility holes for the necessary wires to go through. By using this type of housing, we encountered design challenges such as size restrictions and ensuring proper sealing. The housing has a 12.7 cm diameter hole on both sides for the control system to go into. The Water Shut-off system was custom designed by our team to ensure a safer ROV. The system was created by using a Relay to turn off and on the current flow through the positive lead of the ROV. An N-Channel MOSFET that uses a pull up resistor to keep the Relay on while its input is floating controls the coil of the relay. Two wire leads were attached between the MOSFET's gate and the ground on the Relay in a way so that when water allows the two leads to have continuity with one another; the MOSFET will turn off, thus turning off the Relay and the main power to the ROV.

SURFACE CONTROL

The Surface Control Box was designed for maximum usability. USB ports and Video I/O was placed in a way that allows for easy cable management and use. The power in and out was placed in a place where it would not be tangled with other wires. The laptop was put in an area where it would not have wires going across it to allow for easy access to the keyboard and mouse to use the software that was developed for the ROV. 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 20: Surface Control Box
Photo Credit: N. Lees

FUSE

To meet the safety requirements of the MATE competition the team incorporated a 25 Amp 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.

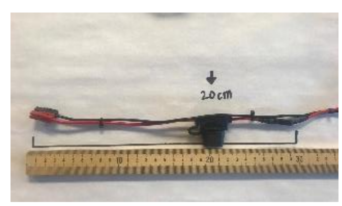


Figure 21: Fuse located w/in 30cm of main power line box
Photo Credit: N. Lees

SOFTWARE DESIGN

SOFTWARE AND CONTROL

The software consists of two parts, an onboard microcontroller and a personal computer that sits on top of our control box. The PC is directly connected to two joysticks and the onboard microcontroller - a Sam 3C83. The PC receives signals from the joysticks and relays the information to the onboard microcontroller, which in turn commands the servos, motors and various other payloads. To connect the PC to the onboard microcontroller, a virtual COM port over USB is used, which is then converted to Ethernet and then converted back to USB when it reaches the Sam 3C83.

Using a PC improves performance in many aspects. One aspect is setting up the ROV, for the PC uses USB connections, a commonly used connection that all customers will be able to understand, reducing set up time. Using a PC allows the company fix software problems at any time and if needed, even implant the software onto another PC if an emergency occurs. The software is compatible with all Windows 10 computers, improving the versatility of the system by eliminating proprietary hardware. In addition to compatibility, this reduces the cost of the ROV by removing the need to buy another system to be placed in the control box.
The PC software is written in C# .NET using the Visual Studio IDE, all of which is produced by Microsoft. Why did we make this decision? We chose C# because it is the most powerful language in the .NET framework, which makes it an excellent development environment for windows applications. We chose windows for it is the most commonly used PC operating system, with many affordable options for our customers. The object-oriented language is also compatible with Visual Studio. Visual Studio is an IDE that we used to create a GUI (Graphical User Interface). With many additional tools to make the development process significantly easier such as drag and drop capability, automatic code generation and a vast amount of online documentation, Visual Studio was the best pick. This is important to the customer as it allows adjustments to be made to the form or underlying code.

Our onboard microcontroller uses the Arduino C wrapper, which 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. The company selected the Arduino wrapper due to its legibility and 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.

A unique aspect of the software is our ability to send all the signals needed for the operation of the vehicle over one byte. Our largest challenge with achieving this was the axis of both controllers, so in the PC software we created a function to scale the x and y axes values of both controllers and convert it into a 60-bit section inside the byte. The x axes of joystick 1 would be given the values 0 –60, the y-axes of joystick 1 would be assigned the values 61 – 121, this process is repeated for the x, and y axes of joystick 2. After assigning the axes, there are 12 bits left, 244 – 255, which are assigned to various buttons on the joystick. Using only byte allows for a quicker and smoother operation of the vehicle.

PILOT CONTROL SYSTEM

A Logitech Extreme 3D Pro flight stick allows the pilot to control the mobility of the four motors on the ROV and the two servos on the Mini ROV. A second Logitech Extreme 3D Pro flight joystick allows the teams to control the movement of the manipulator. In addition, the joystick operates a camera servo, temperature sensor and lights.

