H2O BOOTS: RANGER CLASS
Technical Report 2019

North Broward Preparatory School
7600 Lyons Road
Coconut Creek, FL 33073

1) **Abstract**

We are the H2OBOTS, representing North Broward Preparatory School in Coconut Creek, Florida! While creating a breathtakingly complex robot, we used Fusion360 as our design tool of choice. Our vector design was selected due to it having maximum mobility in the water. From last year, we added the mini-ROV and reel which are both 3D-printed to make the overall weight of the ROV lighter. We also implemented six cameras instead of the basic two we did last year. With the presented tasks we added a switch-operated claw to aid us in fulfilling the given tasks; whether it is picking up rocks and fish, inspecting the foundation of the dam, our self-designed tools have enabled us to perfect a smooth running system. With the inspection of the dam task, we found a deep connection to an issue that we currently have in the US. Infrastructure in America is aging; therefore the dams are getting weaker, with over 4,000 dams currently needing repair. Drawing this connection, we were able to envision ourselves solving this problem in America when creating our robot, as we implemented specific features that will aid us in inspecting the dams. For tools and products, we determined what adjustments were needed by trial and error; for example, making adjustments to meet the weight requirements and determining what types/thickness of the wires that we needed. We

gained the skills of rebounding from setbacks and used it as motivation to further improve.

2) **Company Information**

Team Members	**Grade**	**Title**	**New/Returning**	**Career Goal**
Bobbi-Jo Suppelsa	9	Chief Executive Officer	Returning	Biomedical Engineer
Lena Kalandjian	9	Electronics Assembly/Soldering	Returning	Pediatrician
Kylee Vest	9	General Robot Assembly	Returning	Marine Biologist
Ava Cannold	9	Chief Operations Officer	New	Civil Lawyer
Madison McEwen	11	Chief Financing Officer/Software Programming	New	Biomedical Engineer

Photo credits: Betty-Jo Suppelsa

Team Role	Image	Description/Justification
Bobbi-Jo (9th)		CEO: Bobbi-Jo has the ability to learn from past experiences and instill lessons for the future. She implemented the first all-female robotics team at NBPS, and brought the idea of a MATE ROV Underwater team to the school as well. With past experience of robotics camps she was best suited for this position.
Madison McEwen (11th)		CFO: Madison is experienced with delegating and overseeing the financial operations of many clubs effectively. With emotional intelligence and self regulation, Madison was best suited for this position.
Kylee Vest (9th)		GRA: Kylee is experienced with building robots from past classes and is familiar with assembling parts and the tether. Kylee was best suited for this position.
Lena Kalandjian (9th)		Electronics & Soldering: Lena is experienced with soldering techniques and particularly enjoys the electronics aspect of building the robot. Lena was best suited for this position.
Ava Cannold (9th)		COO: Ava is known for managing the group and making sure we stay on task. She is most organized and constructive; Ava was best suited for this position.

Team Mentors	Position	New/Returning
Steven Craw	High School Instructor	Returning
Tony Suppelsa	Motorola Solutions Foundations Sponsor	Returning

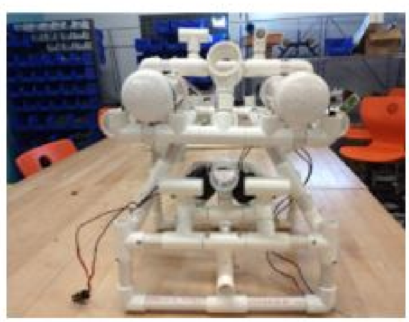
Photo credits: Betty-Jo Suppelsa

Left to right: Ava Cannold, Lena Kalandjian, Steven Craw, Bobbi-Jo Suppelsa, Kylee Vest, Tony Suppelsa, Madison McEwen

3) **Design Rationale**

FRAME:

Base Frame Design


Our 2019 ROV frame is built out of ½-inch diameter PVC pipe as a vector design. The current frame was designed around existing components of last year's robot; however simpler it was, it was a vector design and was very successful in the water and the benefits drastically outweighed those of the square design. This year since we added more components, we made sure that the robot had enough flotation so it would no sink directly to the bottom. To ensure this, we added 4 ballast tanks on top of the robot -- every cubic centimeter of air in the ballast can lift one gram underwater. When we tested it in the water, our robot was perfectly balanced and floated neutrally in the water. One goal that we had for this years frame was to keep the entire ROV **as compact as possible** to be able to have maximum control over the robot and complete measuring tasks as accurate as possible.

