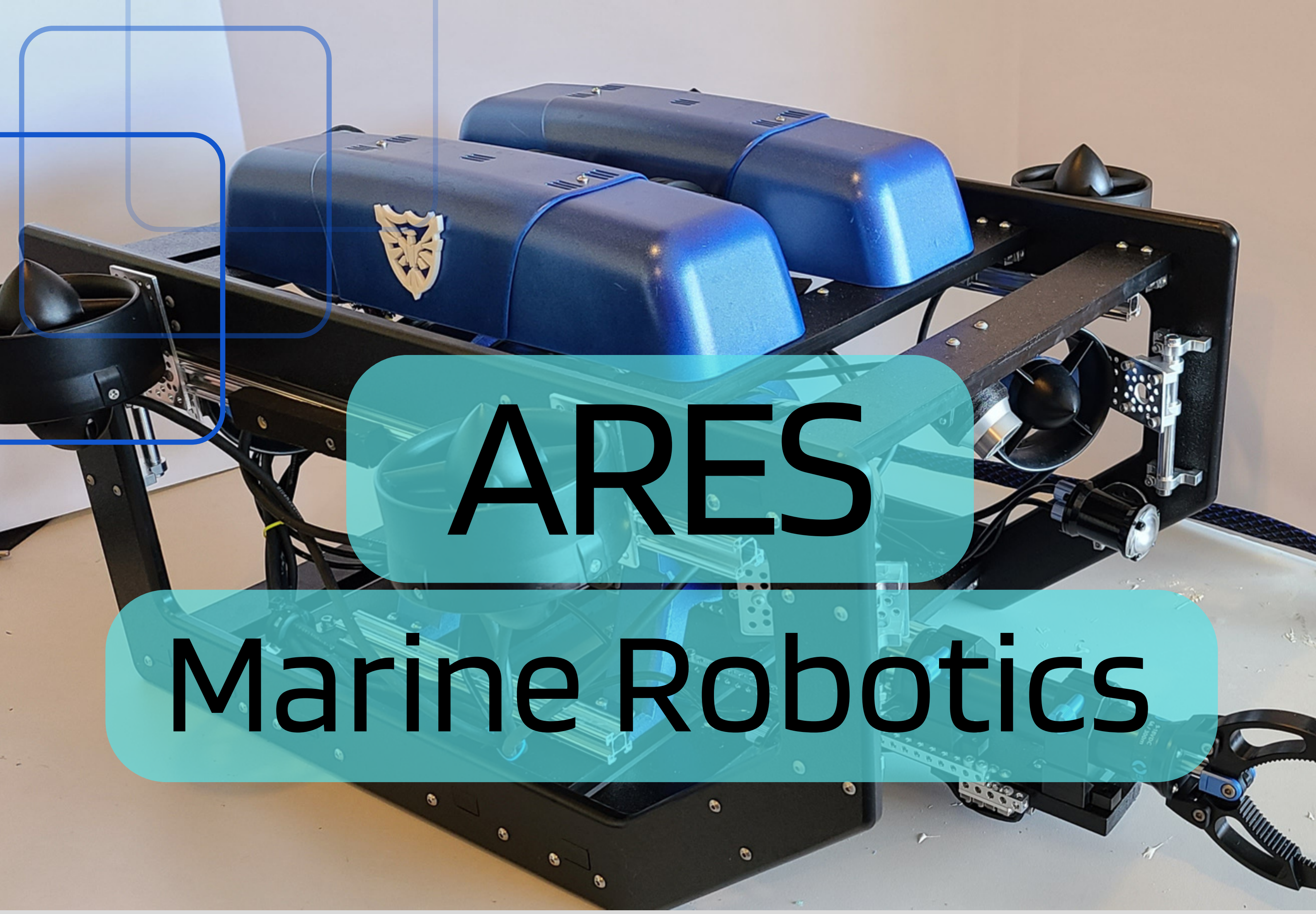

ARES Marine Robotics

Sydney West: CEO & Systems Integration Engineer
Emmett VanMason: Chief Mechanical Engineer & 3D Printing Specialist
Navaj Nune: VP of Software Engineering & Chief Technology Officer
Mason Rose: Pilot & Chief Safety Officer
Cadence Picker: Chief Project Manager

Chris West: Mentor and Coach

2022 - 2023 MATE ROV Competition

ARES Marine Robotics
Hanford High, Richland High, Homelink, DELTA High Schools
West Richland, Washington, USA

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Abstract

ARES Marine Robotics is a company of five high school students based in Richland, WA. ARES is devoted to solving prominent marine issues, raising awareness about aquatic environments, and developing a capable machine able to protect and maintain these environments.

ARES has created an ROV (Remotely Operated Vehicle) that can be used to help preserve earth's waterways. 'WhiteWater' is equipped with a complex control system composed of eight powerful thrusters and a set of Arduino Mega micro controllers. Combined with its rotatable gripper, the machine is capable of almost any underwater task. WhiteWater is able to help maintain aquatic energy sources, assist in the preservation of coral reefs, and support native fish populations. WhiteWater's three strategically positioned high definition cameras provide a wide perspective of the surroundings, and the depth perception needed to accurately manipulate objects and perform the MATE demonstration tasks. ARES has designed and printed numerous custom, high quality components in order to enhance the capabilities of WhiteWater. Mission specific claw attachments have been manufactured in order to expand on its uses, and make ARES more efficient in competing the MATE missions. Custom fabricated and printed 3D parts are also used frequently on WhiteWater for a variety of applications such as mounts and safety features.

These features that WhiteWater possesses prepare us not only for the MATE competition, but also for real world scenarios. We can utilize the skills learned in the MATE ROV competition in the real world to protect the environment and nature. Anything done in the pool by WhiteWater can be replicated in nature to protect the environment. Tasks previously done by divers are made much easier by a capable machine. For example, Whitewater can measure and help create a 3D model of coral, identify reef species and apply treatments to coral, without damaging the environment. ARES Marine Robotics strives to design a successful machine for competition whilst impacting the world by spreading awareness and helping to preserve earth's oceans.

Company Overview

ARES Company Spec Sheet

Company/Club Name: ARES ROV
Home State: Washington
Distance To Competition: 1,073 miles to Longmont, Colorado

This is our third year competing in MATE ROV competitions and our second year competing in Ranger class. We competed in and won the Navigator class at the Lincoln City MATE Competition in 2021 and placed second in the Ranger class at the Lincoln City MATE Competition in 2022.

Figure 1: Members of ARES Marine Robotics Company/ Team.

Sydney West (Second to Right**):** 10th Grade at Hanford High School
Role: CEO and Lead Systems Integration Engineer
Qualifications: Third year of competing at the MATE ROV competition, participated in multiple robotic teams in FLL for four years, has worked on and made various robots since third grade, CPR Certified.
Future Goals: I plan and strive to become a Marine Biologist with the inclusion of ROVs by enrolling in the University of Hawai'i for college education. I'm greatly interested in the ocean and the use of technology to understand and protect it.

Emmett Van Mason (Far Left): 10th Grade at Richland High School
Role: Chief Fabrication Engineer and VP of Systems Engineering
Qualifications: Third year competing in the Mate ROV competition, participates in the FTC High School Robotics.
Future Goals: I would like to become a mechanical engineer building and designing environment protective robots. I enjoy working with my hands and solving complex problems.

