Hydro-Kinetics

Homeschooling

Plantation, FL, USA

Company Members

- Maia Munera (8th grade) – CEO, Government and Regulatory Affairs, documentation
- Zor Waters (9th grade) – CFO, Design Integration Lead, R&D
- Caleb Godbey (10th grade) – Systems, Engineering, Operations
- Ian Michko (10th grade) – Systems, Engineering, Electronics
- Emma Fravel (9th grade) – Engineering
- Franco Calmet (8th grade) - Buoyancy, CAD
- Joshua Godbey (8th grade) – Safety Officer

Mentors

- Mark Waters- Mentor
- Hunter Michko- Mentor

20 MATE ROV World Championship

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Abstract

Hydro-Kinetics was established in 2021, and there are seven members ranging from 8th-10th grade. The goal of the company is to learn about robotics and inspire the younger generation to take up this hobby, as technology is a very large and important part of society nowadays, and our motto is “The best way to Learn is to Teach”.

The team was not only created for this purpose, but also because the members were informed of a request for proposal from the MATE foundation. The company was inspired to create a remotely operated vehicle (ROV) that would complete this mission while being both reliable and accessible, so the members came up with a design that would be easy to understand and maneuver. The ROV is equipped with two manipulators, a 3d printed probe, a simple but reliable measuring system, and a straight-forward photo-stitching process. Our two objectives–reliability and accessibility–are met with this ROV and that is why it is the best option for the MATE request.

Fig. 1. Company members *(photo by Lonnie Fravel)*

Design Rationale

Hydro-kinetics was founded this year in order to learn about and practice robotics. Our design process is still being developed, but it is based on brainstorming and experimentation.

The members begin by informing themselves about underwater robotics and assigning roles until the Manual is published. The company members then read through it and start brainstorming and discussing the design. Instead of starting with the ROV assembly, the team builds props so that the members can get an estimate of how big the ROV has to be and what it has to be capable of. Around this time, the fly-through video from MATE is released. This gives us enough information to start our design and build process. Hydro-kinetics then has a meeting discussing the requirements of the ROV and other key factors such as size, weight, budget, and time. Once the team has been sufficiently informed and prepared, the members divide the work amongst the company, with different tasks each being performed by groups of 2-3 people for optimal safety, efficiency, and communication. Once the groups are selected the members create two or more ideas to test, and when the tests are complete the options are compared based on performance, safety, and replicability. If only one option passes it is reviewed by the group as a whole, and if it fails, it is sent back to be reevaluated. If both pass then both will be viewed as viable options, and the decision that is made will be based on cost, time, and practicality. Once a decision has been finalized the part is added to the ROV and the design team begins the next item. This process allows the team to come to conclusions and finalize decisions efficiently.

In this mission, the team realized that the most efficient way of creating the ROV from scratch would be to use tried and true methods and kits such as the Triggerfish Kit, as it would help us save time and create more specialized tools for other tasks.