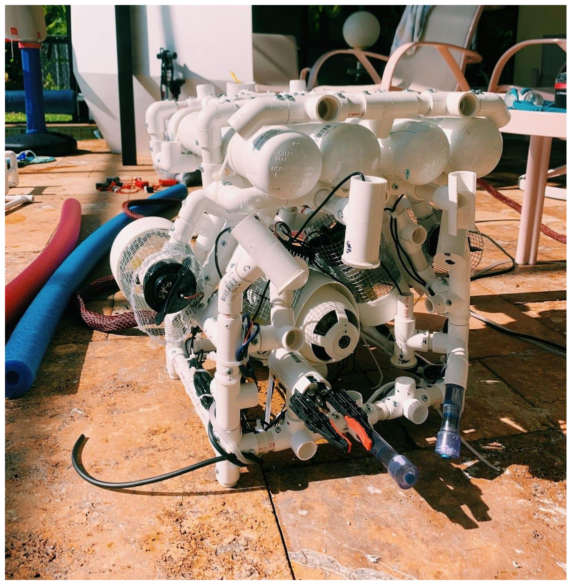
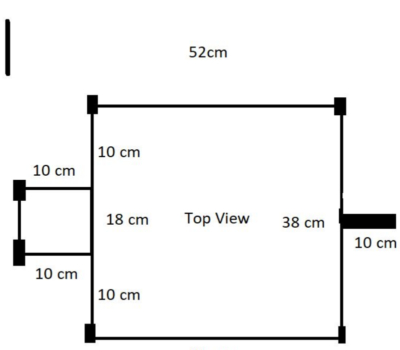


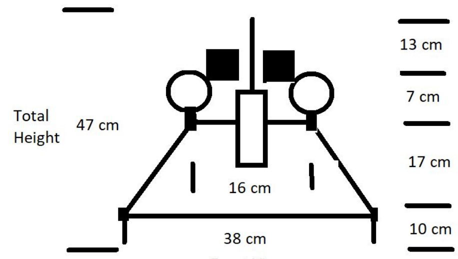
Photo credits: Bobbi-Jo Suppelsa

Drawing Dimension of Rov

Top View Dimensions



Side View Dimensions



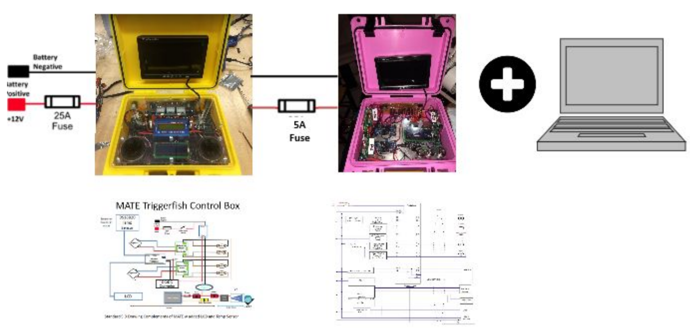
Vector		Square	
Pros	**Cons**	**Pros**	**Cons**
● More maneuverable in the water ● Easier to control with the joysticks on the control box ● Can complete tasks more accurately ● More compact	● Less space for motors and cameras on the inside and therefore have to be placed on the outside, exposed to potential damage	● More space inside to fit extra components	● More difficult to control with the joysticks on the control box ● Less maneuverabl e/accurate ● Very bulky when trying to fit through tight spaces

