SEAL Robotics Team

Greensboro, NC

Team Member	Role
Austin Ramey	CEO
Oliver Voorhees	Chief Engineer and Java Programmer (Graphical Display)
Ben Liebkemann	Java Programmer (Graphical Display) and Engineer
Logan Smith	Chief Safety Officer
Nathan Ruppel	Prop Expert, Design Engineer
Owen Voorhees	Chief Arduino C Programmer (drive functions, depth)
Marissa Maynard	Design Engineer, Challenge Expert, Tech Writer
Harrison Ascencious	Marketing Expert, Design Engineer
Jay Jasso	Engineer
Jonathan Bacon	Design Engineer, Prop Expert
Walt Liebkemann, Kurt Ruppel, Brock Longley, and Ned Voorhees	Team Mentors

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Abstract

SEAL Robotics constructed MAKO, a Remotely Operated Vehicle (ROV) to meet the requirements Put forth by the University of Washington (RFP) Our ROV was designed to be a light maneuverable design able to complete task in multiple underwater fields. Mako will be able to locate and retrieve objects, have the capability to instal or recover a seismometer device, along with Installing a tidal turbine and instrumentation to monitor the environment. This is a very important job as Mako has the capability to go into dangerous situations people could not normally go.

We knew that Mako needed to be small, maneuverable and durable. In addition, all of the electronics are mounted on the surface as opposed to on the ROV. There are 4 on-board cameras that are for all angles of viewing. Mako has two high torque linear grippers that are mounted in two orientations (Vertical and Horizontal, on the front and rear). This allows Mako to manipulate any object and complete any task it may face. We also designed an integrated tape measure to properly measure distances underwater. Mako contains a depth sensor and software used to navigate to or maintain a certain depth. It also has an air hose integrated into the tether that can be used to inflate an underwater lift-bag for lifting heavy objects. Mako will help people accomplish dangerous task for years to come.

Completed ROV (Mako)

Company Profile

SEAL Robotics Team was founded for students, by students. Its purpose is to share, teach, and spread knowledge in STEM. Our name, SEAL, stands for Science, Engineering, Automation, and Leadership. We started from scratch this year with just a few members who had previous experience in robotics or MATE (Marine Advanced Technology Education). Our goal is to promote the mindset along with skills and knowledge to help our members succeed with their future careers. Our team has also worked with and made prototype control modules using PLCs (Programmable Logic Controllers). This taught us real industrial skills that are used in the automated manufacturing field. Our focus is MATE Robotics. Mixing electronics with robotics and water creates a whole new challenge that encourages ever stronger development of skills in the engineering and business world. SEAL Robotics is run by its members with adult mentors, giving guidance along the way. This method gives each of the members their own responsibility and roles that they are responsible for. This helps with all areas covered from engineering and leadership to communication and marketing.

From left to right: **Walter** (mentor) **Austin** (CEO, Grade 11) **Kurt** (mentor) **Logan** (Chief Safety Officer, Grade 10) **Nathan** (Prop Expert, Design Engineer, Grade 10) **Harrison** (Marketing Expert, Design Engineer, Grade 8) **Jonathan** (Design Engineer, Grade 8) **Brock** (Mentor) **Marissa** (Design Engineer, Tech Writer, Grade 8) **Ben** (Java Programmer Graphical Display Grade, and Engineer Grade 8) **Owen** (Chief Arduino C Programmer Grade 8) **Ned** (mentor) **Oliver** (Chief Engineer and Java Programmer Grade 11)

Company's Approach to the Design and Build of Mako

Our team worked together well to design, build and test Mako. We held group discussions to determine the best ways to design utilizing previous MATE designs. We added some of our own features to optimize the way Mako performs the task. Each member had their own job to complete during the design, build, and testing phase of Mako.

Team Roles for Each Member

During the beginning of our build season, we held group meetings for all members to help design the main parts and goals of our ROV. Once decided upon, we dedicated roles and jobs for each of the members to work on. Some of the more experienced members helped to advise in some areas which made things more efficient. We had a team for programming, prop building, tether, and ROV build. Splitting up the work allowed us to get more done in a timely and efficient manner.

Technical Documentation - Done as a Team

We found that different members of the team had knowledge needed to write the different parts of the documentation. One of our mentors helped us by directing us to look carefully at the technical documentation **rubric**, then we split up the needed sections for each team member to complete. We dedicated several of our 3-hour team meetings solely to doing technical documentation. This allowed the shared knowledge of all the members to be placed into one.

Project Management

We had a lot of work to do since we were starting this year from scratch. We did not have a previous ROV to "upgrade". In early December one of our mentors pointed out that if we did not establish a schedule and timeline, we would not likely make the deadlines for the competition. Together we wrote the following timeline, and generally met our goals of dates during the season by checking back against the schedule to see how we were doing.

Timeline and Scheduling

On the 15th of Dec. the team came to an agreement of the final design for Mako. January 21st the first prototype of Mako was completed. February 11th we finalized the design for all manipulators for challenges. March 18th we had our first pool trial, we now are finished with the initial build process of Mako and are in the testing stage. We meet every Sunday from 2-5p to work on testing and future improvements, and meet other times at the pool to practice. Listed below is a more detailed timeline and schedule.

Our Timeline

Timeline Date	Task
1-Sep-17	New Robotics Team Organization and Planning
3-Sep-17	Work and research begins on PLCs, and how we can use them in the MATE competition.
1-Oct-17	Research continues on PLCs, ladder logic, MODBUS interface.
22-Oct-17	First Parent Meeting for new SEAL Robotics Team
31-Oct-17	Initial SEAL Robotics website is up, http://www.seakoboticsteam.com
15-Nov-17	PLC Control Station with plexiglass top is completed.
1-Dec-17	Research performed as a team on designs, and utilizing MATE technical reports from previous years. Notes taken on successful designs, manipulators, standout features.
15-Dec-17	Team comes to an agreement on our design's general dimensions, propulsion, chassis material.
1-Jan-18	Decision made to abandon PLC approach for this year. Robust solution, but there are too many technical hurdles to stay on schedule for this season.
14-Jan-18	Parent Meeting
14-Jan-18	Start building "Props", which are the PVC objects we will interact with in the pool.
21-Jan-18	Get one T100 thruster to work with a PS/2 controller
21-Jan-18	Build of Prototype Chassis Completed
21-Jan-18	Complete Build of "Props"
4-Feb-18	Have thrusters mounted on chassis in initial configuration for testing
4-Feb-18	PS/2 controller and software controlling all 6 thrusters in a crude configuration
11-Feb-18	Finalize design for all manipulators for challenges
18-Feb-18	Execute first pool trial with just chassis
1-Mar-18	First draft of technical report
4-Mar-18	Complete build and installation of all manipulators
18-Mar-18	First trial in pool with manipulators and props
20-Apr-18	Final Draft of Technical Report, SID, Safety Documents, etc.
5-May-18	Regional Competition
21-Jun-18	International Competition

Planning our Meetings

At the beginning of every meeting we talk about our progress from past meetings and what is going to be worked on for the day. We plan for every member to have a specific job to work on, and when their job has been completed they check with a senior member or a mentor to find out what they should work on next. This helps us make the most of every meeting. At our meetings, we usually have three teams, electrical, mechanical, and extra. The electrical team focused on the electrical box, drive controls, and GUI (Graphic User Interface) The mechanical team constructed the different parts of the ROV in segments. Each member on the mechanical team performed a different task to make meetings more efficient. They also assisted with the assembly of the tether. The “extra” team was used to build the props, which would later be used for testing Mako. They also worked on parts of the manipulators and cameras. This whole process allowed a full learning experience for all of our members and helped to stay on schedule.