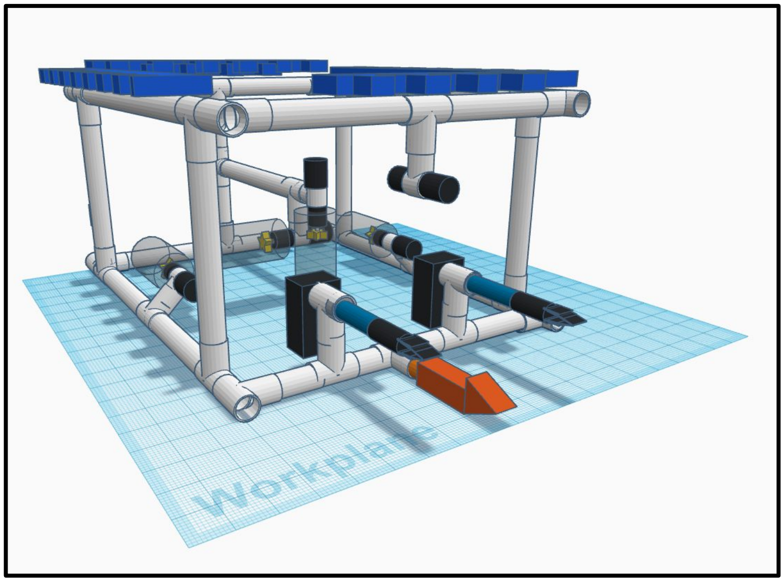


Fig. 2. ROV CAD Design *(photo by Franco Calmet)*

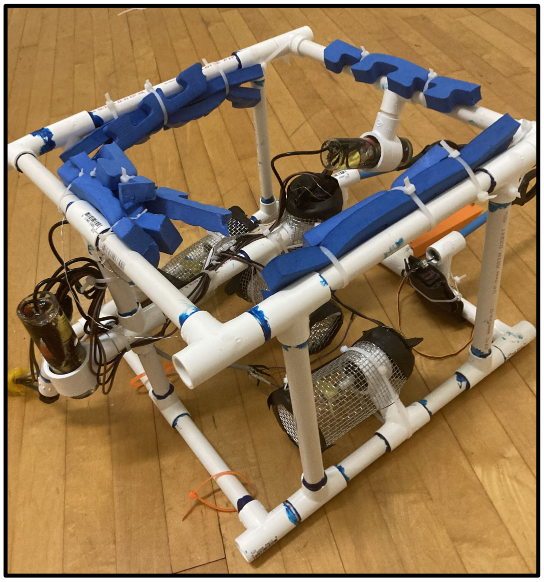


Fig. 3. ROV *(photo by Zor Waters)*

Mechanical Components

Frame

When designing the frame for the ROV, the company considered various options, and settled for two prototypes because they had been previously tested by other companies and were cost-effective. These prototypes were made entirely out of 1/2-inch PVC, which is widely available in any hardware store. One of them was a square prism shape, and the other was a trapezoidal prism. The group assembled both prototypes but settled on the simpler square prism because it is easier to control in the water, provided more space, and it was easier to place all the different mechanical components. The base of the frame is made of four pieces of PVC that have equal lengths of 40 cm, and the frame has a height of 25 cm. this frame is very effective because it is lightweight, compact, versatile, and easily adjustable because PVC is a very forgiving material to work with.

Fig. 4. Frame *(photo by Maia Munera)*

Fig. 5. Control System *(photo from SEAMate website)*

Control System

The control system came with the Triggerfish Kit and is housed inside a compact protective equipment case. The ROV uses 2 dual axis analog joysticks, for inputs. The inputs from the joysticks go to the two saber tooth modules that came with the Triggerfish Kit, to translate them into commands for the motors. Each joystick controls two motors. One joystick controls forward/reverse movements and turning, while the other joystick controls up, down, and sideways movements. Not only do the saber tooth modules tell the motors what to do but they also protect the system from trying to move a motor both directions simultaneously, which would break them.

Mechanical Components

Propulsion

The ROV moves around with four thrusters, and these came with the MATE ROV Triggerfish set. The motors connected to the propellers are designed off of bilge pumps, and the bilge pumps are useful for a few reasons. The first is that they are relatively sturdy and are waterproof, making them the perfect fit for ROVs.

Four thrusters allow the ROV to efficiently complete tasks that would not be possible with less, while not overcrowding and weighing down the ROV as with more. The first two thrusters allow the ROV to turn and move forwards and backwards, while the third lets the ROV descend and ascend at will. The fourth propeller is used for lateral movements. This system allows the ROV to make precise movements.

The thrusters are controlled with analog joysticks on the triggerfish control system box, and depending on how far the pilot pushes the joysticks in a certain direction, the speed of the movements can be modified.

All thrusters are covered with a wire mesh guard to remove the risk of getting hurt by the spinning propellers. The guard is fastened to the underneath of the thrusters using zip ties, and it is also secured with multiple layers of electrical tape on the edges to prevent punctures and accidents. (see fig. 6)

Fig. 6. Propulsion *(photo by Zor Waters)*

Buoyancy

In order to maneuver the ROV through the MATE ROV mission, the company needed to find a way to create neutral buoyancy in the ROV. After brainstorming different materials and ways to achieve this, the company decided to start with pool flotation foam. After a test in the water, the team members realized that at certain depths, the foam would become waterlogged, and this would cause the ROV to sink. Another option was to use gym mat edging, which is a closed-cell foam material, and when tested, this proved to be the most efficient way to create buoyancy. As an added benefit, this material is affordable, easy to replace, and simple to shape and cut, so if needed, troubleshooting is easy.