System Interconnect Diagrams SID

Fuse Size Calculation = ROV Full Load Current *150% = 20A *150% = 25A

- Yellow Box 15A + Pink Box 5A = 20A Total
- Ranger Max Fuse size is 25A

- System Control box setup, Control Box, Game Box and Computer Vision



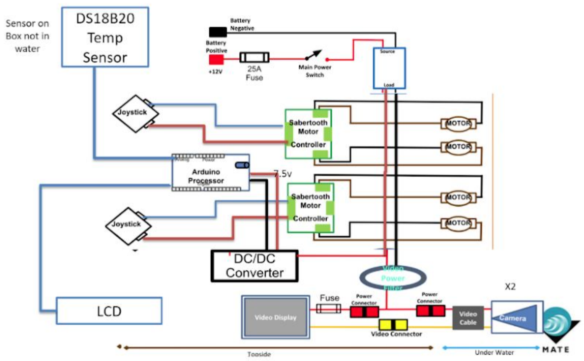
Source of Images: Bobbi-Jo Suppelsa, EasyCAD, and Microsoft ClipArt

The yellow control box controls the driving of the ROV, while the Pink Game Control box controls the functions of the game (Claw, Temp Sensor, Metal Detector). The computer is used for computer recognition of images, shapes and aids in allowing measurement of shapes.

H2OBOTS SID

Ranger Team

Yellow Control Box

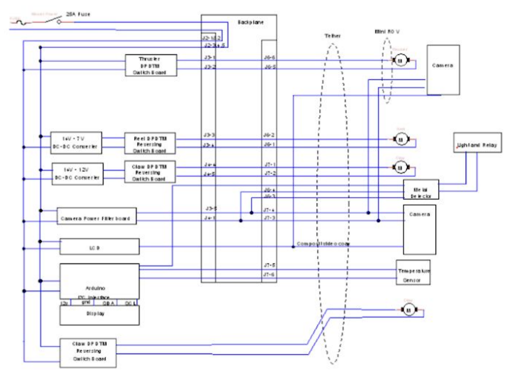


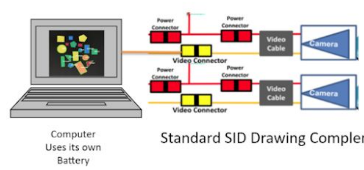
Standard SID Drawing Complements of MATE w added LCD and Temp Sensor