Team Approach to our ROV Design

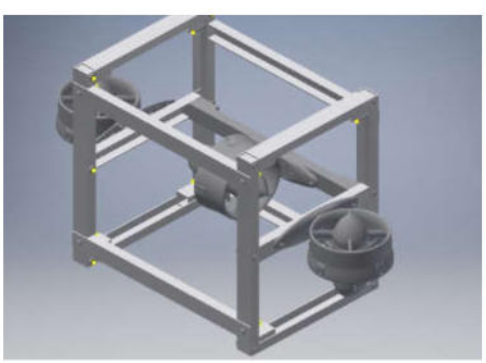
We dedicated a few of our team meetings to researching successful designs from both industry professionals and previous MATE teams, and talked about what we wanted for our ROV design. We then wrote down some of the items we liked from each. We made our own changes and variances to accommodate what we thought was best for the tasks at hand. All of this research and design work was done on paper before we purchased any materials or components. Similarly, we held a full day team meeting to discuss and design the manipulators (grippers, prong, air hose, etc.) that we thought would be-most effective on Mako. Having these full team meetings allows for everyone on the team to have input when discussing the design.

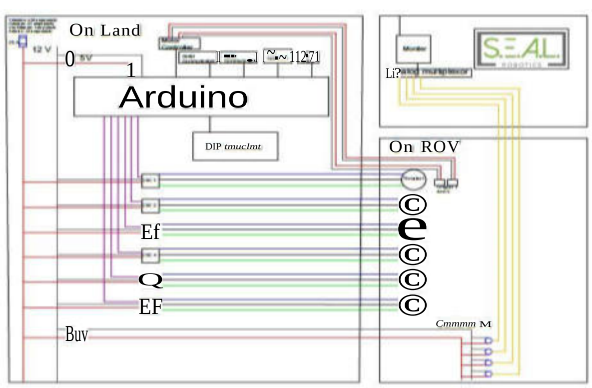
Below are our initial draft notes from our first design session back in December 2017. It is interesting that in the end, our ROY is a very close match to these notes!

Component	Notes
Blue Robotics T100 Thrusters	6 (3 vertical, 2 fore/aft, 1 strafe)
Dimensions	30 cm cube
Bonus points for size	- Less than 60 cm (23.6") diameter sphere. The two largest dimensions of the vehicle and tether must fit through a round hole of 60 cm (23.6"). - Thrusters are 96.5mm (3.8") in diameter. - Side of frame should be an absolute maximum of 40.7 cm (16"). - Allowing for ballast tanks, arms, tether, etc., suggestion is to prototype at 11" x 11" x 8" (L x W x H).
Bonus weight points	< 12 kg
Balast tanks	PVC ?
Prototype Frame Material	Extruded c-channel aluminum
Final Frame Material	Extruded c-channel aluminum

ROV System Design and Design Rationale

SEAL Robotics has created Mako, an ROV designed to complete different tasks and challenges in underwater environments. We used Autodesk Inventor CAD and AutoCAD It in the design process.   Mako has a very small footprint making it fast, lightweight, and maneuverable. The chassis is lightweight yet strong material, C channel aluminum. Mako has two grippers that can be used to manipulate things in its work envelope. It uses six cameras for optimum viewing angles including forward, backward, bottom, and manipulator viewing areas. Two of the cameras are “flex cameras”, that can be relocated on the ROV as needed. Something we are very proud of is the depth sensor that is on the bottom of Mako. This allows Mako to “hover” in any given depth or navigate to a target depth. That in tandem with the powerful blue robotics T100 thrusters mounted in a tripod fashion allows it to act like a “gyro”, keeping it stable and level underwater. For safety features, Mako has shrouds covering all of the T100 thrusters, this prevents any objects from getting to the props. It also has 3d printed corners on all of the sharp edges protecting against possible cuts. All wiring connections are securely soldered and waterproofed using a combination of liquid electrical tape and heat shrink.





Prototyping

We did a lot of prototyping this year. Examples:

1) Depth Control and PID tuning: We attached a single T100 thruster to our depth sensor on a strip of metal and put it in a trash can of water. Owen used this for weeks to write and test out the PID software to get hover and other depth functions working optimally.
2) Lift Bags: We created at least 7 different lift bags and attachment mechanisms before we settled on one.
3) Grippers: We built 6 different gripper configurations before we settled on the VEX grippers we used.

With each prototype, we did testing and were able to evaluate the strength, reliability, and effectiveness of each design for a given task. Using that data, then we would create a the next prototype for the given task.

General Design Goals

Some of the members had a previous year in MATE and learned a lot from the last ROV construction. Our primary design goals were:

1) *No dry* /wx/electronics on board the ROV itself
2) *Light* and *agile* design
3) More *stability* under water
4) Above all, *reliability*

We started by using light weight aluminum C-channel for the chassis. This material is light and strong but also easy to work with. The design is small to eliminate weight and make Mako as agile as possible. This allows for faster maneuvering speeds. We wanted no electronics housed on the ROV, as with past experience leaks created a lot of issues. This system will allow it to be a lot more reliable. We wanted to have a more stable hover when in the water. For this reason we have a tripod vertical thruster configuration. The software we utilized with the help of a depth sensor helps us maintain our depth and orientation in the water. We wanted to have full visibility of all usable angles on Mako, for this reason we are using four cameras. Each one is specifically placed to allow for visibility in the work envelope. Each manipulator is fixed, as opposed to other movable designs, as it gives a stronger and more durable approach.

Final ROV Design - Underwater Portion

Below is information on each of the components of the underwater portion of our ROV system:

Frame / Chassis

We decided on a small, simple, cube-like frame made of aluminum C-channel. The frame will make maneuvering through the water easier, and since the material we used is lightweight, it will not put exorbitant amounts of strain on the thrusters, which are trying to control our depth and movement. The frame is in a cube shape with two side-bars made to accommodate one longitudinal thruster each, and a bar on the top from left to right to accommodate floatation, cameras, and the depth sensor. Mako also has a floatation housing with foam used for buoyancy to achieve near neutral buoyancy.

Propulsion

Propulsion for our robot is provided by six Blue Robotics T100 thrusters, three of which are controlling the vertical movement (making a tripod configuration), two that are controlling the longitudinal movement, and one that is controlling the lateral movement. Each thruster provides five pounds of thrust forward, and four pounds of thrust backward. All of our thruster guards,
both front and back covers, were 3D printed and coated in epoxy.

Cameras

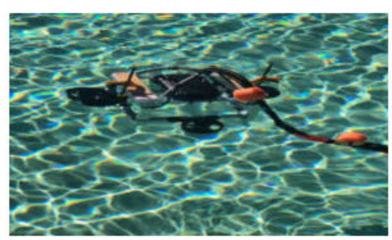
For our cameras, we decided to use Car Front View Cameras, and Chuanganzhuo Universal High definition CMOS Non-mirror Image Waterproof Front View Cameras. We have six black, 16.5mm cameras mounted on our ROV, positioned to see both grippers, our measuring tape and to guide us through the water. Two of our cameras, facing both the front and back of our ROV, are placed at an angle that allows them to see our grippers- and the water both in front and back of our ROV. Another one of our cameras is angled to easily view the measuring tape that measures the distance from the designated object. Our fourth camera is placed underneath our ROV to give us a full view of the water in front of us. Finally, there are two “Flex Cameras” that can be relocated on the ROV frame on the fly as needed.