Figure 22: 3D Pro Joystick
Photo Credit: N. Lees

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:

to inspect and repair cracks in the dam wall; measure temperature, phosphate and pH levels of a water sample; Count and identify benthic species; release trout fry in designated areas and locate and remove Civil War cannon from the bottom. The ROV can perform these missions by implementing special features that will help improve the Dmobility, offer multiple mounting options for payloads, and improve the electronics and programming. The payloads and their tasks are as follows:

TEMPERATURE SENSOR

North Paulding Robotics was tasked with measuring the temperature of the water at the water sample collection point. Our team decided to use a T-PRO DS18b20 Temperature Sensor, which is mounted to the frame and directly connected to the onboard microcontroller. To establish communication between the atmega2560 and temperature sensor we used the Dallas One Wire Protocol. To decrease the amount of data being transferred between the microcontroller and PC, the temperature is only read when requested by the operator.

Figure 23: Temperature Sensor
Photo Credit: N. Lees

MANIPULATOR

The ROV is equipped with a custom-built manipulator that incorporates special features that allow the manipulator to rotate 360-degrees. The manipulator is also lightweight, and compact in size. The Manipulator consists of four major components: Rotational system, Outer Tube, The Claw, and a Tilt Mechanism. We built the Manipulator for multiple reasons across all three tasks. In task 1, the manipulator is used to remove and repair the damaged screen of a trash rack. In task 2, the manipulator is used to lift the rock off the bottom of the pool so that the benthic species can be counted and identified, remove the degraded tire and to place the reef/fish ball into the designated area. Finally, in task 3, the manipulator is used to place the red and black markers to distinguish if the cannon shells have detonated.

Figure 24: Assembled Manipulator
Photo Credit: N. Lees

The rotational system allows responsible for 180 degrees of rotation. It is made up of a 161mm threaded rod that is cut into two pieces combined with two nuts and a metal coupling. It is connected to a Hitech HS-5646 waterproof servo. On the other side of the threaded rod, there is a custom 3D printed ball bearing system and a slot for the claw. The wheel is measured at a diameter of 38mm and a total height of 74mm. In the top of the of the circular wheel, there is an 8mm width, 37mm length and 33mm depth slot for the claw. Two bolts and four lock washers (two washers per nut) tightly secure the claw. The claw's function is to grab multiple objects throughout the three assigned tasks.

The company purchased 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 utilize the Savox SW-1210SG waterproof servo to power the claw and a SPT 400 Tilt System, which is used to give us a 135-degree range of vertical 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 uses a Hitec HS-5646WP Servo.

The tilt mechanism was mounted onto our frame with a Picatinny rail system. The rail underneath the base of the frame measures 280 mm long and has a width of 22mm. The tilt is attached to the rail system with a quick-release rail mount that measures 60 mm long and 45mm wide. The company decided to utilize this rail system because it allows the manipulator to be retracted underneath the ROV for sizing, and it allows for a safer and easier transport of the ROV.

Figure 25: Wheel
Photo Credit: N. Lees

Figure 26: Claw for Manipulator
Photo Credit: N. Lees

Figure 27: Picatinny rain system
Photo Credit: N. Lees

MEASUREING TOOL

The company decided to utilize the measuring system One to help measure the cracks in the dam and the cannon to complete our mission. The system is an online ruler that we can put in front of a snapshot and measure an object. The manipulator will be used to ensure that the scale of the snapshot is the same throughout the mission. We will touch the object being measured with the manipulator and then will adjust the ruler to the length of the object. Next, we will multiply this measurement mm/pixel factor to get the final measurement of the object. (The scale the camera changes the image by when the manipulator is touching the object.)