Max Fuse Size = 20A = 20A *150% = 30A = Max Fues 25A

Computer Recognition

Pink Game Box

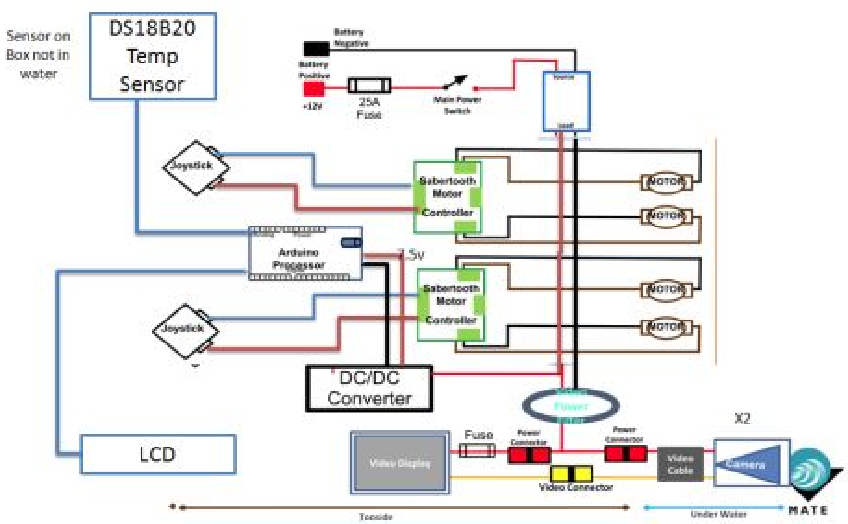




Standard SID Drawing Complements of MATE

Yellow Control Box SID

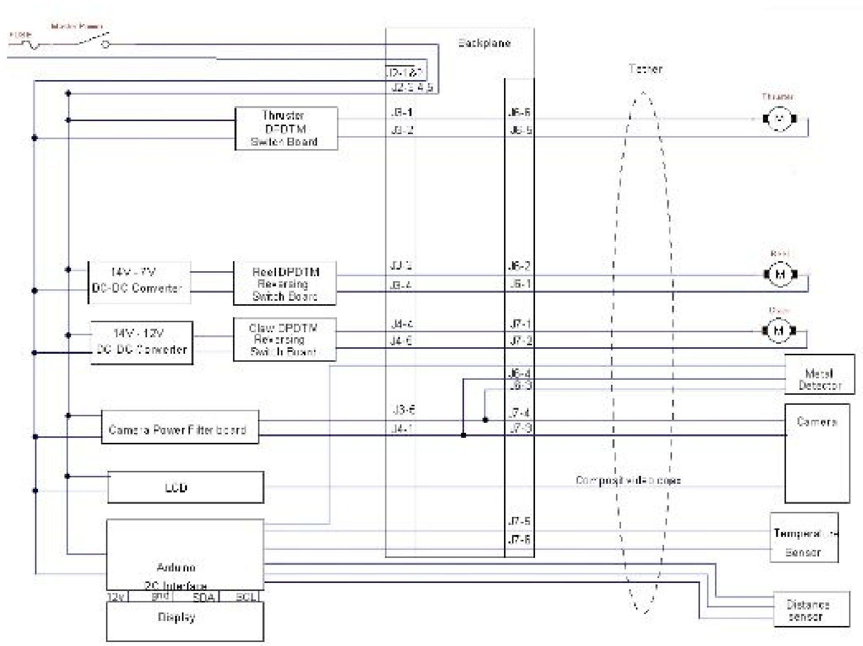
MATE Triggerfish Control Box



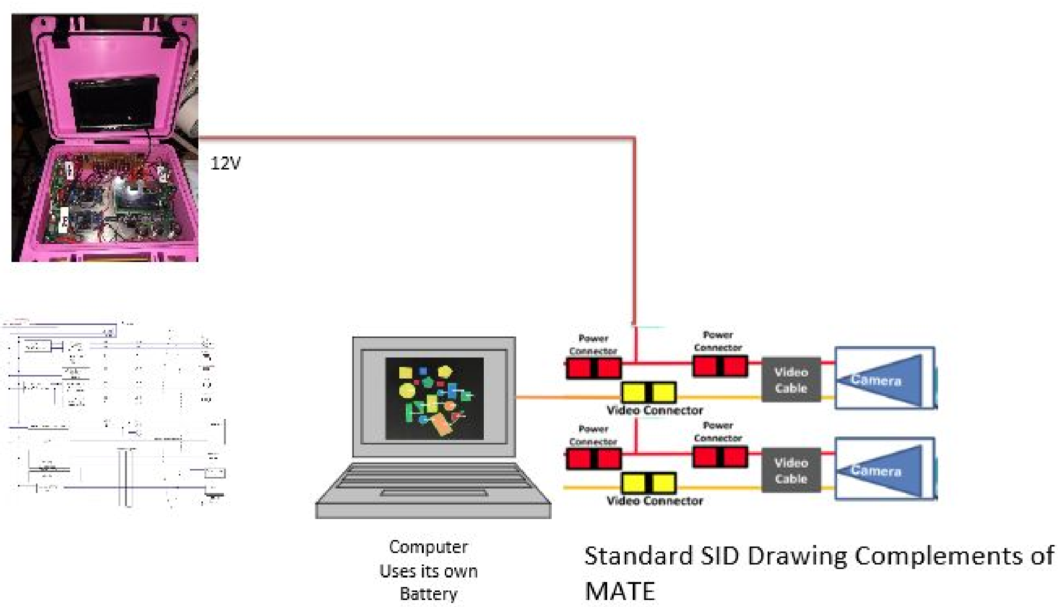
Standard SID Drawing Complements of MATE w added LCD and Temp Sensor

Source of Images: Standard SID Drawing Compliments of MATE with added LCD and Temp Sensor.