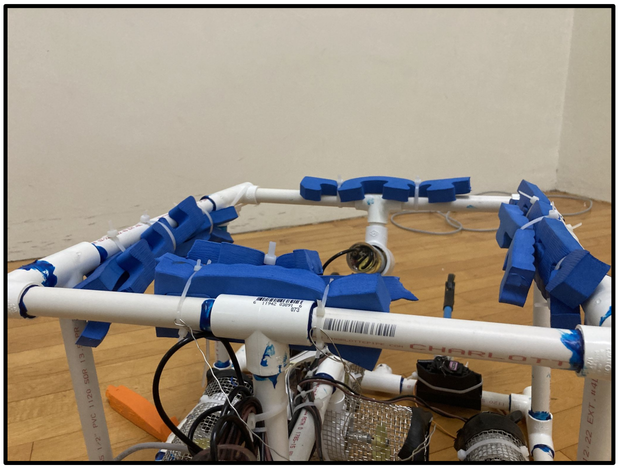


Fig. 7. Buoyancy *(photo by Zor Waters)*

Fig. 8. *(photo by Zor Waters)*

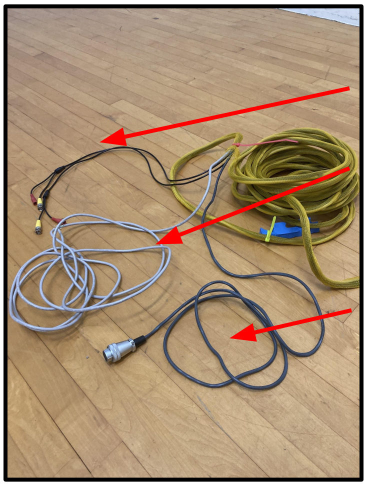


Fig. 9. *(photo by Zor Waters)*

Tether

Since there must be a way for all the electronics in the ROV to be connected to the control box, a tether is used, and the tether is composed of all the wires running from the ROV to the control box encased in a woven plastic sheath. Inside the sheath, there are three wires. One wire is the tether wire which is used for propulsion, and it is a 24 AWG (CAT5 8-wire). The second wire is a 22 AWG video cable and connects to the camera. The third wire is also a 24 AWG (CAT5 8-wire), and it is used to power the servos for the manipulator. The tether casing and wire comes with the SeaMATE triggerfish kit. The tether weighs 2.6 kg, and is 15 meters in length, which provides enough length for the ROV to complete the MATE mission without difficulty. In order to prevent the tether from dragging along the floor, closed-cell foam gym mat edging pieces were spaced out properly and added as flotation, creating neutral buoyancy. During the run-through, a team member is on the side of the pool to properly adjust the amount of tether. There is adequate strain relief where the tether is connected to the ROV, and the tether is properly restrained and secured at the control box and ROV.

Systems decisions

Build vs Buy, New vs Reused

Due to this group being assembled this year, there was no previous ROV to adjust for the purposes of this mission. Because of this, Hydro-Kinetics decided to purchase the Triggerfish Kit from the SeaMATE website, as the kit came with thrusters, a control box, a monitor, two cameras, and it provided a great starting point to expand on. This helped the team save time and create momentum. The group strives for cost-effectiveness, so the members decided to use accessible and affordable materials for the rest of the ROV components as well. For example, PVC was used as the building material for the frame, and exercise mat edging (a closed cell foam material) was used as buoyancy (for both the ROV and the tether). It was a better solution than using standard pool floatation material because when put at a certain depth, water would get in and compromise the buoyancy. The systems made specifically for this mission are also affordable, such as the manipulator which was made with a very affordable grabber claw (around $5.00).

Mission Specific Tools

Manipulator

When looking through the specifications for this mission, the company concluded that there was a need for a manipulator, as many of the tasks—e.g., replacing a damaged section of an inter-array cable, removing a ghost net caught on the wind turbine's structure, and removing marine growth from an offshore aquaculture fish pen—required being able to grab onto things.

When designing the manipulator, it started as an overly complex, custom designed and 3d printed prototype, but it was too time consuming and would be quite expensive. After a bit of brainstorming, the idea was switched to something much simpler, using a grabber device from the Dollar Store. After some experimenting, the team decided on a design that was fully operational and inexpensive to make.

The manipulator is divided into three separate parts. The first is the claw and arm, the second is the PVC connectors, and the third is the servo and its housing. The claw and arm are held together by a looped ring and pin, and the claw is able to rotate but only manually. The part is connected to the PVC with hot glue to secure it and cover any sharp edges, and the arm is sprayed with anti-rust, and the PVC connectors are attached to the frame with the lower section being what holds it in place. The third part is the servo and its kydex housing. The housing is a thermoplastic that is shaped to securely hold the servo while not interfering with rotation. A loop was included in the bottom so to not pinch wires, and the housing is secured to the PVC with zip ties and bolt nuts. The manipulator works with a wire from the claw run through a slot in the servo horn. When the servo rotates, it moves the wire causing the claw to open (push) or close (pull).