IMAGE RECOGNITION TOOL

The image recognition software that will identify benthic species that lie on the lake floor and was designed using tools by Emgu CV a cross platform. The company utilized Net wrapper to the OpenCV image-processing library allowing OpenCV functions to be called using C#, one of two languages used for the entirety of the ROV's software. We decided to use Emgu CV for its ability to tie into our Visual Studio Form. Keeping everything in one form makes the operation of the ROV simpler for the pilots and creates a cleaner display. The Image Recognition will capture an image from a live

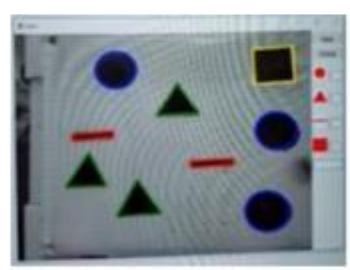


Figure 28: Image recognition program
Photo Credit: N. Lees

video feed, convert the image to grayscale and then remove any noise - pixels in the image that show different intensity values from what they truly are. After this step is complete, the program can identify various shapes and display the number of each shape in the image.

MICRO-ROV AND TETHER REEL MECHANISM

The company designed and developed a micro ROV that is capable of maneuver into a drain pipe to inspect for damage. The micro ROV has an overall size of 166mm by 112mm by 73mm with a tether length of 15 meters and consists of eight 18 AWG wires.

Figure 29: Micro-ROV
Photo Credit: N. Lees

Two 12V DC motors allowing the ROV to move forward and backwards propel the micro ROV. Equipped with two custom wheels to help navigate the ROV through the pipe. The micro ROV is equipped with an underwater waterproof fish finder color cameras with built-in lights. The camera extension cable length is 20m long. The camera incorporated a light source of 12 high-power bright white led lights to illuminate any areas of the pipe that show damage. Keeping the control box simple the company used to double throw switches. The switches were wired to allow the polarity of the motors to be changed, allowing the direction of the ROV to be reversed.

The retraction device that winds and unwinds the tether for the micro ROV is crucial for the smooth operation of Task 2. The tether is retracted by reeling in a string that is connected to loops on the tether, allowing the tether to be pulled in or released as the micro ROV moves. The tether has small rings along its length, and a braided fishing line that runs through the rings. One end of the line is connected to the Mini ROV, and the other runs to a modified Savox 360-degree servo that winds up the line. The servo was modified by wiring the power and ground wires directly to the motor and removing a stopping pin in the gears so the gears can spin freely. As the line winds up, the opposite end of the fishing line draws nearer to the servo, and it bunches up the tether into loops. When completely wound up, the tether is compacted into several loops at the back of the ROV. The whole system of retraction is located at the back of the ROV because of the proximity to the Mini ROV, allowing the Mini ROV to have as much tether length as possible.

Figure 30: 12V propellers
Photo Credit: N. Lees

Figure 31: Retracted 12ft tether
Photo Credit: N. Lees

Figure 32: Micro-ROV control box
Photo Credit: N. Lees

Figure 33: Micro-ROV docking station
Photo Credit: N. Lees

METAL SENSOR

To identify whether any of the objects laying on the bottom of the lake are cannon shells, our company incorporated a metal detector onto the ROV design. Our simple metal detector circuit consists of one 1k resistor, a 330-ohm resistor, a 1N4148 diode and coiled copper wire which is all connected to the mega 250. A message will be displayed on the ROV Dashboard form if metal is detected.

Figure 34: Metal Sensor
Photo Credit: N. Lees

GROUT DISPENSER AND TROUT FRY BASKET

The company designed and built a multipurpose tool that will allow the ROV to place the grout in the crack and the trout into the designated area in one trip. The dispenser is made from PVC pipes as consists of a series of sliding plates that will allow the ROV manipulator to pull the slide out and disperse the grout or trout into the designated spot. The sliding mechanism is made from a thin acrylic sheet with a pull mechanism attached to it. The dimensions are 30cm long, 8cm width and 28cm height.

Figure 35: Grout Dispenser and Trout fry basket
Photo Credit: N. Lees

SAFETY

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.

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.