Depth Sensor

Our depth sensor, which was generously donated by Keller America, is located in the middle of our ROV. It is used to give us an accurate depth measurement of Mako at any location beneath the surface. The depth sensor is a level gauge which sends an output signal of 0-5V. It uses level transducers to send the depth of its location to us through its cable which is part of our tether.

Buoyancy

Our buoyancy for our ROV is provided by “Great Stuff’ expandable foam and polystyrene foam compressed into a Tupperware container secured to the top of Mako. We used a wide Tuppeiware container that was similar in size to the top of our ROV to allow it to remain upright and steady instead of swinging around our buoyancy point like a pendulum. Window insulation bead is assisting our tether in maintaining a near neutral buoyancy.



Tether

Below is a listing of each wire in the tether, and the wire's purpose:

Jacketed Wire	Wire Color	Wire Gauge	Wire Usage
Cat6 #1	1-Green	23 awg	Not currently used - spare
	1-Green and White	23 awg	Not currently used - spare
	1-Orange	23 awg	Front Gripper (+ or - depending on motion)
	1-Orange and White	23 awg	Front Gripper (+ or - depending on motion)
	1-Brown	23 awg	Rear Gripper (+ or - depending on motion)
	1-Brown and White	23 awg	Rear Gripper (+ or - depending on motion)
	1-Blue	23 awg	Not currently used - spare
	1-Blue and White	23 awg	Not currently used - spare
Cat6 #2	2-Green	23 awg	Depth Ground #1
	2-Green and White	23 awg	Depth Power (12V)
	2-Orange	23 awg	Not currently used - spare
	2-Orange and White	23 awg	Not currently used - spare
	2-Brown	23 awg	Depth Ground #2
	2-Brown and White	23 awg	Depth Output (0 to 5V)
	2-Blue	23 awg	Not currently used - spare
	2-Blue and White	23 awg	Not currently used - spare
Triplex 1	Black	18 awg	Strafe Thruster
	Green	18 awg	Strafe Thruster
	Red	18 awg	Strafe Thruster
Triplex 2	Black	18 awg	Left Forward Thruster (wire 1 of 2)
	Green	18 awg	Left Forward Thruster (wire 1 of 2)
	Red	18 awg	Left Forward Thruster (wire 1 of 2)
Triplex 3	Black	18 awg	Left Forward Thruster (wire 2 of 2)
	Green	18 awg	Left Forward Thruster (wire 2 of 2)
	Red	18 awg	Left Forward Thruster (wire 2 of 2)
Triplex 4	Black	18 awg	Right Forward Thruster (wire 1 of 2)
	Green	18 awg	Right Forward Thruster (wire 1 of 2)
	Red	18 awg	Right Forward Thruster (wire 1 of 2)
Triplex 5	Black	18 awg	Right Forward Thruster (wire 2 of 2)
	Green	18 awg	Right Forward Thruster (wire 2 of 2)
	Red	18 awg	Right Forward Thruster (wire 2 of 2)
Triplex 6	Black	18 awg	Right Vertical Thruster
	Green	18 awg	Right Vertical Thruster
	Red	18 awg	Right Vertical Thruster
Triplex 7	Black	18 awg	Left Vertical Thruster
	Green	18 awg	Left Vertical Thruster
	Red	18 awg	Left Vertical Thruster
Triplex 8	Black	18 awg	Rear Vertical Thruster
	Green	18 awg	Rear Vertical Thruster
	Red	18 awg	Rear Vertical Thruster

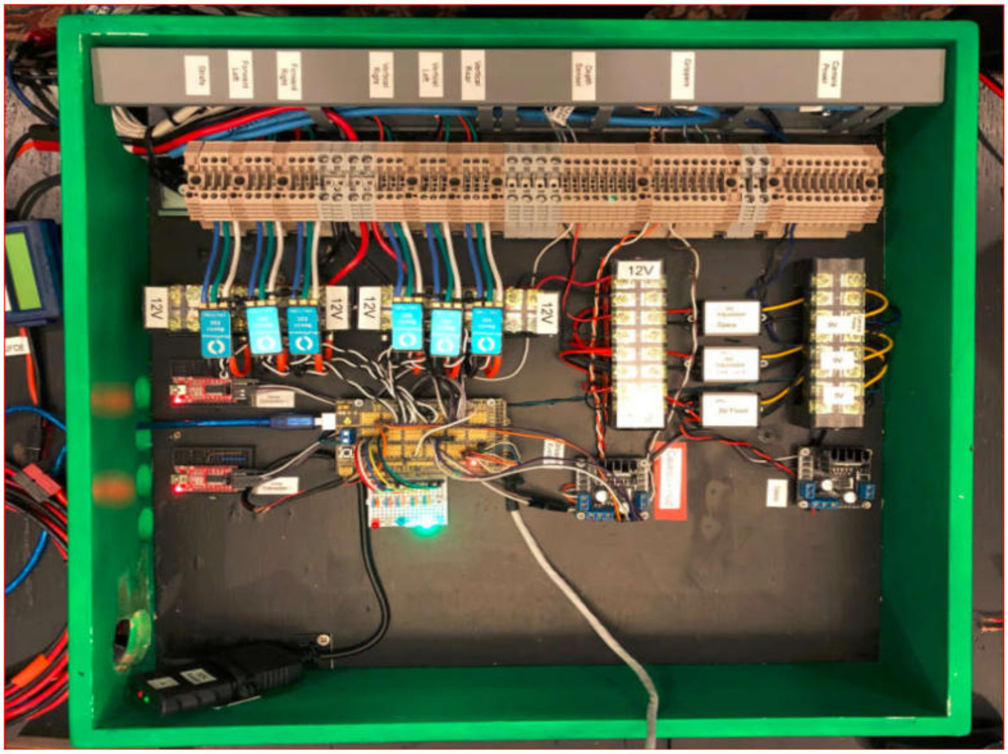
Grippers

We are utilizing two VEX linear grippers: one mounted horizontally on the front, and the other mounted vertically on the rear of the ROV. They are both mounted directly to the chassis for optimum strength and rigidity. They are powered by VEX continuous rotation motors. They are waterproofed by using vaseline packed into the casing of each motor. The power is provided at 12 volts on a cat6 pair, and due to the voltage drop from the length of our tether, it is perfect for the VEX motors that-run off 7.2 volts. The grippers are controlled by pulse-width modulation controlled by two slider potentiometers. This allows for optimum control when trying to make precise torque adjustments in the grip. Using software to control the grippers allows us to limit the torque, preventing gears from stripping out as well.

Final ROV System Design - Surface Portion

Below is information on each of the components of the topside portion of our ROV system.

Final Labelled Control Box



- No AC power is present in the Control Box.
- No fluid power is used on this ROV System.
- No Lasers are used on this ROV System.