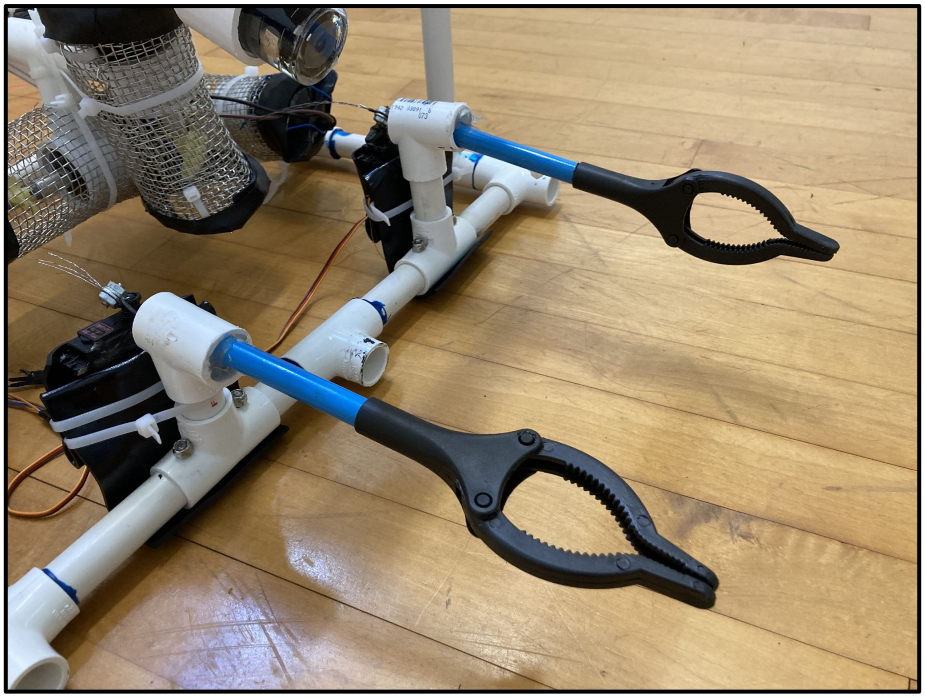


Fig. 10. Manipulators *(Photo by Zor Waters)*

Measuring System

In the MATE ROV mission, two of the tasks require being able to measure objects underwater. Hydro-Kinetics fist devised a very complex measuring system using lasers mounted on step motors and trigonometry, but after testing, the measurements were not accurate as it was very difficult to align the lasers perfectly and control the angles with sufficient accuracy. Learning from this, the team decided to simplify the measuring system and use what was already on the ROV — the PVC pipe that was in the view of the camera that was facing downwards. One of the team members marked the pvc every centimeter, so when the ROV flies over the object, it is quite simple to measure it.

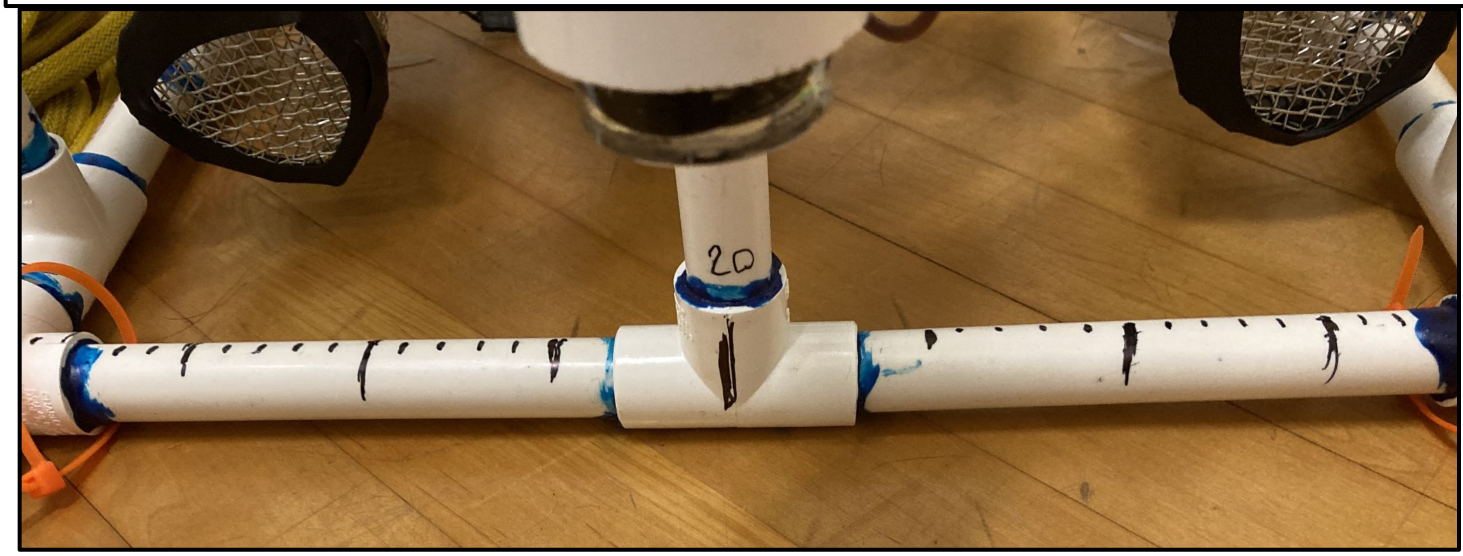


Fig. 11. Measuring System *(photo by Zor Waters)*

Photomosaic Stitching Process

For the MATE ROV mission, one of the tasks is to create a photomosaic of the wreck. The team decided to use OBS Studio to take the photos (on the second monitor), which is a broadcasting studio platform. The team downloaded an on-demand screen capture filter that would allow the photos to be taken with the click of a button on the keyboard, while the video was being captured, and this made it easy because the images would be saved directly to a file of choice. However, the cameras included in the SEAMate Triggerfish Kit came with backup lines, and when the member in charge tried to stitch the images, it came out warped because the software was trying to stitch the lines together. The solution that the team came up with was to crop the images once they were taken, and then upload those images to the actual software that would stitch the images together, which is called Kolor Autopano Giga 4.4. Once the images are uploaded, the only thing left to do is to click a button on the screen, and then the images stitch together automatically.