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

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

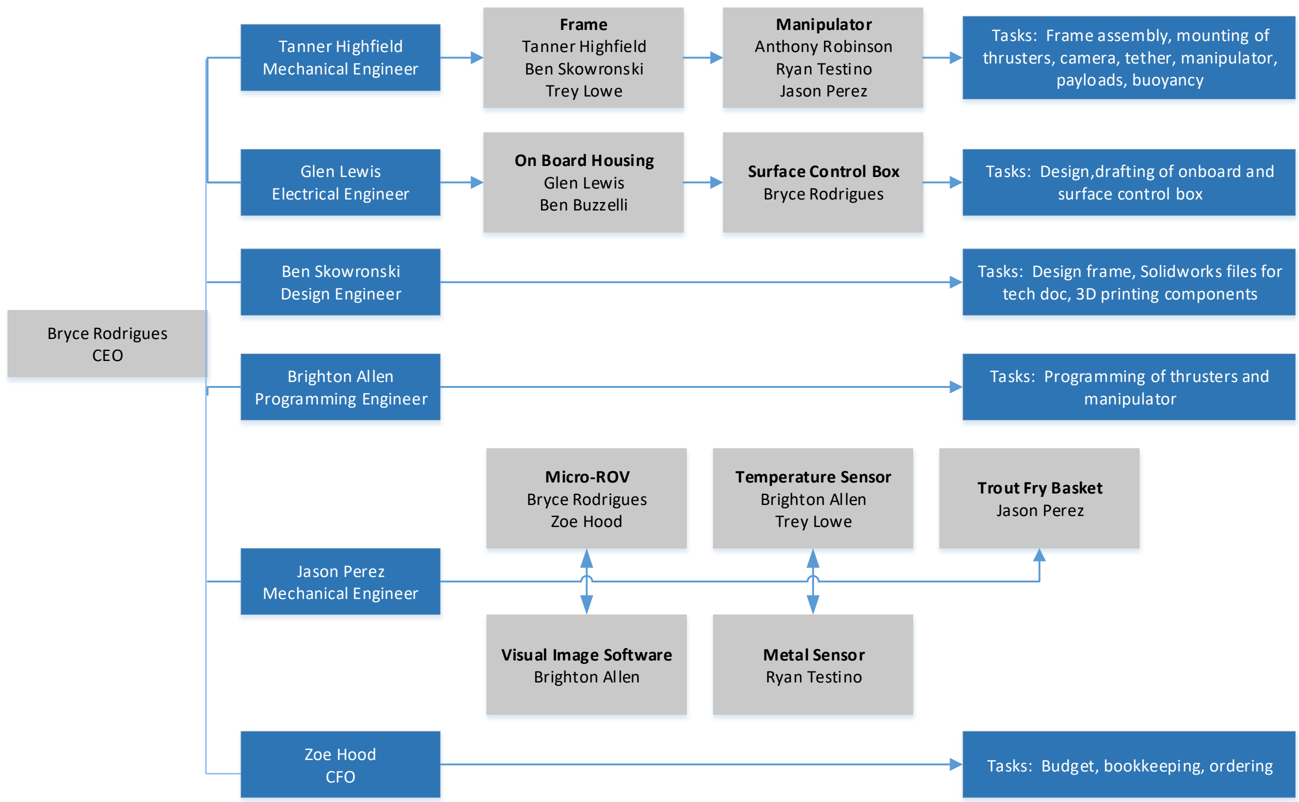
Tether: Company members on the site of operations are to roll up the tether before all company members leave the area of operation to avoid company members from tripping and getting hurt.

LOGISTICS

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.



PROJECT MANAGEMENT

Our company met together after the 2018 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.