Main Fuse

<u>ROV Overcurrent Protection Calculations:</u>

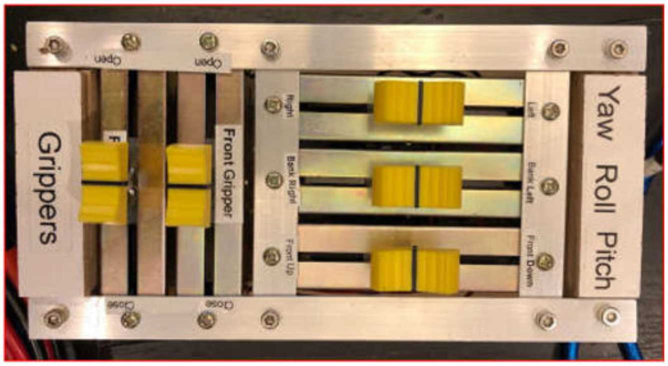
Device	How Many	Current Draw Each (Amps)	Total Current
Thrusters	6	**2.25**	**13.5**
Cameras	**4**	**0.1**	**0.4**
VEX Grippers	**2**	**1**	**2**
Arduino	1	**0.23**	**0.23**
	Total Calculated Current (Amps)		**16.13**
	Overcurrent Protection Factor		150.00%
	Fuse Calculation (Amps)		24.195
	Round to Fuse Size (Amps)		**25**

Based on the calculations above and the MATE limits, the Mako ROV system uses a 25 amp slow-blow fuse. The fuse is positioned well within 30 cm of the Anderson Power Pole connection, as per the specification.

Arduino Mega

The drive system is powered by an Arduino Mega. This controls the driving functions, the depth controls, the grippers, and sends data to the Java GUI using our custom serial interface.

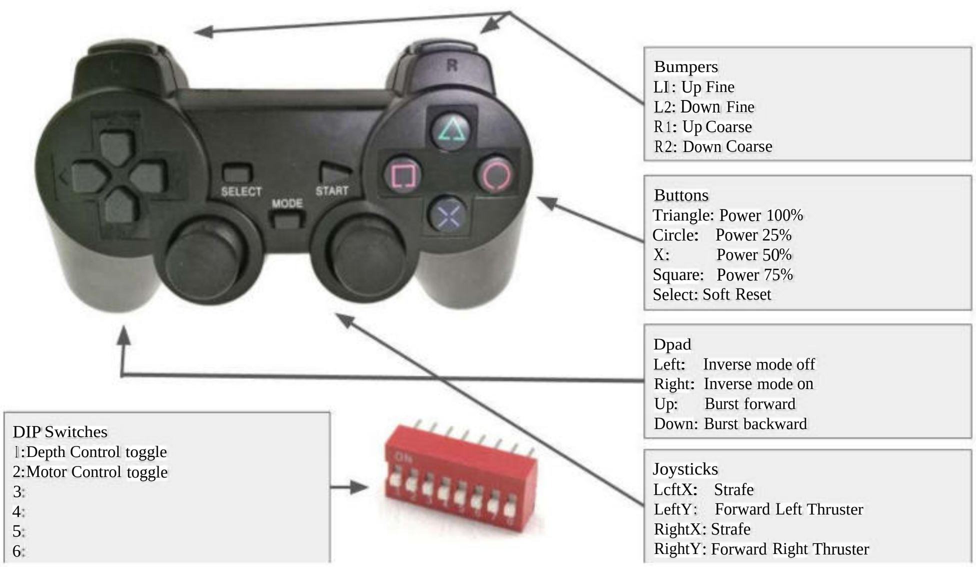
Gripper Controls



The Grippers are actuated using motor controllers. A 12V pulse width signal is sent by the motor controllers to the Grippers in order to actuate them. The grippers are controlled using slider potentiometers. We built this control from scratch using plywood and aluminum. We chose to use sliders for the controls to allow fine tuning of these elements. Below is an image of our custom built control that we use to control the Grippers, as well as to fine tune Pitch, Roll, and Yaw.

Drive Controls

Controls for the ROV are up, down, left, right, turn left, turn right, forward, and backward (Pitch, Roll, Yaw). The ROV is primarily driven using the PS/2 Controller Interface. Thrusters can work together to adjust pitch, yaw and roll. This is because the thrusters are in a tripod formation. The driver can adjust each utilizing the slider shown above. Here is a picture of the control scheme:



Custom Arduino C Drive Control Software

All of the Arduino C code was written from scratch this year by team members. There are over **1800** lines of code. The code uses the Ps2X library to communicate with the PS2 controller.

Drive Control Software Features

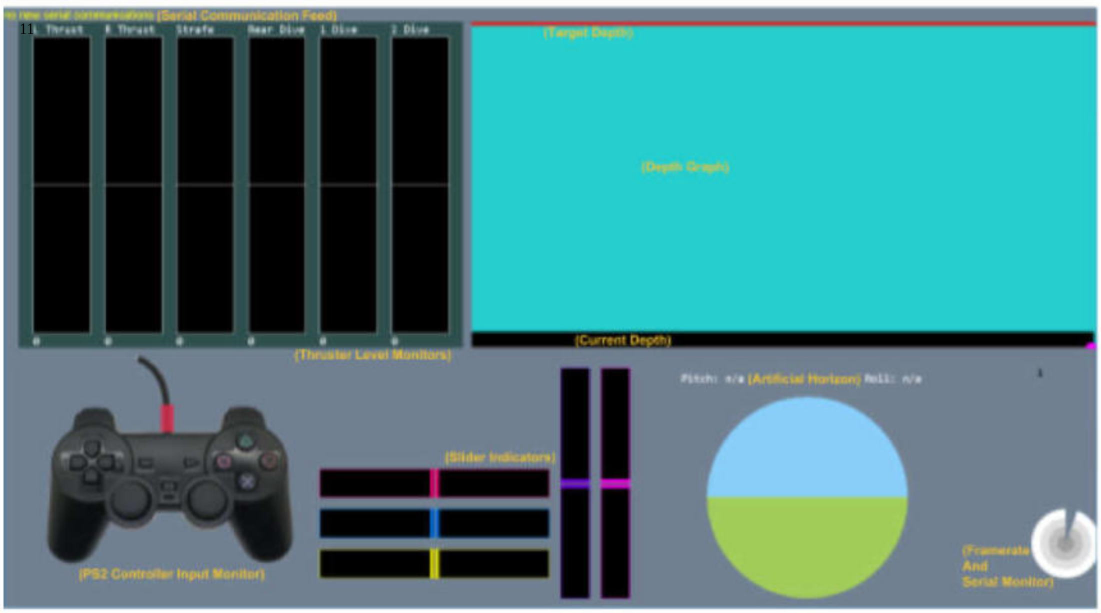
Precision Mode

We have crafted a precision mode ability that will let us reduce the maximum power of the thrusters when making fine adjustments as we complete the challenge tasks.

PID Controller for Depth
The Depth Stabilization function is used to let the ROY either move to or stay at a particular depth when driving or doing tasks. This is accomplished by use of P-I-D Controller software. PID stands for Proportional-Integral-Derivative in the controller software. This software was written by team programmers after doing research on YouTube. We currently are only using the proportional and integral functions to accomplish depth control.

Custom Graphical Display Java Software (GUI)
We wanted to have an intuitive graphical display to show the status of the systems of the ROV. **Our two Java programmers designed and wrote the Graphical Display from scratch**. Below is an annotated screenshot of the display.

Annotated Screenshot of the Graphical Display



Custom Designed Serial Interface
When we first decided to make a Graphical User Interface(GUI) from scratch for our ROV, we were challenged with the task of coming up with ideas to get data from the Arduino to the computer. We experimented with many different concepts but ultimately decided on the idea of constantly receiving a string from the Arduino with letters and values denoting components and data. We use the RXTXcomm java library to communicate with the Arduino. Basically, the Arduino compiles its data into a formatted string and sends it to the computer using a serial connection via a USB shield. In the java code we have created and implemented an object that receives the string and gives the information taken out of the string when it is called for.

Thruster Level Display
In the GUI, we have created labeled bar graphs showing the level and direction in which each individual thruster is operating. This is useful for making sure that all inputs are being mapped correctly and that no thrusters are out of order.