Cameras

Many of the tasks in this mission such as flying over the transect line, creating a photomosaic of a wreck, and inspecting an offshore aquaculture pen require the ROV to be able to capture live footage. The company decided to use two color cameras for two different views of the ROV's surroundings. These cameras are included in the Triggerfish/Barracuda Video System Kit. They are waterproofed using the acrylic tubes that came with that kit, epoxy, and JB-Weld. These cameras are automotive backup cameras, which are widely available. The video cable that connects to the main control system is 15.2 meters long.

One of the cameras is mounted on the front of the ROV (where the probe and manipulators are attached) and is facing forwards but angled downwards a bit so that the probe and manipulators are visible. This camera, however, still has a view in front of it and is used for flying over the transect line. The other camera is on the opposite side of the ROV and is facing downwards so that the member in charge of the photomosaic can take pictures of the pool bottom that will then be stitched together. The rear camera is also used for measurement.

These cameras are directly connected to the 17 cm triggerfish video system kit monitor. The camera facing downwards is also connected to a desktop computer, which is used as our second monitor. This allows us to use the triggerfish monitor to see in front as the ROV navigates over the wreck site while the desktop monitor has a bird's eye view of site and allows us to take pictures directly from the computer to be stitched together.

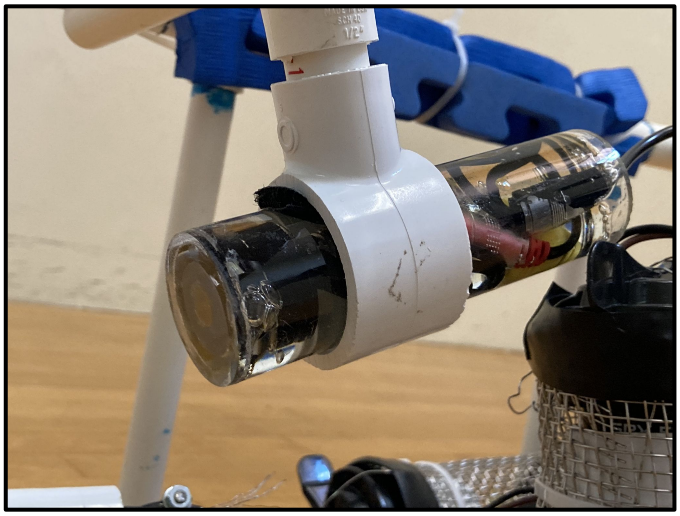


Fig. 12. Front Camera *(Photo by Zor Waters)*

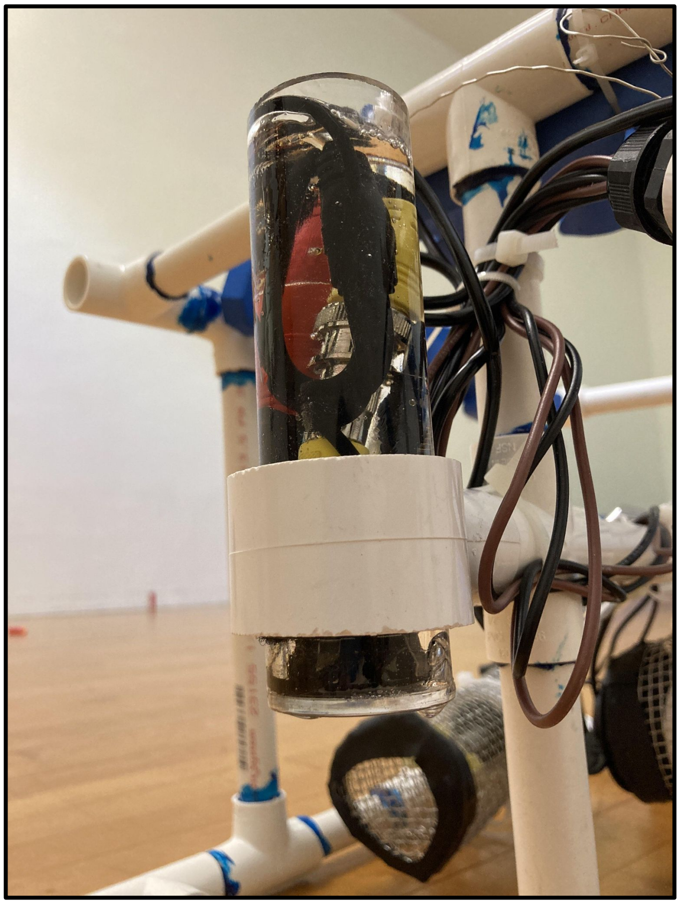


Fig. 13. Back Camera *(Photo by Zor Waters)*

GO-BGC Float