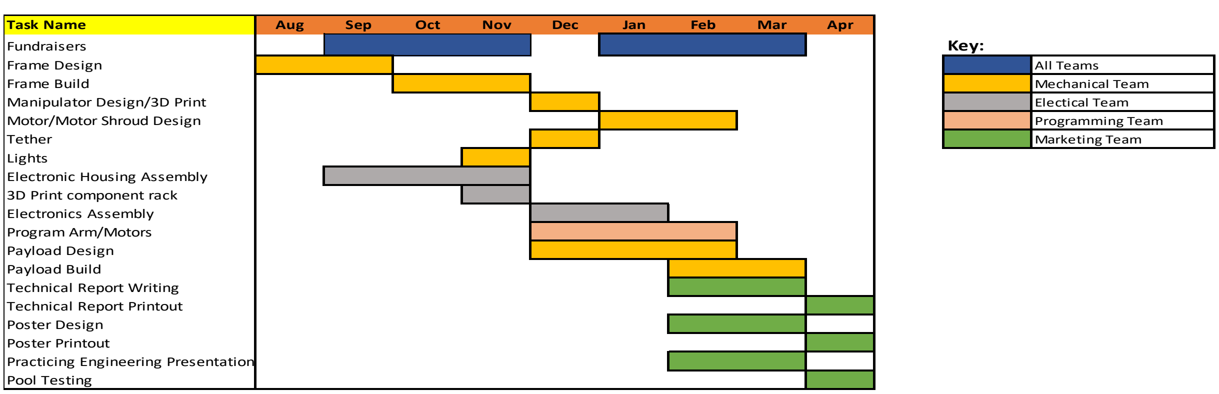


Figure 36: Gantt chart to assist with project management by providing a schedule with deadlines for different components

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.

BUDGET AND PROJECT COSTING

Our company proposed a budget for new vehicle development after reviewing the requirements for the 2019 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 $6,000.00 for vehicle development and $6,500.00 for operating expenses including travel and accommodation. Actual vehicle development costs totaled $5,087.62 and operating expenses totaled $6,020.00. The company remained in budget with a remaining balance of $117.38. Budget and costing sheets can be found in Table 1 and 2.

Operating Income 2018-2019

Fees	Company member's fees ($475 per company members, total 11 members)	$5225.00
Donations	Donations/ STEM Days/ Fundraising	$6000.00
	Total Operating Income	$11,225.00

Operating Costs 2018-2019

Travel	Hotel costs, Transport and food for 11 members Hotel rooms (6 rooms @ $130.00 per night = $3120) Transportation from Dallas GA to Kingsport, TN ($150.00 for 4 vehicles= $600) Food $50 per person per day ($200 per person = $2200)	$5920.00
Registration Fees	MATE registration fee	$100.00
	Total Operating Costs	$6,020.00
	Balance	$5,205.00

Table 1: Operating Income and Operating Costs for 2018-2019 ROV build

Project costs 2018-2019

Item		Notes	Type	Amount	QTY	Total
Mech	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	Thruster shrouds, camera, manipulator mounts.	Purchased	$35.00	4	$140.00
Frame	Frame material	Flat Al sheet metal	Purchased	$235.82	1	$235.82
	Frame	CCN machine cutting	Purchased	$220.00	1	$22.00
	Welding	Services and welding	Donated	$0.00	1	$0.00