Pink Control Box SID

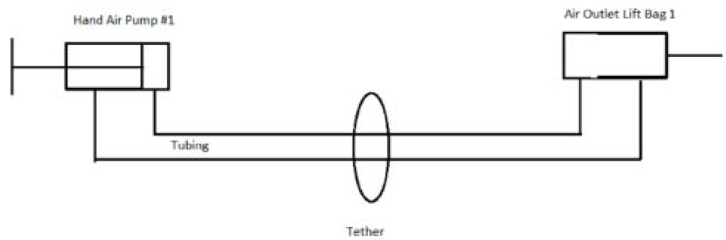


Computer Vision SID

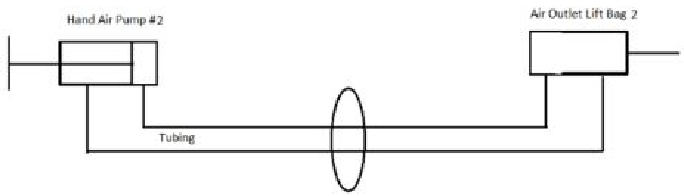


Airline SID

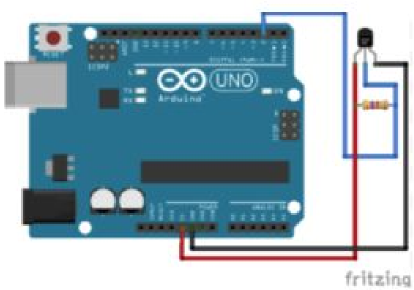
SID Airline #1



SID Airline #2



Temperature Sensor




```
#include <OneWire.h>
#include <LiquidCrystal_I2C.h>

// OneWire DS18S20, DS18B20, DS1822 Temperature Example
//
// http://www.pjrc.com/teensy/td_libs_OneWire.html
//
// The DallasTemperature library can do all this work for you!
// https://github.com/milesburton/Arduino-Temperature-Control-Library

OneWire  ds(11);  // on pin 11 (a 4.7K resistor is necessary)
LiquidCrystal_I2C lcd(0x27, 16, 2);

void setup(void) {
  Serial.begin(9600);
}
```

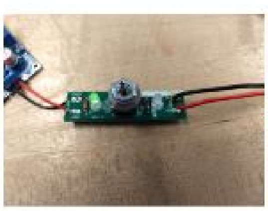
Pink Game Control Box Design

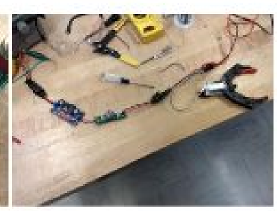
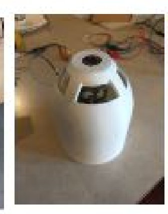
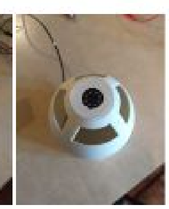
We received the pink box for Christmas present. We ordered the backplane board from the mate store and solder wires to the connector pins to make the circuit connections to the tether. We order parts from the Triggerfish 2.0 kit (Metal Plate, Video Power board and the Arduino kit) to make the functioning circuitry. We used the soldering test circuit switches from the MATE store in order to drive the motor on the mini rov and forward / backward motion required. See pictures before showing the MATE store parts. Almost all of the parts were originally ordered from the MATE store to be used in the pink box design. The arduino kit came with a DC to DC converted and we later upgraded to one with a digital display. We decided to keep the drive part separate from the game part. That way each year we can reuse the driving part and save time.