Cadence Picker (Far Right**):** 9th Grade at Three Rivers Homelink
Role: Project/Task manager
Qualifications: Third year competing in the Mate ROV competition, worked with EV3 robots, Micro Bit Bots, and was on a FLL team for one year.
Future Goals: I'm unsure what I want to be in the future; however, I would like to do more research on becoming an author, counselor, radiologist, or detective. Whatever job I go into, I want to use all my skills to their fullest. I also want to enroll in the University of Washington for college. I love drawing, writing, and learning about space exploration and strive to expand my knowledge in these areas.

Navaj Nune (Second to Left): 10th Grade at Hanford High School
Role: Lead Programmer and VP of Software Engineering
Qualifications: Third year competing in MATE ROV competition, competed in FTC High School robotics competition, Competed in FLL in middle school for three years, coached a junior FLL team, and robotics certifications through VEX for software and mechanical engineering.
Future Goals: I want to pursue my dreams of becoming a Surgeon by attending Medical School. I am also passionate about business and would like to establish my own hospital in the future. Robotics and technology has a major role in the advances within the medical industry today. I want to utilize my knowledge in robotics to further my ventures as a Medical Professional. My dream is to enroll into Brown University BS MD Program. I also enjoy programming, robotics, science, math, and communications.

Mason Rose (Center**):** 10th Grade at Delta High School
Role: Chief Pilot and VP of Fabrication Engineering
ations: Third year competing in the MATE ROV competition, three years competing in the FLL competition during elementary/middle school, and two years of participating in Camp Invention.
Future Goals: I want to reach my goals of either becoming an electrical engineer or an architect. I am also very passionate about robotics, science, and graphic design.

Grade Range: 9th-10th grade

ARES Company Evaluation

How would you describe your company's overall success?

- Our company's overall success can be described as broad and impactful; we strive to be successful in many areas within our company by involving ourselves within our community to provide an inspiring and quality experience for those of our community. One example is being involved in two iterations of the polar plunge. We created a stand that allows members of our community to experience robotics hands on by allowing them to take part in a game using our outreach

ROV—Rusty. We also searched for other opportunities, such as national night out and a handful of STEM/STEAM nights at schools, to provide a similar experience to inspire those in fields of STEM. Our company has also created a relationship with Columbia Basin Dive Rescue (CBDR) which has opened various opportunities such as being invited to the polar plunge events as well as training with CBDR. Another example is expanding our horizons by designing and constructing an AUV (autonomous underwater vehicle) which has proven to be challenging but rewarding.

What do you consider the best thing about your company and your ROV?

- The strongest point of our company is our ability to work as a team, to discuss difficult decisions, tackle complex problems to find solutions, an example is creating Cetacea—our AUV—we struggled to conceptualize a design for a watertight seal that would be structurally integral; and create expertly designed elements for our ROV all whilst enjoying each other's company. And in regards to our ROV, the greatest aspect of WhiteWater is the opportunities it has provided our company. This includes invitations to film CBDR during their training sessions to provide them footage to train new divers and opportunities to inspire younger children in fields of STEM.

What, if any, future plans do you have for enhancements or improvements?

- ARES has many future plans to prepare for the MATE ROV competition and perform real life tasks: we are updating different systems we utilize including revamping Rusty's control box, a ROV we designed for outreach events; Refining WhiteWater's buoyancy, and improving Talon, our claw attachment, by designing and manufacturing additional attachments; and integrating additional sensors for our AUV, Cetacea, for competition(s) and other potential uses. There are additional improvements we plan to make further forward which includes adding small rollers or ball bearings at the bottom of WhiteWater to minimize the damage to the bottom of the frame and design and manufacture a high quality case for Cetacea to provide easier transportation.

What was the most rewarding part of this experience?

- The most rewarding aspect of this experience is being able to have many more opportunities in the future: potentially creating an LLC to be an official company and the possibility to create a hull inspection business. We have also had excellent and eye opening experiences during our fabulous engineering journey over the years. As a company building connections with other teams is equally as rewarding as learning form and just interacting with others is unforgettable. However, the most valuable aspect is utilizing the opportunity to spend time with friends while gaining knowledge and skills in STEM.

How has preparing for this helped strengthen your company's skills and outlook?

- Preparing for the MATE ROV Competition has strengthened many of our company's members' individual skills. Many of us have learned how to utilize different CAD programs—specifically Fusion 360—to create multiple iterations using the engineering design process. This has also opened the opportunity to fabricate many 3D printed parts thanks to Emmet VanMason, a valuable member on our team. We have also learned how to solder and prepare penetrators to prepare wires. Many of us have improved our social capabilities through extensive interactions through outreach events. These experiences can add to building a strong set of skills preparing us for not only the competition but also for life beyond high school and college for a variety of job opportunities.

What would you do differently next time?

- ARES Marine robotics had a very successful year however there's always room for improvement. Next time we plan on being more efficient with our time as well as taking part in more outreach events which may include school STEM/STEAM nights at local schools, take part in locally organized public events, and starting fundraisers to support other companies to reach their goals. We also considered establishing an LLC this year and we hope to expand our business in the years to come and make a positive impact on the marine robotics community.

ROV Specs

ROV Name: Whitewater
Total Cost: $8190.74
Size and weight: Appx 70cm x 59cm x 30cm; ~16.45kg
Total Hours: 2400 Hours, spread over a period of about four years.

Safety Features:

- Tension hooks attached to both the topside control box and ROV keep the tether secure and prevent it from pulling on connections.
- Top side electronics are enclosed in a custom designed and fabricated powerbox.
- No sharp edges are exposed as they have been filed down or covered.
- Both enclosures are tightly waterproofed, with all wires entering through sealed penetrators.
- All wiring and connections are crimped or soldered and covered with heat shrink wrap for an extra layer of protection.

Special Features:

- Three optimally placed HD underwater cameras provide the best underwater view.
- Our "Talon" - 180-degree rotatable Newton Subsea Gripper (from Blue Robotics) claw when paired with many custom designed attachments specialized for different MATE demonstration tasks allow us to perform various tasks and manipulate a variety of objects effectively underwater.
- Numerous custom-designed 3D printed parts which have collectively taken around 120 hours of print time
- Custom designed frame cut from marine grade HDPE (high-density polyethylene) plastic

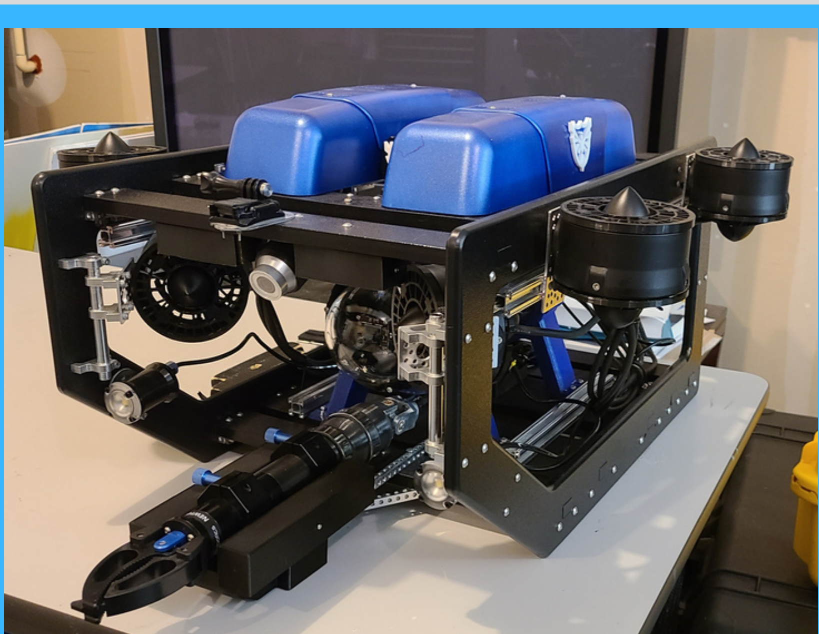


Figure 2: ARES Company Designd ROV "WhiteWater".