Thruster	Seabotix Thrusters	2 up/down, 2 forward/reverse	Reused	$200.00	4	$800.00
	Seabotix thruster	Backup thruster	Purchased	$950.00	1	$950.00
	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
	Brackets	Sliding mechanism for arm	Purchased	$104.95	1	$104.95
	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
	Clear plastic tubing	20 meters	Purchased	$22.00	1	$22.00
	Ethernet cable	100ft	Purchased	$56.99	1	$56.99
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
	Sabertooth Dual 12A motor driver		Purchased	$65.99	3	$65.99
	Raspberry Pi 3 module		Purchased	$34.99	1	$34.99
	Molex connectors	Detachable tether	Purchased	$9.78	100	$9.78
	Relay module	Jbtek 4 channel DC 5V	Purchased	$6.99	4	$27.99
	TP link S-port Switch		Purchased	$9.95	1	$9.95
	Arduino stackable heater kit		Purchased	$5.70	1	5.70
	Al metal	Shelving mounts	Purchased	$6.00	1	$6.00
	DROK mini voltage converter		Purchased	$18.86	4	$75.44
Box	Silver case	Housing for pool side components	Purchased	$54.99	1	$54.99
	Laptop	Coding	Re-used	$200.00	1	$200.00
	On/off switch		Purchased	$21.99	1	$21.99
Camera	Cameras	High Definition cameras	Purchased	$79.00	3	$237.00
	Tilting Mounting Bracket	Servocity Tilt camera mechanism	Purchased	$24.99	1	$24.99
	Video Quad Splitter Multiplexer Processor		Reused	$50.49	1	$50.49
	HS 646 WP Waterproof Servo		Purchased	$62.99	1	$62.99
Buoyancy	Aluminum tube		Purchased	$189.64	1	$189.64
	Resin	Clear Casting and Coating Epoxy Resin-16oz Kit	Purchased	$22.95	1	22.95
	Plunging mechanism	Al bar	Purchased	$9.00	2	$18.00
	O rings		Purchased	$3.49	4	$13.96
	Hose connectors/valves	Brass T- connectors 1/4" fitting (pack 4)	Purchased	$14.99	1	$14.99
	Tubing	100 Psi certified clear tubing 100 ft	Purchased	$34.99	1	$34.99
	Logitech 3D Pro Flight Stick	Control the ROV	Reused	$72.50	2	$145.00
	Acer 60cm Computer Monitor	View from 3 cameras	Reused	$298.00	1	$298.00
MicroROV	Washers	6 washers for wheels (box 100)	Purchased	$11.99	1	$11.99
	motors	12 V brushless motor	Purchased	$	2	$24.99
	Camera	High Definition cameras	Purchased	$79.99	1	$79.99
	Project Box	Control box to house electronics	Purchased	$9.99	1	$9.99
Payloads	Temperature probe	DS18B20 waterproof sensor	Purchased	$11.88	1	$11.88
	SAM3X8E sensor		Donated	$0.00	1	$0.00
	Relay board	Hi-Letgo 12 V Channel relay board	Purchased	$4.49	1	$4.49
	Resistors	1K and 330 Ohm resistors (pack 10)	Purchased	$14.00	1	$14.00
			Total Project Cost:			**$5087.62**

Table 2: Project costing sheet for 2018-2019 ROV build

SYSTEM DECISIONS

BUILD VS BUY

At North Paulding Robotics, the ROV components were custom built, but some tasks only seemed logical to be completed using a premade/bought component. Much of the onboard control box was purchased because the parts are extremely difficult and time consuming to manufacture. Some of these items include USB connectors, wires, and 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. We chose to build our Ballast tanks because there was no commercial option that would fit our needs. Another reason we decided to build the tanks ourselves was because they needed to have very specific size requirements and lift capabilities.

Last year's manipulator was custom built by the company and designed to allow 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. This year the company decided to reuse last year's design with a few modifications. The rotator for the claw and old servo were modified to fit the current design specifications. These modifications allowed the company to use the funds in other areas of the build.

NEW VS RE-USED

This year the company decided to start with a fresh build, new frame and design allowing the company to innovate and develop a more effective ROV than previous builds. The company decided to reuse the four Seabotix thrusters due to their reliability over the last four years, keeping costs down for each build. Other components reused were the Joysticks, acrylic housing, and the Computer Monitor because these components are not able to be manufactured in house.

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 year's frame did not provide enough space for mounting. As the material was donated, the cost did not impact the budget for build.

In the previous build the company onboard system housed the Arduino boards, Sabertooth motor controllers and shelves for mounting. The housing was difficult to work in due to the confined space and wires. The company has continued to use this acrylic housing. However, a new shelving unit has been incorporated into the build to maximize the space within the acrylic housing.

TESTING AND TROUBLESHOOTING

Each payload and component of the ROV was tested during its initial build phase. Modifications to size, power and performance were made before permanently attaching the part to the frame. Once the company was satisfied with the component it was tested in water to ensure all components were tightly sealed to prevent water leakage. Mounting of components were "test" mounted first to ensure that the components fitted and were within the size restriction of the frame. Components that did not pass the initial test were redesigned and 3D printed to meet the specifications needed by the company. Once the ROV was ready for pool testing the company followed the Safety Checklist mentioned earlier to ensure safety of company members and limit damage to the ROV and its components. The buoyancy tanks were prototyped using cheap PVC to generate accurate data for the tank's lift capabilities and have a reference for the size they would require on the frame. In the event of a failure during testing, our protocol was to remove the ROV from the water, disconnect power, inspect for physical damage to the ROV, and run a series of diagnostic testing to evaluate the status of the ROV.