Mini ROV and Claw Design



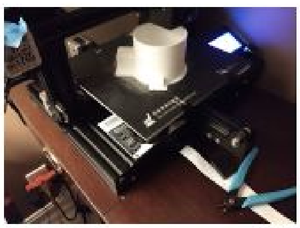
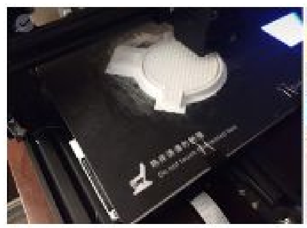








The claw uses a DC to DC voltage converter to slow it down so it does not move as fast. It was taken off of a Makerbot robot toy and converted to be used underwater. Normally running at 6 volts and we originally started at 12V.

Fish Drop Cup Design

The fish drop cup was design free hand copying from a flip top mason jar as the example. It was drawn using Fusion 360 and 3D printed on an Ender-3 printer.

Special Features

- Manual rotation positioning claw zero or 90 degrees
- Reel and mini-sub
- 3D printed canisters with Fusion 360 CAD software
- Cameras
- Motors
- Tether
- Switches
- Arduino board with temp sensor.

How ideas were originated/selected
○ Flythrough video
○ Searching on internet for other ideas from past events and teams
○ Testing in Pool

- Features and design process explained

	Gripper: Last year we were not able to release the lift bag, so this year a claw was needed. The MakeBlock Robot Gripper was cost effective and worked well after waterproofing. The gripper was reinforced with metal bolts at the hinge to make it stronger, and waterproofed with Neosporin and electrical tape. The gripper is controlled by a switch on the control box, with the wire running through the tether. *Image source: Amazon.com*
	Metal Detector: A metal proximity sensor senses when metal is close by, and alerts us with a red LED when metal is in close proximity. It also uses these to zero the XY coordinates of 3D printers and CNC machines. *Image source: Amazon.com*
	Temperature Sensor: We are using the DS18B20 Waterproof Temperature Sensor Probe to measure water temperatures with the ROV. It is combined with an Arduino controller and LCD to display the temperature real time on the control box, which can be seen easily by the operator. *Image source: Amazon.com*
	Lift Bag: We used a two gallon Glad bag and PVC with a 3D printed coat hook to create a lift bag. The hook will latch onto underwater objects and an airline running through the tether with an air pump on the end will fill the Glad bag with air and therefore lift the object up in the water. *Image source: Betty-Jo Suppelsa*

- Data comparing alternatives table

Robot Gripper	
MakeBlock	**Blue Robotics**
• $14 • Cost effective • Already runs on 12 volts • Built in self	• $329 • Too expensive

current limiter so it does not burn out • Tested the gripper and it worked	

Metal Detector	
Proximity Switch	**TraGoods Metal Detector Module**
• $8 • Smaller	• $10 • Too large

Lift Bag	
Glad Storage Bag	**Diver Lift Bag**
• $8 (10 bags) • Easily accessible • Tested the bag and it worked	• $45 (1 bag) • Expensive

- Science and techniques behind design tasks

For the gripper, you need an H-Bridge switch that allows you to go forward and backward similar to the soldering test circuit that we used for the H-Bridge switches.
For the metal detector, when metal gets close to the sensor, the red LED light turns off letting us know that it has detected metal in close proximity.
For the temperature sensor, it is a digital thermometer that uses the Arduino controller to read and display the temperature on LCD.
For the lift bag, you need to get air into the lift bags to increase the buoyancy and lift the object from the bottom.

Targeted the smallest size to maximize points at 60cm diameter.
Reused last year frame design to minimize cost and ROV build time.
Having as little of pipe between fittings allowed for minized weight.
The gripper was only $14 from Amazon which is about the cost of a single 12V DC motor. Blue Robotics also sells a gripper for $329.
Used PVC for the cameras mounts instead of the acrylic tube that hold less epoxy weight for the cameras. To make it fit we soldered each of the camera wires separately instead of putting them into the epoxy for sealing.