Teamwork - Project Management

Managing resources, procedures, and protocols effectively was critical in designing WhiteWater and Cetacea for the MATE competition and managing day-to-day operating challenges.

Funding, supplies, and equipment were all carefully allocated and utilized to keep the project on track and within budget. Communication was our most powerful team tool. We spoke with one another and with other companies to assist in the production of our custom-designed parts. ARES developed a systematic strategy for organizing all workshop materials, ensuring easy access to critical tools and supplies. We maintained our budget by thoroughly studying anything we intended to purchase and spending our money sensibly and prudently on the necessary products.

We designed and followed particular procedures, including design and testing methods, to assure compliance with the competition's requirements and reliable performance in the field. To solve any issues that surfaced throughout the project or in day-to-day operations, troubleshooting and maintenance protocols were also designed and applied. We extensively tested each of the various systems in the ROV or AUV before combining them. We established specifications for all of our designs and continued only when all of the relevant criteria were met. In the event of a problem, we determined the main cause and resolved all minor and large issues. We tested a system after it had been fully assembled in a variety of circumstances to ensure that every function performed as intended.

A Gantt chart, as can be seen in Figure 3, was used by ARES to maintain organization and productivity and to ensure that all necessary tasks were completed on time. The Gantt chart was a valuable tool for organizing all of the processes involved in designing and manufacturing our ROV, monitoring our progress, and adjusting our deadlines as needed. We were able to allocate resources efficiently, set milestones for each activity, and establish realistic deadlines by using a Gantt chart. This chart provided us with a clear picture of our progress toward our ultimate goal and assisted us in staying on track.

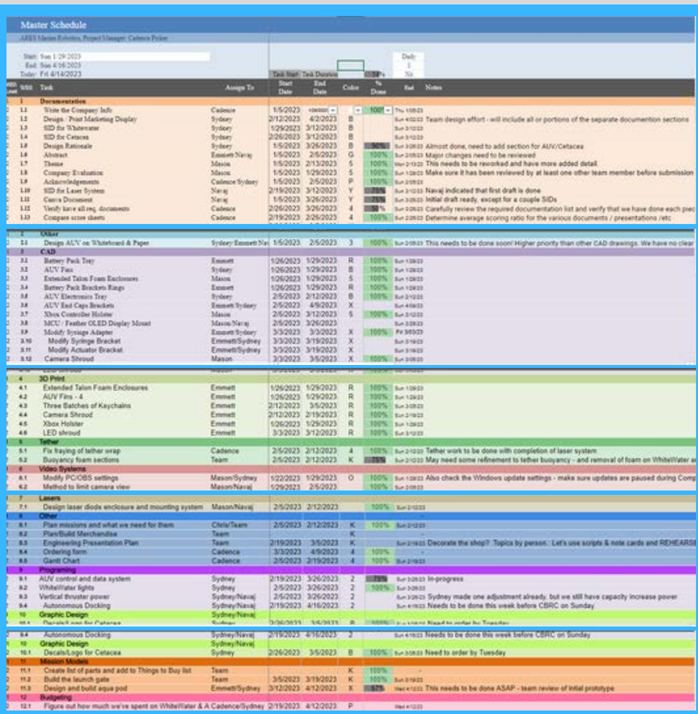


Figure 3: Example portion of the Gant chart we used.

ARES was able to successfully design and construct an ROV and AUV that fits the requirements of the MATE competition and operates successfully in operational environments by strategically managing these resources and implementing streamlined procedures and protocols.

Critical Analysis - Testing and Troubleshooting

Vehicle Testing Methodology

Testing Methodology for ROV (WhiteWater):

1. **Physical Testing:** The ROV was physically tested for its ability to withstand underwater pressure, buoyancy, and maneuver in different directions. The vehicle's mechanical components were tested to ensure they function correctly under various conditions.

2. **Communication Testing:** The ROV was tested for its ability to transmit and receive data from the surface. This includes testing the vehicle's communication systems, such as its serial and optical communication systems.
3. **Video and Imaging Testing:** The ROV's video and imaging systems were tested to ensure that they function correctly and could provide high-quality images and video footage.

Testing Methodology for AUV(Cetacea):

1. **Physical Testing:** The AUV was physically tested for its ability to withstand underwater pressure, buoyancy, and ability to perform vertical profiles.
2. **Communication Testing:** The AUV was tested for its ability to transmit data to the surface through a wireless communication system.
3. **Sensor Testing:** AUV's depth sensors were tested to ensure that they are accurate and provide reliable data. This includes testing the vehicle's pressure sensors and other environmental sensors.
4. **Battery Testing:** Since the AUV operates on batteries, it was essential to test its battery life to ensure it can complete its mission. This includes testing the vehicle's battery capacity and overall power consumption.

Troubleshooting Strategies and Techniques Used

Reviewing the System Documentation: The first step in troubleshooting our AUV, Cetacea, or our ROV, WhiteWater, is to review the system documentation, including the technical specifications, such as the software.
Conducting System Tests: Our AUVs and ROVs are equipped with a range of equipment, such as thrusters, gripers, sensors, and other systems that were tested to diagnose problems.
Inspecting the System: One of our essential tests is that inspecting the system allows the technician to identify loose or disconnected components.
Collaboration: We used collaboration to solve complex problems by bringing together diverse perspectives, expertise, and resources to generate innovative solutions that could only have been achieved by working together.
Keeping Records: Keeping records of old 3D design files, software, and other engineered components helped us to identify recurring problems and track our system's performance over time. We made constant records of every new or altered system to be used in future maintenance and repair activities.

Prototyping and Testing to Evaluate Design Options

Brainstorming: When we evaluate possible design options, we begin by listing various ideas from each other to open ourselves to a variety of different solutions before we start to narrow it down.
Illustrating Diagrams: Once we have a potential design in mind the next step is to draw it out. This can help us notice any potential issues with the design, and solve issues early in the process.
Construction of Initial Designs: Initial prototypes are typically constructed using 3D printing technology. The design will be modeled in 3D design software and printed allowing us to make these prototypes quickly and with little effort.
Testing: After the construction of our initial prototype(s), we begin testing it with the system it is designed for and determine if it is the right solution ad if we need to reevaluate the design.
Revisions: Whether we had to reevaluate the first prototypes or improve the preferred design, revisions are made based on the results of the testing to improve the functionality of the design.
Implementation of Final Design(s): After revisions and further tests have been made to the final design, it is officially implemented into the system it was designed for.