CHALLENGES

TECHNICAL CHALLENGES

This year the company decided to try using PCB boards as the main control center for the ROV. Unfortunately, after numerous attempts of trying to solder the components to the PCB boards we had to switch back to the wired control box like the one used last year. This lead to delays in completing the ROV and limited the pool time that we had to practice.

In addition, we struggled with the fiber optic component of the mini ROV. When testing the circuit board, the component burnt out. The company CEO then made the call to switch to regular tether to control the mini ROV.

NON-TECHNICAL CHALLENGES

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. Due to the regional competition being later in the year than normal, the company faced many challenges with being able to meet due to multiple conflicts with final and testing dates.

LESSONS LEARNED

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. Throughout the year multiple CAD design software have been implemented into the design process of the ROV. These skills directly translate into the modern-day engineering work force.

INTERPERSONAL LESSON

Our company has grown rapidly since last year, learning to communicate and be open to listen to each other's opinions 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 trusted them with complex challenging tasks during the build.

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.

BRYCE RODRIGUEZ - SENIOR MEMBER

"As the new CEO of North Paulding robotics, I have learned many new ideas and concepts from working with our members and mentors alike. Throughout the year, with the help of all the members, I grew as a leader and as a person. We took the lessons we learned from last year and added it to our arsenal of ideas. With the combination of old lessons learned and new experience I can truly say this year was a fun one."

GLEN LEWIS –ADVANCING MEMBER

"Over the years, ROV has taught me many new skills, and helped me to discover interests I didn't know I had. When I first began ROV, I came in with the mindset of "robots are cool, let's do that", however, as time moved on, I began to discover that I truly enjoy the process of electrical design. This year we decided to move away from our normal circuits using wires, and instead design and create PCBs for much of our electronic systems. This, however, did not come without challenges. Not only did we have to create the circuits from scratch, avoiding things such as development boards, we also had to discover how a PCB really worked. These challenges proved difficult and very time consuming and forced me to learn how to better deal with problems and troubleshooting. The permanence of PCBs also forced me to think more about planning for new parts, rather than just shoving something into the circuit when it came up."

RYAN TESTINO- NEW MEMBER

"Being my first year at robotics, I was skeptical at first as to how I was going to fit in with the many veteran teammates who have been in the program for years. However, everybody has been more than welcome to show me new skills and techniques that will help me in hopes of becoming a marine engineer in the future. Also, robotics has improved my problem-solving skills greatly as many complications arise at each meeting, but with exceptional teamwork and curious minds, nothing stands in our way."

FUTURE IMPORVEMENTS

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 2019 MATE challenge. Next year, the company would like to have multiple members working on similar tasks, so that if one cannot make a meet, the component or payload will still be completed in a timely manner. The company would also like to implement a better usage of PCBs to reduce the size and increase the visual appeal of our control systems.

OUTREACH

North Paulding Robotics had the privilege of attending and participating in numerous community outreach opportunities throughout the year.

- STEM nights at Allgood Elementary, Shelton Elementary and Burnt Hickory Elementary for the 2018-2019 school year
- Presentation to the Board of the Dallas Rotary Club
- Mentoring middle school program with their ROV builds
- Inspecting the Allatona Dam wall for cracks using their ROV
- Interviewing at the MATE regional Competition for SCAD Georgia Southern University
- Honorable mention in the their 1st place win at Regional MATE Competition in the following magazines:
    - Bentwater Magazine
    - Governors Towne Club magazine