The Go-BGC float is made with 2" PVC that is 35cm long. The float is separated into two separate sections, the top and bottom. The top section is dry and houses the electronics such as the Arduino nano, 9V battery, 5A fuse, and pressure release plug. The bottom half is waterlogged and has the bilge pump motor which allows the float to move up and down. The two sections are separated by an acrylic disc sealed with holes drilled for wires, and is waterproofed with epoxy. To control ascent and descent the float controlled by an arduino, will be on run on a timer to control the motor.

Fig. 14. GO-BGC Float *(Photo by Zor Waters)*

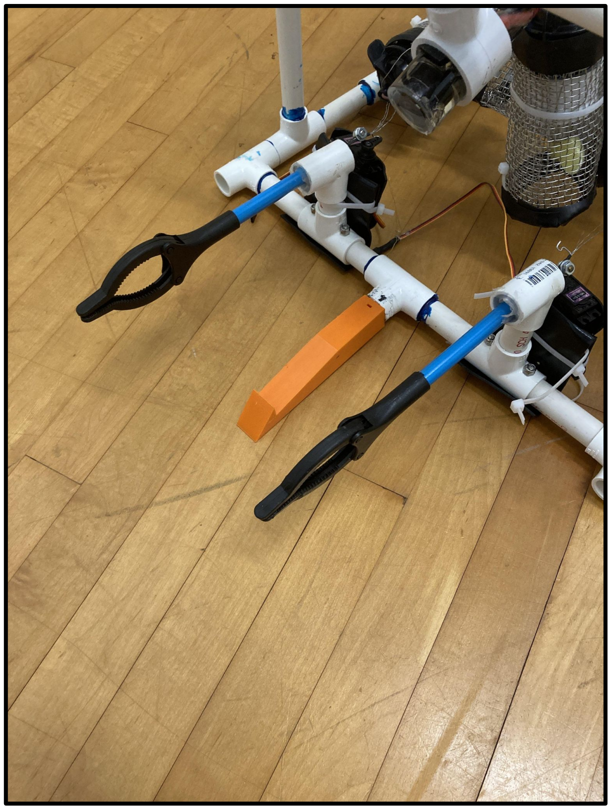


Fig. 15. Probe Mounted on ROV *(Photo by Zor Waters)*

Probe

The probe was based off an idea from the tips and tricks section from the MATE ROV website. However, it was adapted for the purposes of the company. The probe was designed with a slope in the front to help hook under objects and keep them from rolling off. It was also meant to have a "finger" to remove things from its grasp but the company lacked the time to properly test it. The back of the probe is 17cm long, 3cm wide and designed to fit into the 1\2" PVC and is held there with a zip tie for easy attachment and removal.

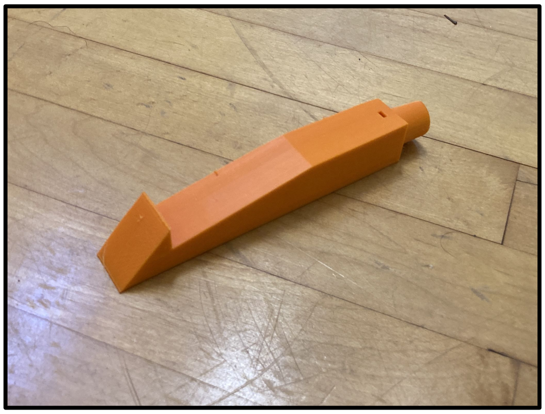


Fig. 16. Probe *(Photo by Zor Waters)*

Safety Rationale

Safety really comes down to communication and teamwork. The steps taken to ensure safety protocols are to protect not only yourself but your entire team and those around you. When dealing with electronics and tools it is important to understand and look at it as "If anything can go wrong, it will." When you expect the both the expected and the unexpected you can prepare for anything. If you do not take everything into account, you put yourself and those around you at risk. This is why safety is of utmost importance to Hydro-Kinetics.

Equipment is always checked and rechecked especially as it pertains to material stress, electricity, connections points, rotating parts, and other moving parts that create pinch points. Every risk is assessed as it relates the equipment.

Practice of operational protocols reduces the risk of injury substantially.