Accounting

Cost Estimate

Item	Quantity		Cost
White PVC	12	$	28.08
White PVC Tee	8	$	9.76
White PVC 45	8	$	5.82
White PVC 3 way	8	$	21.36
PVC Cutter	1	$	13.98
Lever Lock Tape	1	$	4.87
PVC Solvent	1	$	4.87
5' Blue PVC	4	$	59.96
Blue PVC 3 way	4	$	15.56
Blue Dome Cap	8	$	13.52
Blue End Cap	8	$	13.52
Blue PVC 45	8	$	19.12
Blue Tee	2	$	6.38
Blue Table Cap	2	$	5.78
SeaMate Textbook	1	$	120.00
Solder On Badge	8	$	28.00
Clamping mount for 1" PVC	4	$	27.96
T100 Thruster	4	$	576.00
T200 Thruster	2	$	388.00
Tether Cable Thimble	1	$	5.00
20m ROV Tether	1	$	90.00
Hex Key Set	1	$	6.00
Shelf Liner	1	$	5.97
Water Resistant Glue	1	$	4.98
D- Ring Hangers	2	$	4.56
12' by 3/4" velcro	1	$	9.27
Fasteners	58	$	12.05

Item	Quantity		Cost
Whitewater v2.0 upgrades			
HDPE frame	1	$	664.73
explore HD cameras	2	$	513.78
BR HD camera	1	$	111.22
WL penetrators,tools, BR slim tether	1	$	213.96
Video system laptop	1	$	1,522.30
Potting tools	1	$	9.65
BR Gripper	1	$	439.00
UW Servo	1	$	142.00
USB hub	1	$	22.42
Control station case	1	$	129.71
ROV Transport Case	1	$	510.37
Clamps	1	$	32.57
Hardware	1	$	31.47
Cat5, tether jacket, USB parts	1	$	98.24
USB extender baluns, power adapters	2	$	84.50
Hardware	1	$	17.37
Gripper mounts	2	$	27.50
Buoyancy foam	2	$	37.00
5v power converters	2	$	44.00
Lumen Subsea cable	1	$	215.00
Actobotics/goBilda parts assortment	1	$	381.90
Buoyancy foam	1	$	337.75
Waterproof enclosures and endcaps	2	$	437.66
automatic PVC cutter	1	$	93.69
Foam for tether	1	$	22.99
Lasers	2	$	6.79

Item	Quantity		Cost
Lasers	2	$	6.79
Fillament	3	$	60.00
2" PVC pipe	1	$	7.96
2" Aluminum shaft collar clamp	1	$	43.89
RTC clock	1	$	17.99
Linear actuator	1	$	70.00
Sirenge	1	$	12.99
6 volt regulator	1	$	37.95
5 volt regulator	1	$	37.95
3 volt regulator	1	$	7.95
Maker 10 10 Arduino	1	$	38.60
Logic Level Shifter	1	$	3.50

Shipping	$	86.70
	$	23.72
Total	**$**	**8,190.74**

Figure 4: ARES Company Accounting.

Job Site Safety Analysis (JSA)

Task	Hazard(s)	Consequence / Risk reducing measure
1: Transporting ROV	**1A**: Heavy objects - strain / smash / fall / pinch	**1A**: We use a transport case when transporting the ROV to avoid damage to toes, feet, and other appendages. We move the ROV with care by having multiple people carrying to avoid pinch or strain.
	1B: Pinch / Smash of fingers or hands	**1B**: We avoid damage to fingers, wires, attachments, and other appendages, check thoroughly before closing lids. We transport the ROV with care by having multiple people carrying to avoid pinch or strain.
	1C: Tether tripping hazard	**1C**: We use a safety cone to wrap the tether around. This mitigates a potential tripping hazard which could cause bodily harm such as scraping of the knee, elbow, etc.
	1D: Other tripping hazards	**1D**: We avoid tripping on uneven ground, debris, or other potential tripping hazards, by following the motto "slow is smooth and smooth is fast" to decrease the likelihood of members tripping which may cause unnecessary bodily harm.
2: Setup	**2A**: Pinch / cut	**2A**: We keep the power off when setting up the ROV. We also move and position the ROV with multiple team members.
	2B: Fingers / hair in motors	**2B**: We have installed shrouds for the thrusters, and we turn the power off when working on the ROV. We also put longer hair up to avoid it getting caught in the thrusters.
	2C: Flying debris	**2C**: We avoid potential injury by wearing eye protection when working on the ROV.
3: Launching and retrieving the ROV	**3A**: Slip and Fall	**3A**: We keep a safe and steady pace when walking around the pool. Also, we avoid getting close to the pool unless necessary. We maintain situational awareness of hazards on the pool deck and keep the tether in a neat orientation around a safety cone.
	3B: Hair in motors	**3B**: We ensure the controller is down on the table, so thrusters cannot be activated.
	3C: Pinch / Smash of fingers or hands	**3C**: We ensure crew members handling the ROV have hands safely placed on the sides of the ROV to avoid any damage to fingers, hands, and other appendages.
	3D: Damage to ROV's frame and other attachments.	**3D**: Before moving the ROV from carrying its case to the poolside, we ensure crew members are being careful to avoid damage to the ROV.

Design Rational

"WhiteWater" ROV Features

WhiteWater is a remotely operated vehicle (ROV) that companies should consider when choosing a machine for safe and efficient underwater missions and expeditions. Utilizing custom 3D printed parts, Arduino Microcontroller technology, three cameras, and a rotatable gripping appendage, this ROV is equipped for virtually any underwater task. Over the past few years, ARES Marine Robotics has made many new innovations to improve WhiteWater. Some of these include upgrading the PVC pipe frame to a composite marine grade plastic (HDPE) frame, replacing a stationary claw with a rotatable gripper, and upgrading our previous camera system consisting of low quality backup cameras to a system of three high definition USB cameras. We have also upgraded to elevated brackets that fully encompass the plexiglass enclosure, as well as many more innovative design changes. These upgrades were carefully engineered and tested, through hours of research, brainstorming, designing, and prototyping. When we are faced with a design challenge, we cycle through multiple iterations and prototypes, figuring out which design would provide the best balance of the Vitruvian Principles of Design and beginning the final construction and implantation of the design. Our dedicated team has focused on improving our designs and adding additional safety features and aesthetic elements of our vehicle. Each design change was driven by mission requirements, and reviewed, discussed, and tested.

Electrical System

WhiteWater's main control system is comprised of two Arduino Mega 2560 microcontrollers. This system allows us to accurately pilot WhiteWater using our custom application and provides smooth, precise movements in the water. In performing real life tasks and simulated missions in the MATE ROV Competition, this system provides efficient control over the ROV and allows us to perform precise operations such as cable inspection, removal of debris, and much more.

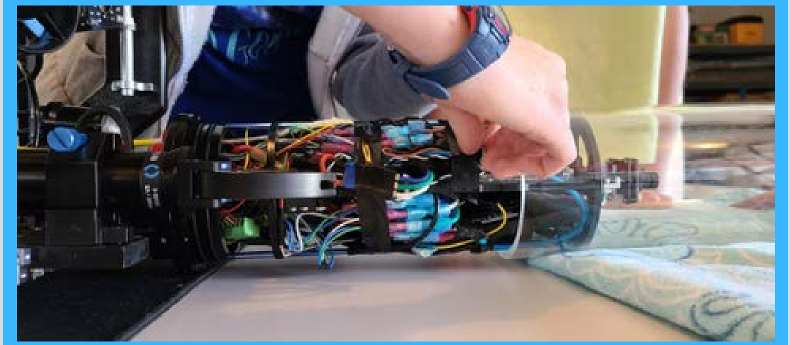


Figure 5: Close-up of installing the main electronics tray assembly.

Onboard

Inside the WhiteWater's enclosure, we have eight ESCs (electronic speed controllers) connected to our microcontroller, for controlling each thruster from the topside control box. In order to send camera signals, we have USB/CAT5 extenders for transmitting the signals over ethernet cables within the tether. Power buses/distribution blocks line the back of the electronics tray for connecting different components to the main power supply. There is one microcontroller located inside the enclosure for receiving the transmissions from the topside control box, and sending those signals to the thrusters.

Control Box (Topside)

Figure 6: Control Box (without top covering panel).

In our control box, we have another Arduino microcontroller that transmits the control signals from our XBox controller down the tether to the onboard MCU. We also have an adjustable and removable platform above the electronics for the laptop to sit on. For our video feed, we use the software OBS Studio, allowing us a variety of controls with our camera feed.