- **Built vs Bought:**

Buit	**Bought**	**New vs Reused**
All 3D-printed components (reel, mini-sub & holder, fish drop, propeller guards)	Triggerfish kit and Arduino Kit from MATE Store Building materials PVC frame Magnets (Amazon) Gripper & Prox Sensor Temp Sensor (Amazon) PVC Pipe and Fittings	Reused frame design from last year -- everything else *new*

Budget: $1,408 (100% Donated)

Theme:

Improving the planet through underwater exploration utilizing STEAM.

ROVs can be used to support inspections, make repairs on hydroelectric dams, maintain and monitor water quality, determine habitat diversity, restore fish habitats and recover historical artifacts. ROVs can accomplish all of the above by their unique design and maneuverability under water; they are able to reach deep and narrow areas in which humans cannot. ROVs are very diverse in their style and are extremely versatile. The cameras on ROVs can help the operators explore deep-sea ecosystems and monitor them over time, which has never been done before in such an efficient way. As far as retrieving artifacts and monitoring water quality, ROVs can do both safely and quickly. In fact, they can do it much safer than a human would be able to if they could.

Company Evaluation / Market Assessment:

Our company, H2OBOTS, has grown significantly in terms of knowledge and skill since last year. We have built a bigger, better, and more sophisticated ROV with several new components that were built with low costs and high efficiency. The best thing about our company is how we have been able to come together and work as a team to solve problems we have faced with relatively low amounts of experience. Since we are only a second year team, we haven't been together for that long and have already had team members come and go. Throughout the process of learning and growing through competition and building experiences, we have learned to put our minds together to think of a solution when solving problems in short amounts of time. In the future, we want to perfect our team's ROV and experiment more efficient solutions to the problems we are trying to solve. We want to grow the MATE program at our school and get more students interested in this field of study; living in Florida, especially, underwater ROVs are extremely important in managing ecosystems like coral reefs and the Everglades, so getting more interest in young people will hopefully create future marine engineers to work on saving our ecosystems. The most rewarding part of our entire building experience was learning how to solve real-life problems as young people. As students, we don't always feel like we have much power in terms of change. MATE Underwater Robotics has shown us that it is possible to produce change as young people, and that we truly are the future. Preparing for this competition has strengthened our company's skills and outlook by teaching us how to construct a robot and control system from

Safety:

Safety is the most important thing to us while working in the lab or practicing by the pool. Therefore, we took numerous safety precautions to ensure the safety of the team members and adults who come within close vicinity of the ROV and workspace.

- All wires and electrical connections are soldered, sealed in hot glue, and shrink wrapped, so they are not exposed to outside forces and therefore cannot short-circuit or be affected by contact with water.

- The camera pods are sealed in epoxy and zip-tied securely onto the ROV.
- To make sure that the PVC framing does not disconnect underwater, we screwed them together at every connection.
- We placed metal cages over the propellers to prevent an injury resulting from getting too close.
    - All sharp edges of cage are coated in hot glue to prevent scratches or cuts.
- No other exposed sharp edges!

Checklist / Procedures:

1. Always wear your safety glasses when working on the equipment and in the lab.
2. Make sure when soldering not to get burned and use the proper soldering iron procedures.
3. Use caution when using power tools and equipment.
4. Always clean up after yourself in the lab.
5. Electrical Wiring should be neat and of workshipman like quality.
6. Always make sure your ROV is plugged into the GFI outlet before plugging it in or putting the ROV into the pool.
7. Always check your wiring on your ROV for lose or exposed wires.
8. Covers should always be over the propellers.
9. Physical Inspection to see if things are going to fall off of the ROV.
10. Looks for Sharp or Hazardous objects that could cause injury.
11. Make sure the tether is secure on both ends of the control box and the ROV.
12. When lifting the ROV in the box make sure to use two people.

Safety Design Requirements:

Anderson SBS-50 connectors to supply power to game box and power supply.

Fuse and Calculations:

ROV Full Load Current x 150% = 20A x 150% = 25A (25A Mx Size Fuse for Ranger Class Allowed)

- FULL LOAD (both control boxes with all operations processing) = 20A, 15A for the Yellow box and 5A for the Pick Game box, so as long as we don't run all ROV operations at once, the 25A fuse works perfectly. The maximum size fuse for Ranger Class is 25A. Even though the %150 calculation is 30A we are going to be using a 25A fuse and with proper ROV management we will not have any issues.