Depth Indicator

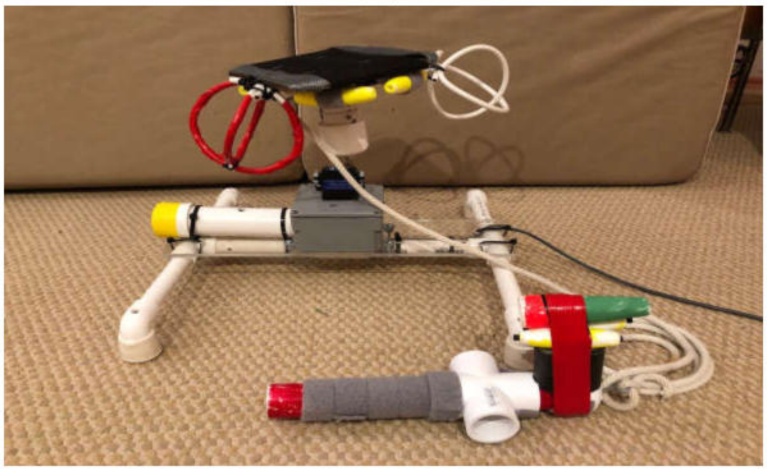
Our ROV is equipped with a depth-sensor to accurately pinpoint how deep we are below the surface. Using the data from this depth-sensor, we have created a 2D line graph showing previous depths, current depth, and target depth, all scaled to the maximum depth the ROV has reached. We have also implemented a color indicator at the current depth to show if the ROV is moving up, down, or staying at the same depth in the water.

Gripper Indicators

We decided to use a simple design in our arrangement of manipulators for this competition, and this is reflected in our GUI. We have simple bar graphs showing the values of all of our slide potentiometers. We arranged the bar graphs to have the same layout as the slider control-box so that the GUI would be more intuitive.

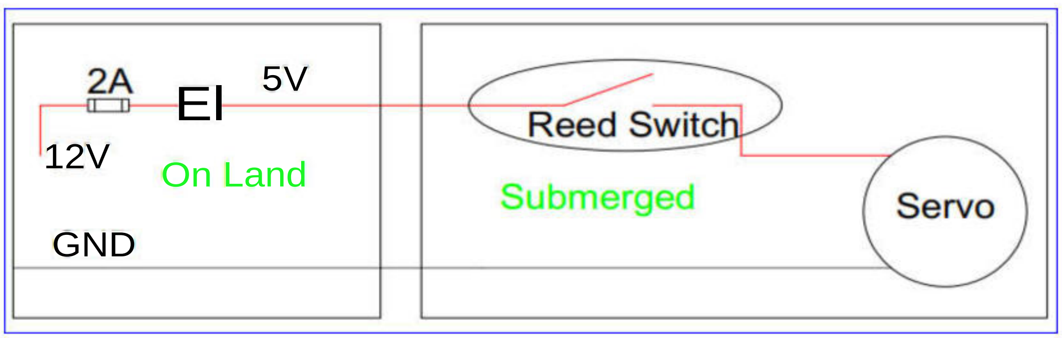
OBS Design and Release Mechanism

Below is a picture of our OBS and release mechanisms. The dimensions align with the specification. Our OBS dimensions are: 42cm (depth) x 42 cm (width) x 40 cm (height).



The Anchor is constructed from 14 inch PVC with rebar inside for ballast. The Mechanical Release is a modified tent stake acting as a pin to keep the OBS attached until it's removed. There is a “grab point” we made from two pieces of coaxial cable. The OBS is a platform covered in velcro, with floats on the comers for buoyancy. We also have a magnetic read switch that triggers a servo to release the OBS. See the separate OBS design document for more in depth detail on the design.

SID for the Magnetic Reed Switch Release Mechanism on our OBS



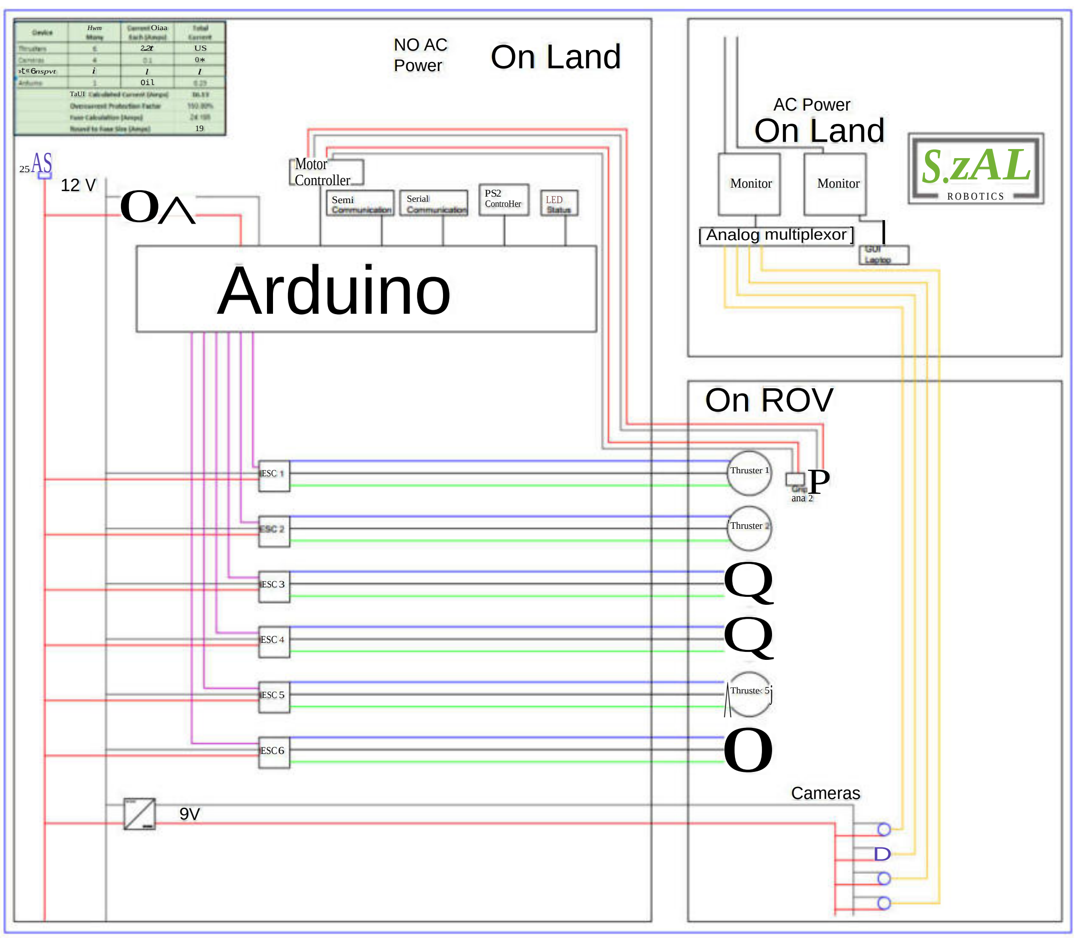
Build vs. Buy Decisions

Since were were a new team this year, we did not have any parts or an ROV to reuse. Because of this, we had a lot of work to do in a short period of time. We also had to set a budget and stick to it. Because of our experience last year, we decided that it was very important to write custom software that we could fine tune, rather than buying software. Wc also wanted a nice graphical interface. These elements took a lot of time to design, test, and fine tune. Because of this, there were some things (such as the VEX grippers) that we did not have time to build from scratch. We made the same decision on the thrusters (buy, instead of make). We knew that building thrusters from electric motors, waterproofing them, building cowling, and testing them to make sure that there were no electrical leaks would take several weeks that we did not have. Besides our software, we did build a number of other things from scratch. For example, we built our chassis by cutting and drilling aluminum stock, and we used 3D printing to make several components such as our thruster guards and our comer bumpers.