Tether

Our tether is 45ft in length, with a flexible open sheathing. This allows us to add or remove new cables within the tether, for easy upgrades in the future. Our cables consist of our main power wires (positive and negative), our signal wire, our two CAT5 cables, and our " BlueRobotics Lumen" power cable (specific to powering one of our cameras). When we're piloting WhiteWater, as a way of managing the tether, we coil it around a safety cone and keep it behind our control station at all times to prevent injury or damage.

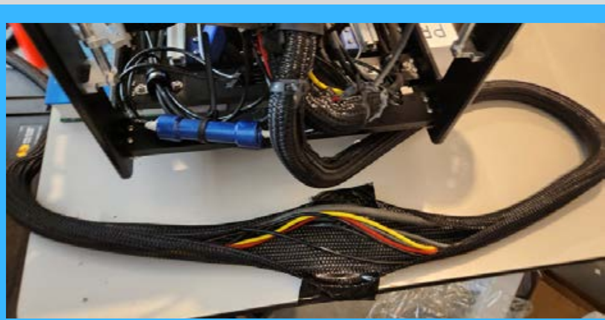


Figure 7: Section of tether showing iner contents.

Controller Details and Operation

We utilize an Xbox One controller to operate systems on WhiteWater, such as thruster control, lights, and Talon manipulation. We've also developed autonomous code that is activated by a button on the controller and is used when docking WhiteWater. We activate our lights, which are positioned downwards on the ROV, by pressing "Y" on the controller. C++ is the programming language we use to code our entirely custom control system in the Arduino IDE. The familiarity of the Xbox controller allows for a more user-friendly experience when piloting WhiteWater.

Thrusters

WhiteWater is equipped with eight BlueRobotics thrusters. Six being T100 thrusters, and two being T200 thrusters. Four thrusters are mounted on the upper rail of the frame to provide vertical thrust, while the other four are mounted on the interior of the frame at a 45° angle for omni-directional turning or 'turning on a dime'. Each thruster is capable of adjustment while mounted, if need be. These eight thrusters allow for vast ranges of mobility, consisting of the typical ascend, descend, forward, reverse, port, and starboard, as well as pitch, roll, and strafe. In both a real world situation and in the MATE competition, these maneuverability options allow us to perform delicate operations (i.e. entering through a narrow space like a hole in the ice, or mapping the seafloor in a specific region).

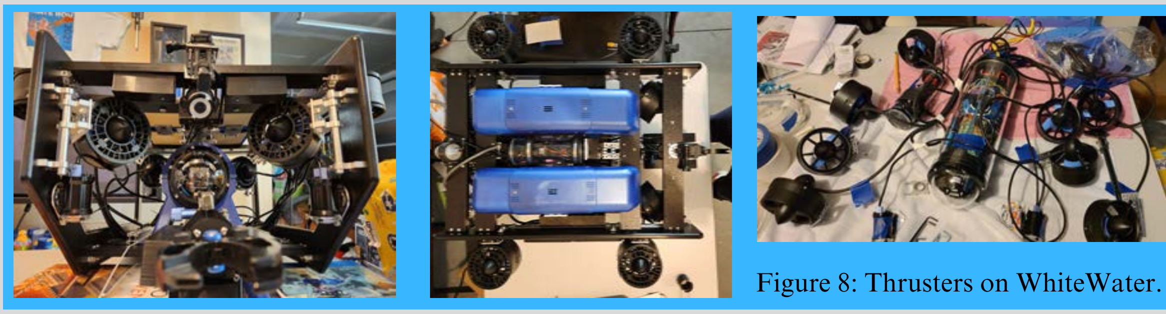


Figure 8: Thrusters on WhiteWater.

Video/Camera System

WhiteWater's camera system is one of its defining and vital features. This system, consisting of three HD USB cameras, is essential for accomplishing missions. The primary camera, the BlueRobotics low-light USB camera, is located at the front of the large electronics enclosure and serves as our main operating camera. The bow camera, a DeepwaterHD Explorer camera, gives us depth perception necessary for completing various tasks. Our third camera, a second deepwater HD camera, is mounted atop the stern crossbeam and acts as our reverse camera to ensure the avoidance of collisions and allow us a 360-degree view of our environment. The three cameras can be positioned at different angles for specific purposes. This proves most useful when completing any mission with the need for different camera angles, such as mapping a specific area of the seafloor.

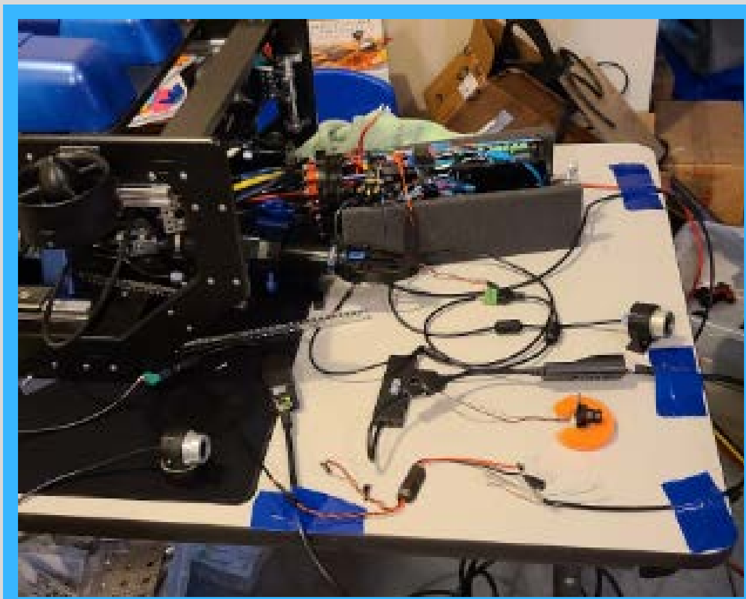


Figure 9: Video system laid out before mounting.

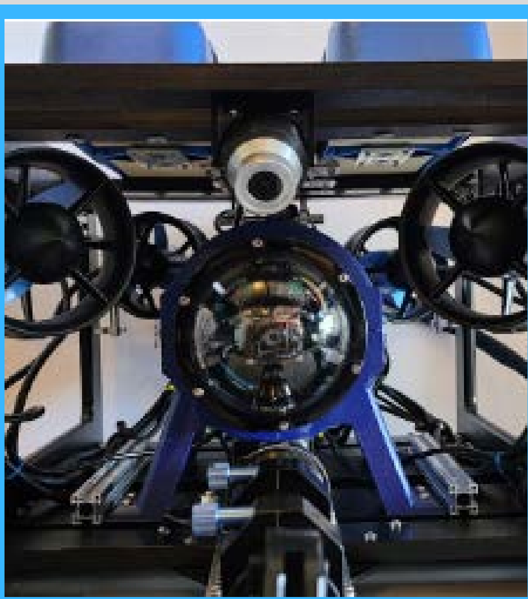


Figure 10: Front view of cameras.

Talon System

WhiteWater is equipped with a rotatable gripper system we call the Talon. Utilizing an underwater servo capable of manipulating up to 80 kg of weight, the Newton Sea Gripper from BlueRobotics, and custom printed 3D parts, the Talon allows us to grab and grip objects positioned at various angles. This functionality is very useful when lifting large or awkwardly positioned objects. In our first year of competing, we utilized a custom designed Lego Mindstorm claw; however we decided to upgrade and use a gripper from BlueRobotics because of the extended capabilities it provides, such as controlled gripping and pressure. To add even more capability to the Talon and our ROV, we customized the Newton Seagripper to have a 90 degree rotational ability using an underwater servo. We also designed custom 3D printed parts that link the servo and the gripper into a unified system of operation, as well as using other fabricated parts as extra extensions of the Talon to assist in a variety of missions.