Control Box wires neatly organized - NO EXPOSED WIRING:
All wiring is soldered, hot glued and sealed with heat shrink tubing.

AC and DC identified: All connections labeled.

Strain relief for ROV: Both boxes are strained relief and the Pink box has two strain relief connectors to hold the thermocouple wires that go to the Arduino controller.

Propellers shrouded to IP-20 standards (12mm): We used wire mesh purchased from Home Depot at 6.35mm opening, which is well below the IP-20 standard size for protection to make the motor guards.

Critical Analysis:

The process of modifying and constructing our robot involved lots of testing and troubleshooting.

Ex. Mini-ROV: The mini-ROV needed much improvement from the first test in the water. When we tried to steer it after launching it out of the main ROV, the mini-sub would just spin/rotate in place under the water. We decided that there was not enough water flowing through the propellers so we drilled holes in the 3D-printed vehicle to increase water flow and hopefully stabilize the vehicle. In the end, this solved the problem.

Main ROV: Testing the complete vehicle in the water was tough at first because the floatation seemed to be off-balance and the cameras were not placed correctly. We solved the buoyancy issue by placing rocks on top of the ROV to add weight and offset the floatation. As for the cameras, we practiced the tasks underwater with the cameras pointing at different angles to decide which positioning was most convenient. We decided on final placements. Lastly, a significant challenge that we had trouble finding a solution for was the LED on the metal detector, as it was extremely difficult to see whether it was on or off underwater through the camera lenses. Eventually, we solved the problem by making the surface underneath white to reflect better and we got a brighter light bulb. Overall, a technical lesson that we learned is to make sure the LEDs we purchase are visible with the cameras that we have.

One interpersonal challenge that our team faced was coordinating around everyone's schedules to organize dates and times for building and practicing. All of our members are so busy and involved within the community, so it was rare to get us all together at once working as a team. Most days, four out of five of us were working while one or more of us had a conflict and this significantly slowed down our build. However, we overcame this challenge and took advantage of the days that we were able to meet together and work as a team. Overall, we learned that we are always going to face challenges in whatever we do, so we have to make the most of the situation and always work our hardest.

Challenges:

Late Start: we did not get started until the middle of January, and we did not think it would take as long as it did to complete since we had our base frame already done.

We are a second year team and had to learn everything from following the MATE installation directions on their website. We followed the build instructions for everything that we did. It took a lot of time to go through all of the information.

Broken Motor Controller took us three weeks to debug as only three of the four lights would come on, and the fourth one would not turn on.

It took all of our remaining build time to get the mini ROV functioning, and we had Low Practice Time on the game parts of the challenge.

Lessons Learned:

Having back up parts for the motor controller would have been good to make the troubleshooting go faster.

Next year we can start at the beginning of the year working on the base ROV in August instead of waiting to the game announcement.

We can invest in making the game pieces, so we have the stuff to practice with before the event.

Future Improvements:

Future improvements that we can make for our ROV are to find the correct ratio for perfect buoyancy in the water and find how to smoothly operate the mini-rov as well as other components of the robot like the metal detectors or the claw. This year, our metal detectors didn't display information accurately and the claw often hyperextended while operating. This was a challenge while performing tasks because it would hyperextend while we were trying to lift something and it would cost us extra time to come back to surface and fix the issue rather than figuring out a way to prevent hyperextension. The mini-rov could have used a lot more improving design-wise and the reel needed more power, so next year if we base the design off our constructions this year, we will need to figure out a better and more convenient way for the mini-rov to have maximum maneuverability and takeoff in the water.

Acknowledgments

MATE Training Documentation and Materials

Steven Craw and Tony Suppelsa, for providing us guidance

North Broward Preparatory School, for providing a workspace, materials, and financial support to construct our robot