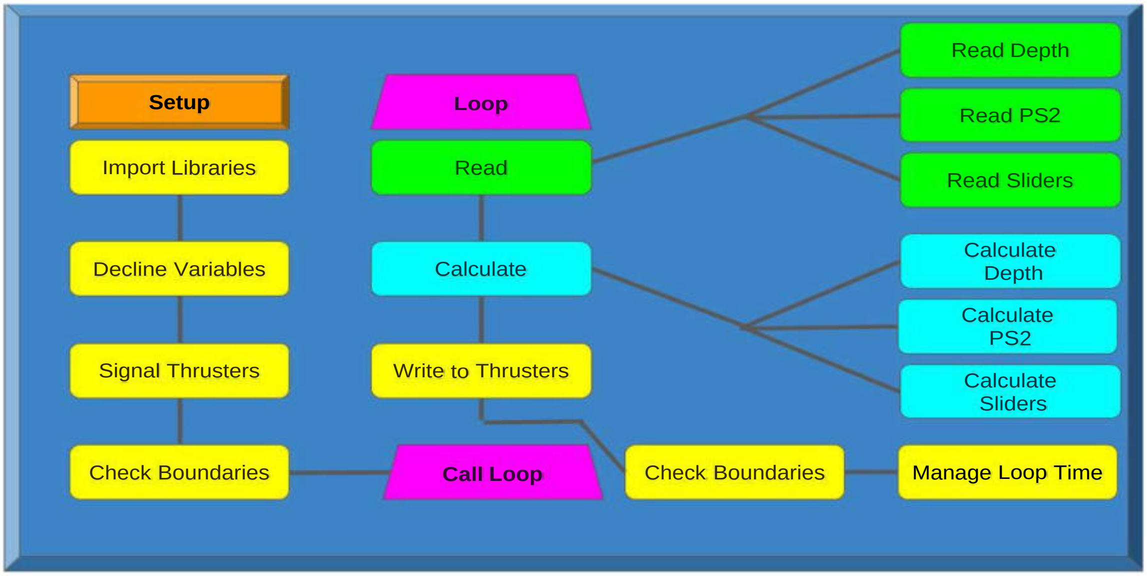
System Integration Diagram (SID)

Below is the SID for our ROV system (Mako).

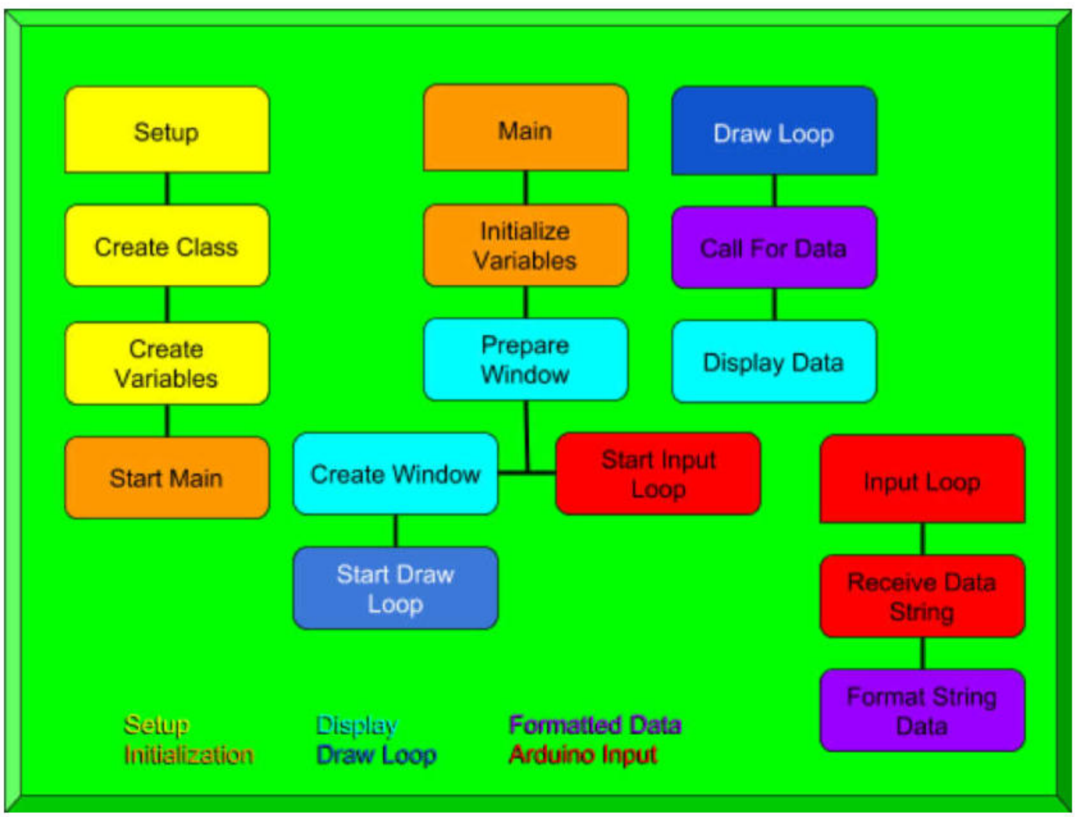
- We broke the SID into “On Land” and “On ROV” portions.
- For reference, we also included a section showing the video monitors and video multiplexer, but they do not get their power from the MATE power supply.



Below is a Flow Chart of our Arduino C Drive Function Software



Below is a Flow Chart of our Java Graphical Display Software



Safety

Safety Philosophy

Safety of team members and the safety of our products is of primary importance to SEAL Robotics. We work not only to address safety issues and concerns, but to proactively prevent them before they occur. We use safety glasses, ear protection, and other safety equipment when we are working with hazardous equipment, and our mentors provide proper training on each tool. On our ROV system, we do not take shortcuts when it comes to safety. For example, we carefully insulate all exposed electrical connections and we use GFCIs when working with 120 VAC power sources, regardless of whether we are near water.

Safety Features

Our ROV includes a number of safety features:

1) Shrouded thrusters that are bright green in color to draw attention to them.
2) Caution labels inside of our control box for hot heat syncs on the motor controllers.
3) No 120 VAC power in our control box, and we included a sign to make this clear.
4) Green comer protectors on the ROV chassis to protect against shaip edges.