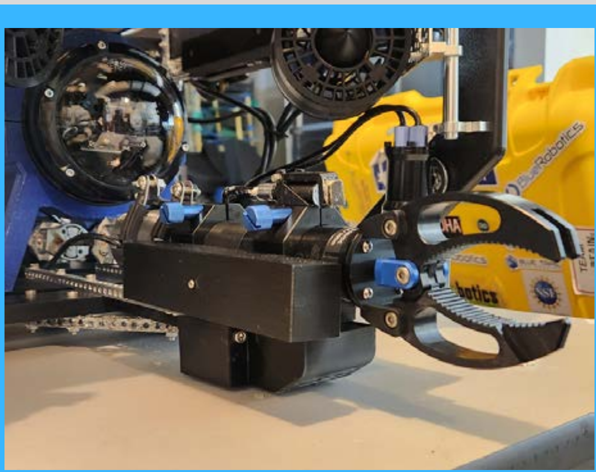


Figure 11: Talon set-up on WhiteWater.

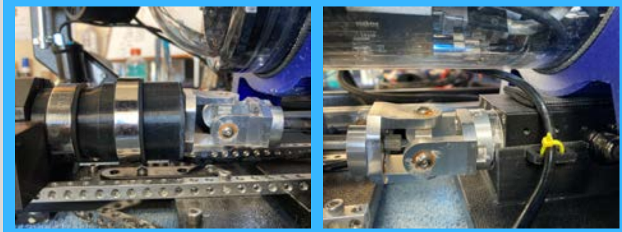


Figure 12: Servo set-up to rotate Talon.

Custom 3D Prints

WhiteWater has many 3D printed parts, all of which are printed by one of our team members. All parts are designed using Fusion 360 or Tinkercad and have become an invaluable component of WhiteWaters design. 3D prints assist in not only the utility of the design, but also the aesthetic appeal. For example, we have custom 3D printed braces for the main electronics enclosure and for our main camera mount. We also utilize them as tools, such as drilling templates to assist with accuracy and precision with our power tools. Custom fabricated parts can prove useful when in need of a custom design element, attachment, similar to their use in the competition. Our Talon, which is responsible for completing various missions involving ROV contact, would not be able to function without the utilization of 3D printed parts. We also use 3D printed extensions of the ROV to assist with specific missions. This year, for example, we fabricated a cage to carry adolescent fish fry and acclimate them into a new environment, safely. We also designed and printed a "pin-pulling" Talon extension, for effectively clearing smaller particles of biofuel. For docking purposes, we utilize a custom printed shield to press the button, finalizing the docking process.

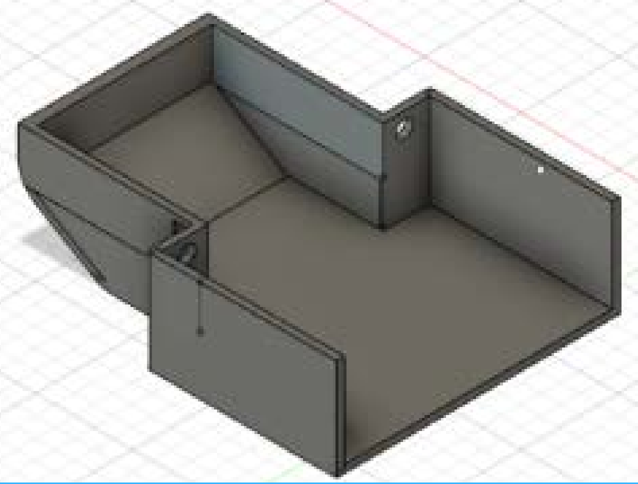


Figure 13: Cad drawing model of "Keel" component.

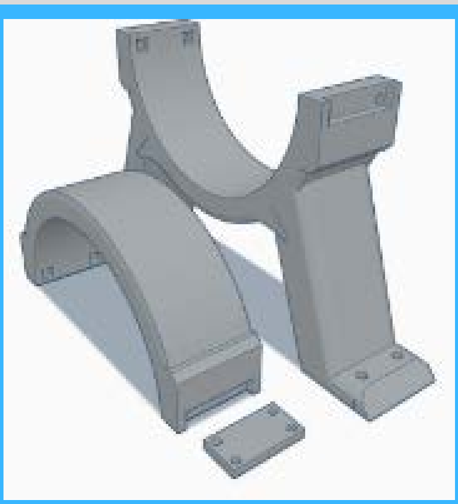


Figure 14: Cad drawing model of Enclosure Brackets.

Frame Design

Our ROV's frame is custom designed and made from a marine grade high density polyethylene plastic (HDPE). It is structurally sound, visually appealing, and overall professional in its specific functionality. In our first year of competing we utilized a frame constructed out of PVC before upgrading it to the high density polyethylene last year. We originally chose this frame design, making it spacious around the "interior", to provide easier access to components we would be working on and improving, as well as to allow better hydrodynamics during flight time. The shape of the frame came from multiple iterations of design and prototyping, determining what would give us the smoothest motion in water, while considering the amount of visual appeal it would provide.

Figure 15: CAD model of custom frame design.

In both the real world and in the competition simulations, this frame adds to our professionalism, our ROV's structural integrity, and our efficiency in completing various missions. Our ballast system is adjustable with flotation blocks placed along Actobotics X-rail for dialing in neutral buoyancy in various bodies of water.

Safety Features

One of our goals as a team is to improve and expand upon the safety of our ROV. This year we have upgraded and added safety components on WhiteWater in order to make the machine as safe and user friendly as possible. For example, we designed and printed custom thruster guards (to IP-20 standards) to prevent thruster related injury, and the thimble on the tension relief hook to allow better tension relief on the tether and penetrators. The Keel is also another safety feature we implemented underneath our Talon attachment to prevent damage to other objects when operating WhiteWater by covering sharp edges.

Overall we've greatly improved our system design. We have the camera system, consisting of three cameras, the control system, with our eight thrusters, and the Talon manipulation system, for rotating our gripping appendage. Each system is balanced in functionality, structural integrity, and visual appeal, as covered with individual descriptions of these systems above.

Custom vs. Customize

On our ROV we use a variety of different components both by our own design and creation or customization of purchased products. Of course we purchase components that we are unable to manufacture ourselves in the given timespan, such as thrusters, grippers, cameras, enclosures, etc, but we combine them with our own modifications and design concepts. For example, we purchased the Newton Sea Gripper from BlueRobotics, but instead of mounting it as they recommend, we went beyond and implemented a rotation system using a waterproof servo, making it our own system. We often take off-the-shelf products and modify and/or combine them with other OTS or custom products to create our own custom systems specific to and specialized for WhiteWater. These combinations of off-the shelf-components and custom modifications add immense functionality to WhiteWater and allow us to complete challenging missions. For example, our Talon system has the capability of rotation because we customized it using other off-the-shelf products as well as custom fabricated ones, and it has proven time and time again that the rotational ability provides a high level of success and a reduced amount of time taken to complete a variety of missions. We also utilize many 3D printed parts that are entirely custom in design and construction. With our current version of WhiteWater, we have reused many of our components from previous years except for minor additions or improvements, designed to enhance WhiteWater's safety features and functionality.