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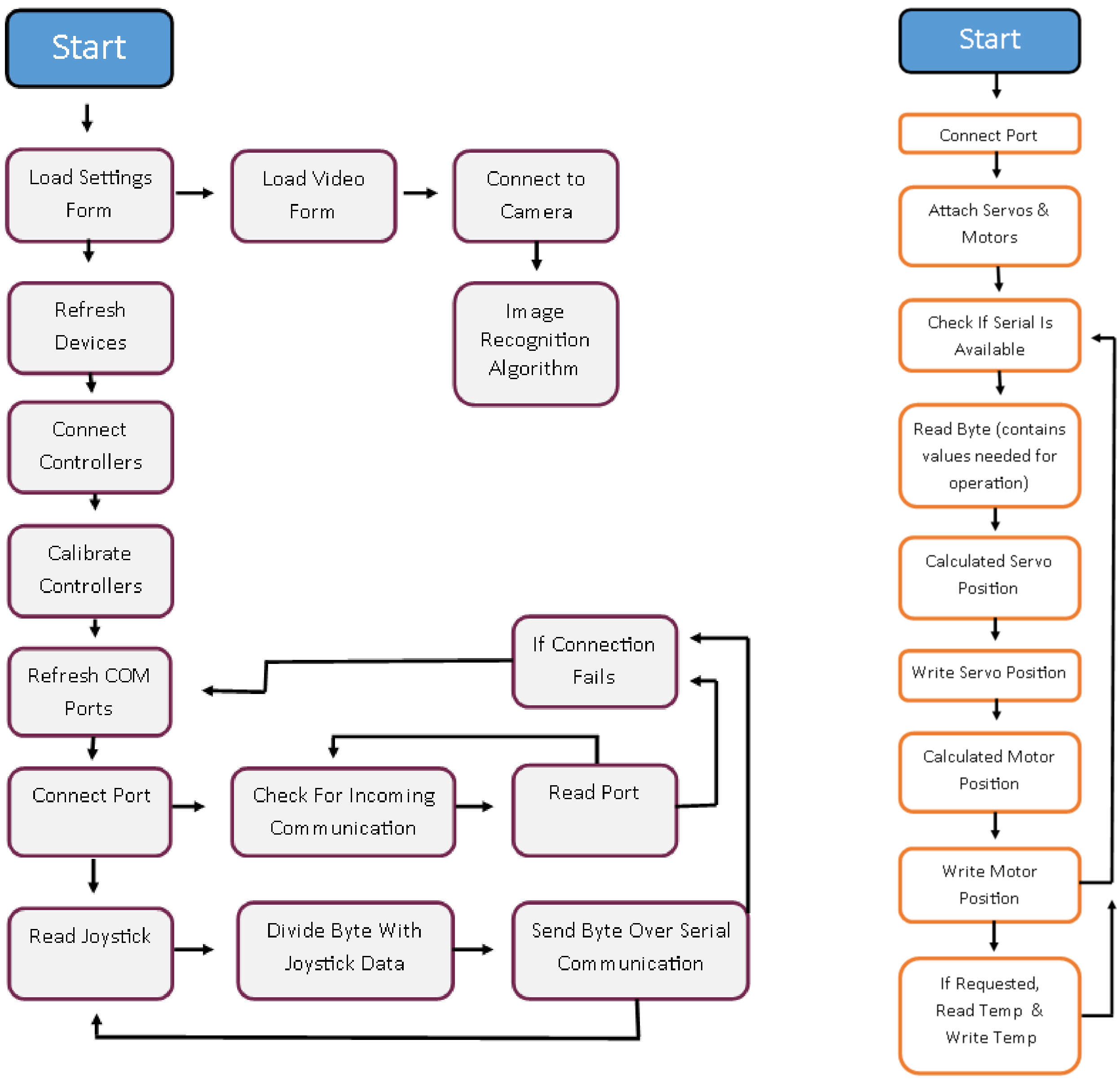
ACKNOWLEDGEMENTS

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 2019 missions and organizing the competitions.
- Eastman Foundation and Kingsport Aquatic Center in Kingsport, TN for hosting the 2019 Competition.
- Governors Towne Club for allowing us the use of their pool to practice for the event.
- 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, Mr. Loomis 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, Kingsport Aquatic Center, Marine Technology Society.
- Longhorn Steakhouse, Southland Greenhouse, and the Dallas Rotary Club for allowing us to host multiple fundraising events.
- SolidWorks for free student license software
- Nick Garber former team member for his assistance and guidance with programming training for our new members

APPENDIX A – SOFTWARE EMBEDDED FLOW CHART



APPENDIX B – SID