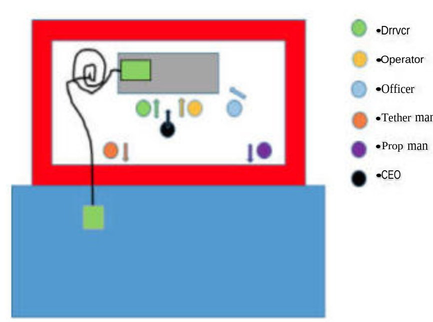
Pre-Run Safety Checklist:

- All nuts and bolts and attachments are secured
- Thruster shrouds are secured and tight
- No foreign objects present inside thruster shrouds
- All wires are secure and in excellent condition
- There are no shaip edges and/or comers on the ROV
- All thrusters are unobstructed
- Drive table set up is clean and organized
- All members of drive team are in “ready drive position”

Product Demonstration Safety Checklist:

- Tether manager is the only person handling the tether (other team members cannot step over the tether)
- Power connection is secure and not near water
- GFCI (Ground Fault Circuit Interrupter) is used for monitors, laptops, and power supplies.
- Control station equipment is securely placed on the table (away from edges of table surface) in a clean and organized fashion.
- Team members must walk at all times (running/jogging is not allowed during demonstration)

Ready positions



Post-Run Safety Checklist

- Make sure all equipment is safely removed from product demonstration area
- All nuts and bolts and attachments are secured
- Thruster shrouds are secured and tight
- No foreign objects present inside thmster shrouds
- All wires are secure and in excellent condition
- There are no sharp edges and/or corners on the ROV

- All motors and servos are unobstructed
- Ensure there are no water leaks or damage
- Members thank judges and staff

Critical Analysis

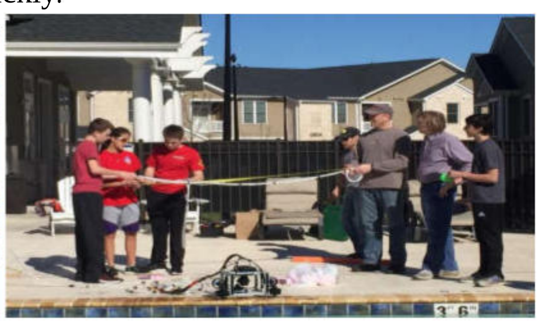
Testing and Troubleshooting

We did a lot of testing while building the ROY, and after we finished the build.

One problem we faced was that the tether wires are so long that the signals sent to devices did not work like they did with short wires. One of our mentors showed us how to calculate voltage drops for different wires, but we needed to do actual testing. We tested this by sending signals over the wires on land at 150% of the real tether lengths. We had to do this for cameras, manipulators, and thrusters. Problems were found with the manipulators and cameras. The camera signal was noisy in cat5, cat6 and cat7, so we eventually moved to dedicated video wires, and it worked. We identified these problems during the build instead of after construction was completed.

One of the utilities the ROV uses is depth control for doing tasks efficiently. This uses a PID controller algorithm that we wrote in Arduino C. We watched youtube videos to learn about this. We tuned our PID software using a single T100 thruster in a trash can of water in our dining room. This way we could see what needs more or less power (gain) and add that to the software controller.

We tested the full ROV in a pool when we wanted to practice tasks. One problem we encountered is we had no precision mode. We swiftly added one to the software and came back to test it the next week. It helped us complete the tasks more quickly.

Challenges that We Faced During Construction and Testing

Technical Challenge: Sometimes you have to scrap a great idea to stay on schedule

When we first started prototyping, our intention was to use PLCs so that our members were taught real-world applications with these devices. After many weeks of working with and learning about PLCs, we eventually determined that PLCs would not generate the PWMs that we needed in order to communicate with the ESCs for our Blue Robotics Thrusters. It would have cost a lot of extra money to buy additional controllers for the PLC, and it still may not have worked. Our solution to this challenge was to switch over to using Arduinos, as they have servo control libraries specifically designed to communicate with T100 thrusters. We learned that sometimes you have to scrap a great idea and start over to stay on schedule.

Organizational Challenge: Communication between Team Meetings

We needed to communicate better outside of our meeting times. We also wanted to have parents looped in on certain team communications.

Our solution to the problem was to use the “GroupMe” application to help us communicate together better. We created special groups for the “Main Team” (everyone, including parents), “Leadership” (mentors and senior team members), and “Outreach” (fundraising and corporate responsibility). This app helped keep everyone on track, and we could discuss issues with the ROY with each other between meetings. .

Lessons Learned

We learned a lot of lessons this year. Below are just a few of them.

Management: Starting a new team is hard

While 5 of our team members did have previous MATE experience, it was really hard starting from scratch this year. We had to buy every single thing that we needed (from just basic wire for testing, to the first servo, to screws). Also, things like creating our website, logo, and setting up a nonprofit organization took time and energy from the team (and from our mentors and supportive parents). It will be nice next year to not have to do all of these things and be able to focus just on the MATE tasks.

Technical: “Waterproof’ does not always mean waterproof.

We learned first hand that buying a “waterproof’ servo or camera does does not always actually mean waterproof for prolonged submersion. We had to learn to use manual waterproofing techniques for a number of items using materials such as silicone RTV, *Liquid* electrical tape sealant, hot glue, heat shrink, and even Vaseline.

Planning: The timeline and budget should be done first

We were working for the first few months without a detailed plan. One of our mentors pointed out that if we did not establish a schedule and timeline, we would likely not make the deadlines for the competition. Next year we will work to come up with a budget and timeline much earlier in the process.

Development of Skills

Soft Skills:
Some of the most important skills our team learned this year were *planning* and *how to work collaboratively* with others in order to develop a successful outcome. Our mentors showed us the importance of planning ahead in ordering parts and having a plan for each team meeting. By working together to design and build our ROY, we learned the importance of sharing ideas and working together.

Physical Skills:
Below is a list of just some of the many skills that our team learned or learned more about this year:

- Soldering and waterproofing techniques.
- Planning the layout of a control box for a neat final product.
- Testing pieces individually (software, thrusters, grippers, etc.) before testing as a whole.

- Working with aluminum in building the chassis (cutting, drilling, grinding, fastening).
- Arduino C and Java programming (lots of it).
- Designing 3D objects with CAD (Autodesk Inventor and AutoCAD Lt.).
- 3D printing.

Future Improvements

We have a number of things we would like to improve on in our ROV system in the future. Here are a couple of them.

Integration of a Gyroscope into Stability Control

This year our stability was controlled by our software interfacing with a depth sensor, as well as three dedicated sliders that could control each of the vertical thrusters. Next year we would like to add an on-board gyroscope to integrate with the stability controls.

Lighten the Weight of the Tether

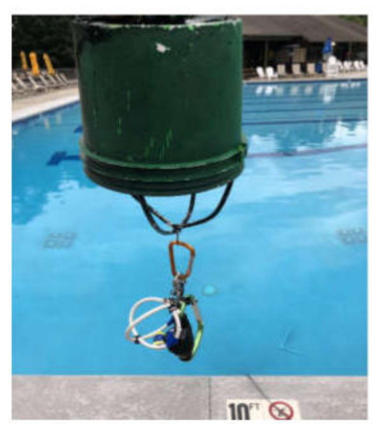
This year we had a goal to not have a dry box on board the ROV. This was because of all the water leakage issues we had last year that led to reliability issues. In order to do that, we had dedicated wiring in our tether running to each of our six thrusters. This made the tether incredibly heavy. Next year we would like to try to find a way to reduce the weight of the tether.

Lift Bags and Air Inflation System

The Request for Proposal indicated a need for a lift bag to lift and release or recover heavy objects underwater. We designed two lift bags to meet that need. We utilized two plastic buckets in our design. One of these has an integrated release mechanism. The green lift bucket has a pin connected to the white cord, this is used to release the bucket once the object has been moved. This is ideal for clearing debris, and then releasing the lift bucket to the surface. Either system can take an object up to the surface where Mako can pull it to shore. Both lift buckets are filled with air utilizing a manual high capacity air pump and hose that is integrated into the ROV tether. Air is pumped into the bucket and displaces the water in the buckets creating buoyancy. SEAL Robotics team prototyped and tested many lift bag systems before settling on this one. In testing, these designs proven to be effective in accomplishing the task.

(Left) Black Lift Bag is intended to attach and recover items to the surface.

(Right) Green Lift Bag is intended to attach to and lift a heavy item, after which time it can be moved and then released from the item.