"Cetacea" AUV Design

Our float-style AUV, Cetacea, is an autonomous vehicle designed to log and read universal time and pressure data during deployment. When positioned at the surface, Cetacea will take on water using a linear actuator and ballast system as the buoyancy engine causing her to begin her dive profile. Once a certain depth is reached, water will be expelled from the ballast system and she will rise to the surface to transmit data to our receiving station in the control box.

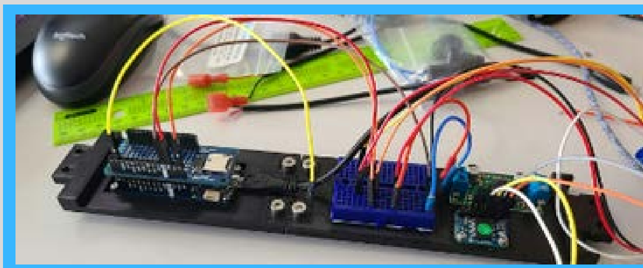


Figure 16: The electronics tray during assembly.

Electronics

Two Arduino MKR WiFi 1010 boards are utilized within Cetacea's electronics system. One is located within the AUV, acting as the client, and the second board mounted in our control box, acts as the server. The client board transmits data to the server via WiFi, while the server receives that data and displays it on the OLED screen. Accompanying the Arduino MKR 1010 boards, we utilize an AdaFruit Precision RTC clock, to track the UTC time and transmit the data to the client MCU. The RTC is powered separately from the other components, receiving power from its own battery pack and running continuously, without a switch.

Sensors

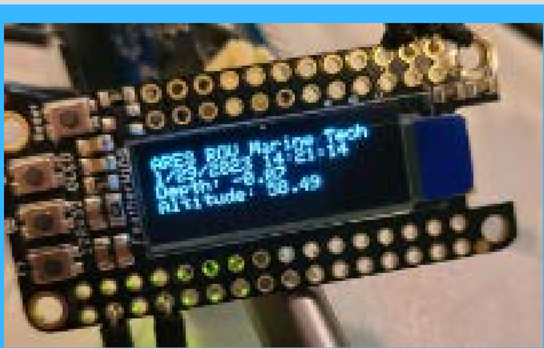


Figure 17: Photo of the data being received and printed by the server.

Instead of using a time limit for when Cetacea should expel or take on ballast, we use a pressure sensor from BlueRobotics to read the depth. When Cetacea reaches a certain depth, the linear actuator will activate and expel the water, allowing her to rise to the surface. Using a time limit would be unpredictable and unrealistic given the circumstances regarding how much time we would assume we might need to reach an adequate depth for a complete profile. Although, at the beginning of deployment, we use a timer from when we activate Cetacea to the first profile, but we do not utilize a timer during her profiles as a sole method to calculate when she should expel or take on water.

Buoyancy Engine

Our buoyancy engine uses a large syringe and an Actuonix linear actuator to take in and expel water in and out of the AUV. This changes the density of the AUV causing it to either rise to the surface or sink to the bottom. We utilize manual buoyancy systems to assist with the main engine, such as a weight ring attached below the fins at the bottom of the AUV as well as a buoyancy ring, placed near the top of the AUV. These features help in providing a stable vertical profile in the water as well as keeping the top of the AUV out of the water to allow for the transmitter to send data to the server in the control station.

Figure 19: Completed AUV testing.

Figure 18: Designing the buoyancy Engine for Cetacea.

AUV Custom 3D Prints

Cetacea utilizes a variety of custom 3D prints, ranging from supporting our electronics and buoyancy engine on the inside, to the aesthetically appealing design features on the outside. The majority of the interior is custom 3D prints, designed to hold the electronics and buoyancy engine in a sleek format that braces against the PVC. There are multiple parts that comprise this interior setup, including: the main electronics tray, the linear actuator bracket, the syringe adapter, the 3-part syringe bracket, and the various prints in between the others for extra support/adaptability. We also utilize non-custom aluminum disks to separate the electronics from the buoyancy engine and to prevent the interior setup from sliding within the PVC. On the exterior, we utilize custom 3D printed fins for aesthetics and balance in the water, which is connected to a bracket for attaching the battery packs. Near the top of our AUV, we have a buoyancy ring that helps keep the top of the AUV above the surface of the water to allow data transmission from the client MCU to the control station. Holding the AUV together, from cap to cap, are the end cap bracket prints. They are designed to provide extra strength and stability. They also provide protection to the penetrators. On the interior, we use custom 3D printed trays and brackets to efficiently secure the components inside. The electronics tray is designed to provide attachment mounts for our boards, including the MKR client, the RTC clock, a shared breadboard, and our various voltage regulators, and a logic-level shifter.

Attached to one end of that are multiple adapter prints that hold the linear actuator in place. Securing the syringe inside the PVC, is a number of interconnected brackets, running down to the very end of the AUV, where 3D printed spokes are present to provide a brace against the end cap when the linear actuator is activated.

Figure 20: Fins, weight ring, and battery pack clips (without battery packs attached).

Safety Features

Just as we improve and utilize safety measures on our ROV, we also implement a variety of safety precautions on our non-ROV devices, such as our AUV. On Cetacea, we have an unsealed cap on each of our battery packs to prevent a burst from over-pressurization. We also run three metal tubes along the AUV itself, from end to end, to tightly seal it and keep it under 1 meter. To prevent damage to the cables or to the penetrators on the bottom end cap, we designed spokes extending from the bottom end cap bracket. On the interior, two O-rings wrapped over metallic disks hold the electronics tray and buoyancy engine in place inside the PVC tube, to prevent damage to the sensitive electronics. Internal spokes bracing the electronics tray and buoyancy engine against the end caps, also add an extra safety measure.