Safety Features and Precautions

Safety Features:

- GFCI Outlet Connectors
- Three Safety Fuses
- Safety Guards for Propellers
- Warning Sign on ROV

Safety Precautions:

- Anderson Powerpole connector within 30 cm of fuse
- Strain relief where the tether connects to the control system
- Strain relief where the tether connects to ROV
- Approach equipment and ensure that all power sources are disconnected.
- Proposed work site areas are clear of all debris and proper safety guards are in place.
- Equipment is checked and verified to be disconnected from all power sources before putting in place.
- Equipment functions are verified and equipment is checked for proper operation and possible damage during transportation.
- All fasteners are checked for proper connections.
- All functions again are tested for proper operation.
- All people are clear of any moving parts or equipment.
- All team members are wearing proper attire (Closed-toed shoes, safety glasses, baggy shirts and/or pants are secured properly, jewelry is removed, long hair is tied back)

Safety Checklist

PRE-POWER CHECKS

- ❑ All members are aware of their roles
- ❑ Check that all team members are wearing proper attire (Closed-toed shoes, safety glasses, baggy shirts and/or pants are secured properly, jewelry is removed, long hair is tied back)
- ❑ Team members are made aware of device being placed in operational location.
- ❑ Operational area is clear of tripping hazards and obstructions
- ❑ Proper safety guards are in place and secured.
- ❑ Equipment is checked and verified to be disconnected from all power sources and ROV is turned off before safety checks.
- ❑ All fasteners are checked for proper connections.
- ❑ All ROV parts are secured in place
- ❑ Check if all equipment is free of sharp edges
- ❑ Call out “Safe”

PRE-WATER CHECKS

- ❑ Connect tether and power cables to control box
- ❑ Turn on ROV
- ❑ Call out “Power ON”
- ❑ Connect camera to second monitor
- ❑ Check all functions (manipulator, camera)

IN-WATER CHECKS

- ❑ Test thrusters

POST MISSION CHECKS

- ❑ ROV successfully returned to surface
- ❑ Turn off power
- ❑ Call “Power off”
- ❑ Remove ROV from pool
- ❑ Clear obstructions and put all equipment back in cart

Project Management

Hydro-Kinetics structures its collaboration and project management processes through the following roles: CEO, CFO, Government and Regulatory Affairs, Design and Integration, R&D, Systems, Engineering, and Operations. These roles were assigned based on skill set and past experience from each member.

Task management was done through Discord and documentation through Google Apps. most of the iterative processes followed an agile approach without formal sprints.

Project Management *(photo by Sandra Giraldo)*

Accounting

Budget

In order to create the budget, the team had a meeting to review the mission requirements and decide what an appropriate amount of money to spend was with room for error, as changes in design were inevitable. Once this meeting was completed, the team came up with a vehicle development budget of $3,500.00.

Once we were informed that we would indeed be competing, we created a travel budget of $10,000.00.

The vehicle deployment costs totaled at $2,758.82, and the travel costs totaled at $9,875.41. The budget and costing sheets are shown below.

The startup investment of the company members was $500 per person, as it was based off of the budget the company had created. Since there are seven company members, it totaled $3,500.

Category	Description/ Examples	Cost
Hardware	Prop Materials	$61.23
	Prop Materials	$29.00
	PVC	$57.00
	PVC & Spray Paint	$27.00
	Prop Materials	$67.32
	Prop Materials	$65.12
Electronics	Triggerfish Set	$850.00
	Power Connectors	$18.17
	Triggerfish Video System	$180.00
	Power Supply	$200.00
	Hydraulics Kit	$15.00
	Triggerfish Thrusters and Tether	$725.00
	Fuses Kit	

	Arduino Kit	$33.99
	Servos (360 Degree)	$34.99
	Servos	$70.00
	Lasers	$29.00
	Ethernet Cable	$22.00
	Potentiometers	$15.00
Tools	Soldering Tools	$12.83
	Crimper and Power Connector Board	$38.77
	Crimper and Soldering Board	$32.82
	Wire Cutters	$6.97
	Epoxy	$14.99
	JB Weld	$5.13
Other	Underwater Robotics Book	$120.00
	Super Glue	$5.90
	Metal Sheet	$7.48
	Copper Wire, Crimp Terminals, Cords	$89.25
	Graber Devices	$5.35
	O-Rings	$15.00
	Silicone	$16.00
	100′ Tubing	$12.00
	Petg Filament	$23.00

	Fish prop	$20.00
Competition	Regional Entry Fee	$200.00
Final Vehicle Deployment Costs:		$3,139.31

Acknowledgements

Hydro-Kinetics would like to give a big thanks to everyone who supported our company:

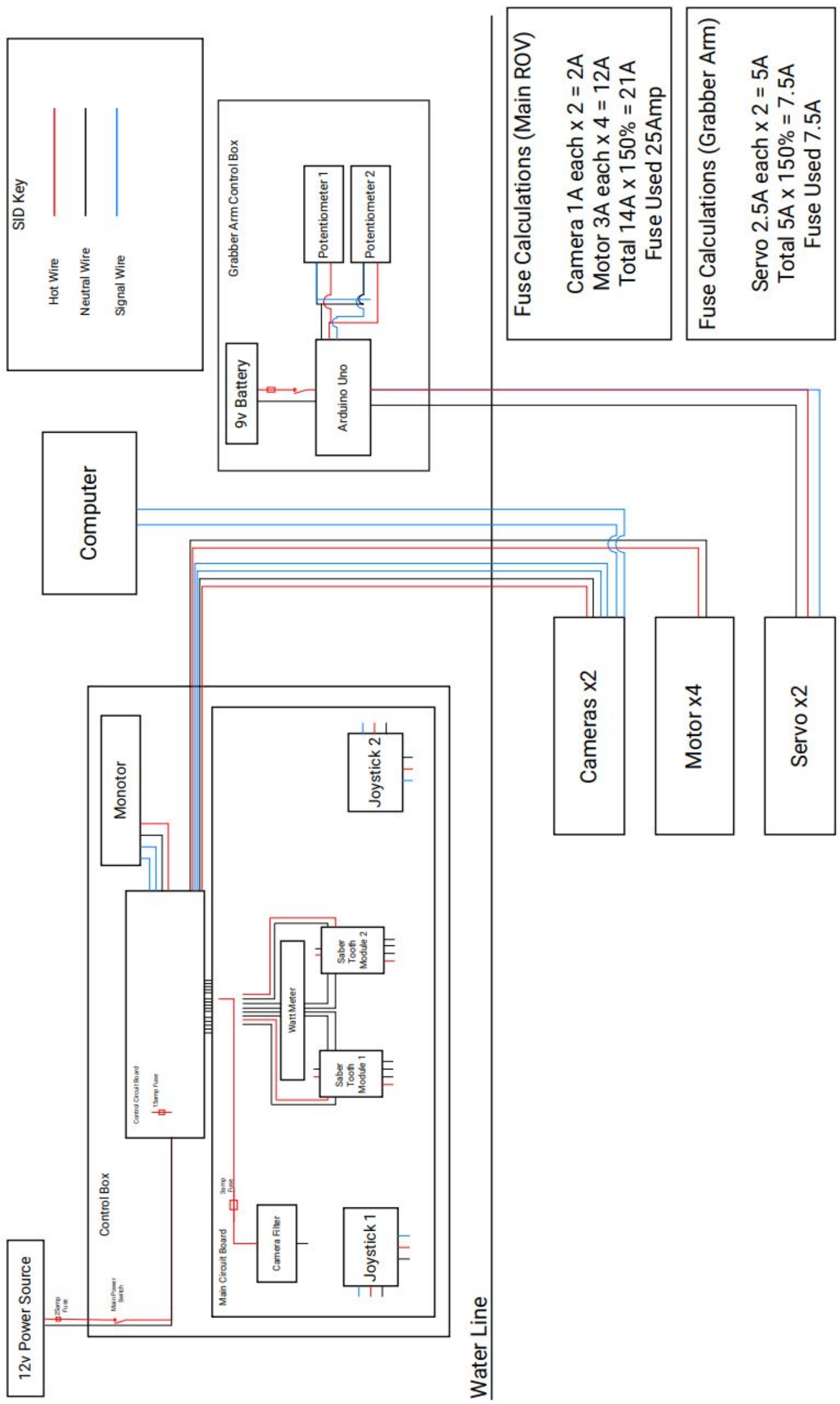
- Mark Waters
- Hunter Michko
- Sandra E Giraldo
- Lonnie Fravel
- Candy Calmet
- Jaime F Munera
- Tracey Michko
- Bethany Godbey
- Morgan Knapp

References

- Underwater Robotics Science, Design & Fabrication Revised Edition
- MATE ROV Flythrough
- Ranger Manual
- Adafruit Learning System
- MATE Educate (materovcompetition.org)

20 MATE ROV
World Championship

SID



SID Key
Hot Wire
Neutral Wire
Signal Wire
Grabber Arm Control Box
Potentiometer 1
Potentiometer 2
9v Battery
Arduino Uno
Computer
Fuse Calculations (Main ROV)
Camera 1A each x 2 = 2A
Motor 3A each x 4 = 12A
Total 14A x 1 150% = 21A
Fuse Used 25Amp
Fuse Calculations (Grabber Arm)
Servo 2.5A each x 2 = 5A
Total 5A x 150% = 7.5A
Fuse Used 7.5A
Cameras x2
Motor x4
Servo x2
Monotor
Control Box
Control Circuit Board
Main Circuit Board
Joystick 1
Joystick 2
Saber Tooth Module 1
Saber Tooth Module 2
Watt Meter
Camera Filter
12v Power Source
Water Line

SID Non-ROV Device

Fuse Calculations (Float)
Motor 3A each x 1 = 3A
Total 3A x 150% = 4.5A
Fuse used 5A