Accounting

Since this is SEAL Robotics first year doing a robotics competition, we did not have parts that we could reuse from previous years. With our limited membership dues and funds for our new organization, we needed to carefully plan our expenses in order to not spend too much money.

We also knew that we had other expected expenses that were not related to actually building the ROV such as the monthly fee for the Forge Makerspace (our meeting place), as well as tools and supplies that are not actually part of the build (Examples: sunshade, power supplies for testing, etc.). We decided that we could probably contribute $2000 to the total cost of building the ROV, and we would need to raise money and get donations to make up any difference in the cost.

Travel Expenses

For travel to Federal Way to the the International Competition, we have estimated the round trip, hotel stay, meals, and other travel expenses at around **$550 per member**. We decided early on that this would be an individual team member expense and would not be covered in our team budget or expenses unless there happened to be funds left over at the end of the season.

Project Budget

BUDGET - SEAL Robotics ROV Build 2018

Category	Item	Projected Cost	Budgeted Value	Notes
Competition Display/Report	Display board supplies, technical report, pictures, etc.	$70.00	$70.00	
Registrations	Competition Registrations	$400.00	$400.00	$200 for Regional $200 for International
ROV - Cameras	Cameras, cables, connectors, adapters, multiplexers, etc.	$350.00	$350.00	
ROV - Lift Bags and OBS	Lift bag supplies, OBS Supplies	$50.00	$75.00	
ROV - Frame	Aluminum stock and fasteners	$75.00	$85.00	
ROV - Grippers / robotic arms	Grippers, motors, servos, controllers, etc.	$200.00	$200.00	
ROV Sensors / Electronics	Reed switches, release circuitry, etc.	$50.00	$75.00	
ROV Sensors / Electronics	Depth Sensor	$250.00	$0.00	Donated
ROV - Tether	Tether wire, waterproofing, air hose, etc.	$250.00	$275.00	
ROV - Thrusters	Blue Robotics T100 with integrated ESC	$864.00	$864.00	6 thrusters at $144 each
Control Box	Terminal strips, bus bars, wiring, Arduino, PS/2 Controllers, Paint, etc.	$250.00	$250.00	
Misc	Miscellaneous extra supplies/padding	$250.00	$250.00	
	Total ROV Projected Expenses	$3,059.00	$2,894.00	
	Expected Funds/Income for ROV build		$1,600.00	*Portion of team income available for ROV*
	Expected shortfall in funding		$1,294.00	*We must raise this much money*

Project Cost Accounting

PROJECT COST - SEAL Robotics ROV Build 2018			
Category	**Item**	**Expense**	**Notes**
ROV Project Expenditures			
Competition Display/Report	Display board supplies, technical report, pictures, etc.	70.00	
Registrations	Competition Registrations	400.00	$200 for Regional $200 for International
ROV - Cameras and Video	Camera cables, cameras, video connectors, hdmi adapter, other video adapters	468.00	
ROV - Lift Bags and OBS	Lift bag supplies including buckets, fasteners, quick release shackles, carabiners, zip ties, paint, OBS Supplies	98.00	
ROV - Frame	Aluminum stock and fasteners	100.00	
ROV - Grippers / robotic arms	Grippers, motors, servos, motor controllers, waterproofing, fasteners	238.00	
ROV Sensors / Electronics	Reed switches, OBS PCB boards and electronic components (diodes, transistors, LEDs, buttons)	125.00	
Misc Electrical	Waterproofing supplies		
ROV - Tether	Tether wire, waterproofing suppies, air hose, etc.	256.00	
ROV - Thrusters	Blue Robotics T100 with integrated ESC	907.20	Bought a spare thruster, but got 10% discount
Control BOH	Terminal strips, bus bars, wiring, Arduino, PS/2 Controllers, transformers, paint, zip ties and wire management	189.00	
ROV - Tether	Velcro, additional waterproofing materials, additional wire, fuse holders and fuses, ballast supplies, epoxy	94.00	
ROV - Cameras and Video	Two 32-inch monitors	297.00	
Control Box	Sliders for control, DC transformers, hookup wire, GFCI, plywood, plexiglass	208.00	
ROV - Grippers / robotic arms	Servo testers, transformers, standoffs, m3 and other fasteners	62.00	
Control Box	Arduino shield, hookup wires		
ROV - Cameras and Video	Analog AV switch box, more adapters	42.00	
	Total Actual ROV Expenses	3,554.20	
Incoming Funds and Donations for the ROV Project			
Donation - Funds	Brown Investment Properties	(100.00)	
Donation - Product Used	Depth Sensor Donated - Keller America	(250.00)	
Donation - Funds	Chester Brown III	(100.00)	
Donation - Funds	Ed Cissel	(100.00)	
Donation - Funds	Zibster	(200.00)	
Donation - Funds	Beta Fueling Systems	(500.00)	
Donation - Funds	Greensboro Radiology	(750.00)	
Donation - Product Used	Heat Shrink Donated - Ancor Marine	(50.00)	
Membership Dues	SEAL Robotics Funds from our dues	(1,600.00)	
	Total Incoming Funds	(3,650.00)	
	Expected Shortfall in Funding	(95.80)	Slight surplus in funds as of late April 2018

References and Acknowledgements

MATE and our Corporate Sponsors

We appreciate the people of the MATE organization for all of the help and resources they provided this year. Similarly, the following companies helped us by donating materials or money or advice to help us build our ROY:

https://www.marinetech.org	www.greensbororadiology.com
https://www.forgegreensboro.org	ttps://www.integraenclosures.com
https://www.macartney.com	http://powermaxconverters.com
http://www.ese-co.com/	http://www.bipinc.com
https://zibster.com/	http://www.betafueling.com/
https://www.kelleramerica.com/	http://www.ancorproducts.com/en

Other People Who Helped Us

We also want to thank the following people who helped our team this year.

Person	Thanks for...
Ed Cissel	Helping and supporting our team members and making a personal donation to the team.
Chester Brown	Making a personal donation to support our team.
Our Parents	Thanks for bringing us to all of our meetings and practices at the pool. Thanks for paying the expenses for us to be able to do this.
Our Team Mentors	Thanks for encouraging us, guiding us, and helping us when we got stuck.

References

We used countless internet websites and YouTube videos to leam about ROVs and to research and design Mako. Those references also include numerous MATE resources from their website (www.marinctech.omj and technical reports from previous years. We also did a lot of research on the MATE Center Curriculum (https://www.marinctcch.org/rov-curriculum-resources/).

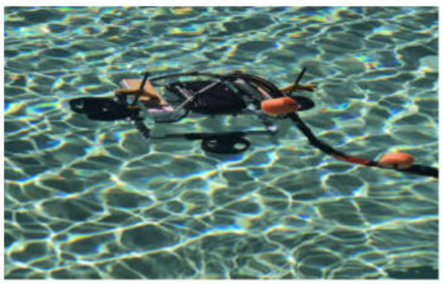
SEAL Robotics thanks everyone who supported us this year!

Additional Team Photos

Some of our members working on Mako. 	 Ben and Oliver cutting aluminum for ROV chassis.

Team members building Ranger props using Matt's instructions (laid out on the table).

One of our team outreaches presenting to a middle school about the ROV and MATE.



Our first buoyancy test run.

Nathan, Jonathan, and Owen putting together the chassis.

Marissa and Harrison building our hub.

Team measuring the tether and adding floatation.

Team members and coach went to give a presentation to solicit sponsorship and funding.

CEO Austin and a team mentor in a design session.