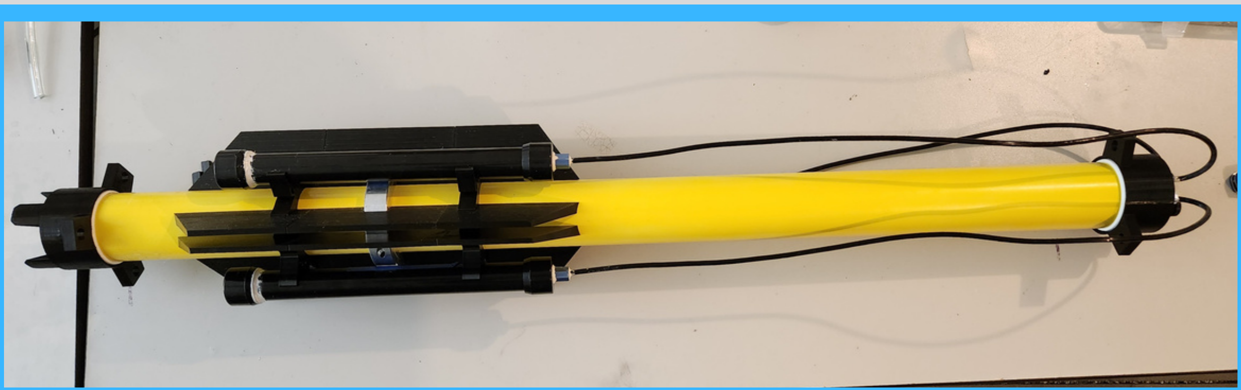
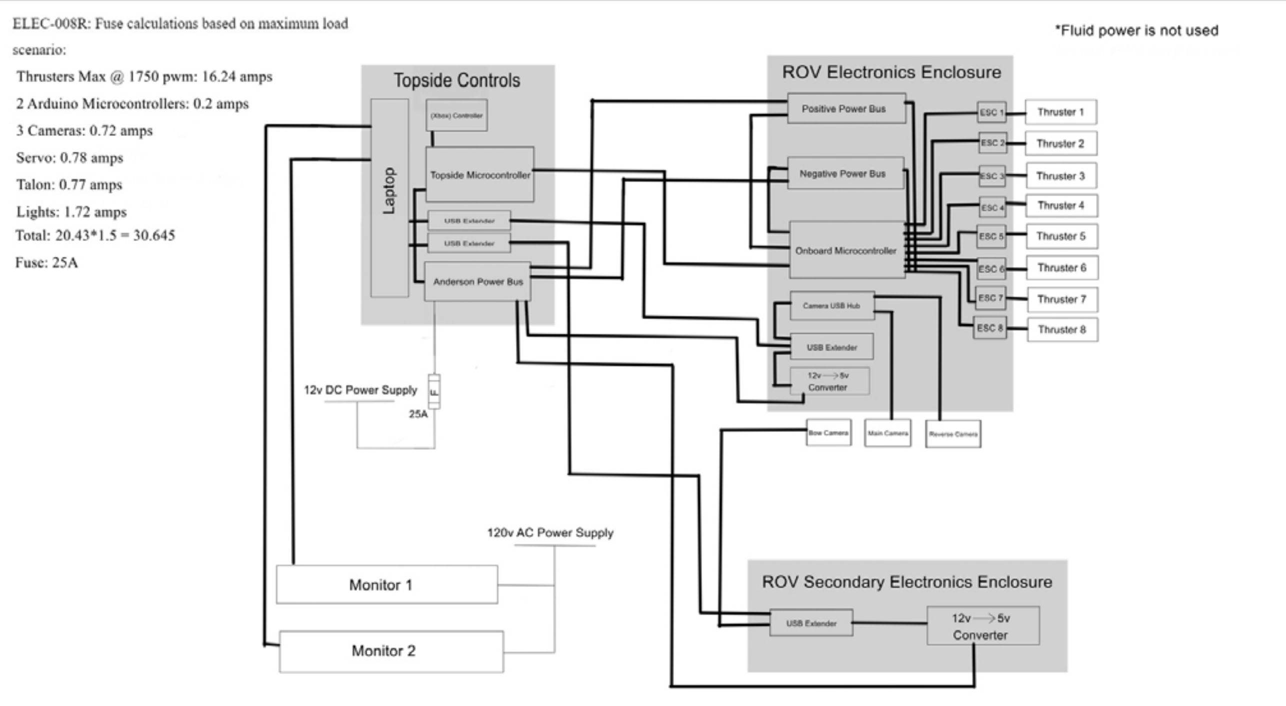


Figure 21: ARES Company Designd AUV "Cetacea ".

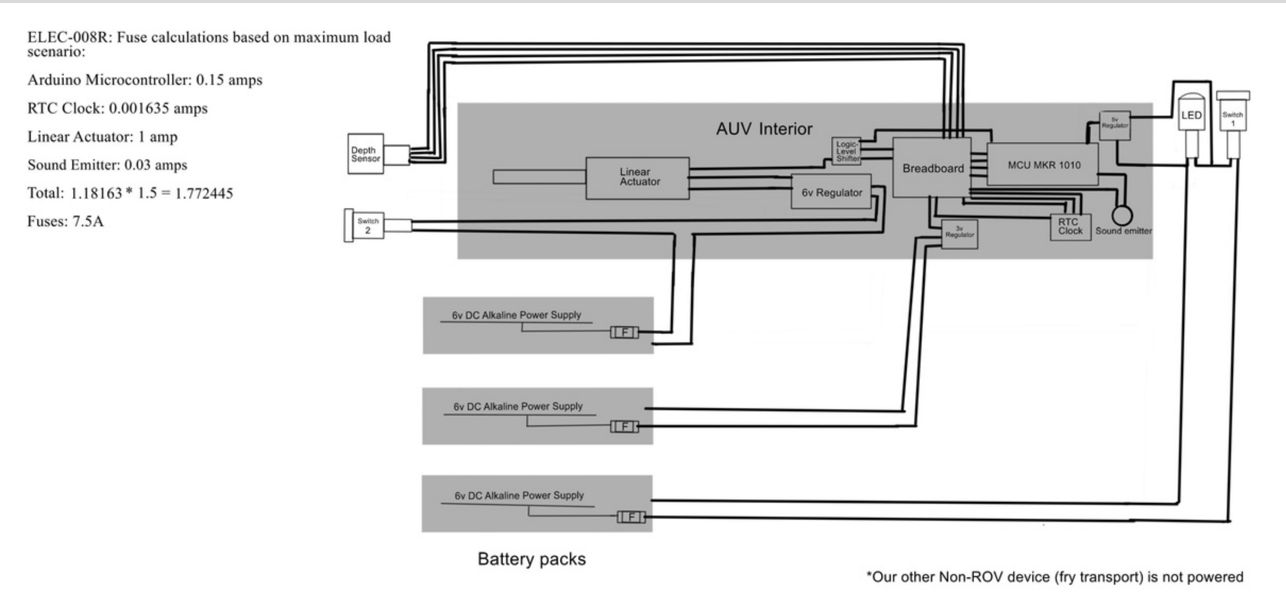
SID's

System Integration Diagrams

"WhiteWater" ROV



"Cetacea" AUV SID



Theme

This year's MATE ROV Competition continues supporting the United Nations by creating missions themed around the United Nations sustainable development goals. The goals are the "blueprint to achieve a better and more sustainable future for all." [1] These goals are created to address a multitude of global issues including "poverty, inequality, climate change, environmental degradation, peace, and justice." [1] This has inspired the MATE ROV Competition to design missions which are impacted by the use of ROVs and are aligned with one or more of the 17 UN sustainable development goals: [3] Marine renewable energy, healthy environments from the mountains to the sea, and autonomous underwater vehicles. The missions represent global problems which influence or are influenced by different ESG factors (environmental, social, and governance factors). [3]

Marine Renewable Energy

UN Sustainable Development Goal(s): [3]

- #7 Affordable and Clean Energy
- #12 Responsible Consumption and Production
- #13 Climate Action

Sustainable energy is a significant aspect for many countries in today's world due to the rising issue of climate change. Countries have relied on the burning of fossil fuels to produce electricity for decades. This has produced a large volume of CO_2 causing climates to be altered across the globe. There are many different sources of sustainable energy: Solar, hydroelectric, wind, nuclear, and more. Social movements have been increasing within the last decade due to the rising issues of climate change. With climate change becoming more and more prevalent, countries are beginning to take part in a variety of ways to help combat this global issue through investing in more sustainable sources of energy.

The approach governments are taking that is prevalent in this year's theme is Marine renewable energy. Governments are investing in different sources of marine renewable energy such as the Merganser. Offshore Floating Solar company SolarDuck, in conjunction with TU Delft, TNO, MARIN, and Deltares, have designed large solar panel arrays that float offshore as shown in figure 22. [2]

Figure 22: [2] shows a photograph of an offshore power array.

The aim of these companies was to solve the limited availability of land allowing solar power to become more scalable. Solar power is a much more sustainable source of energy in regards to fossil fuels as the amount of CO_2 produced during the production of electricity is significantly less that directly impacts the environment.

Due to the solar panel arrays being offshore there are possible issues with damage involving water--such as erosion. ROVs are a useful tool for the offshore solar panel arrays as they can be used in maintenance, cleaning, and inspection for the offshore parks. This is a cheaper solution than routinely hiring divers to do inspections/maintenance on the solar power array. WhiteWater, the ROV we have designed and created for these competitions can be used in similar ways to assist such projects.

Figure 23: [4] Talon griper assembly on WhiteWater.

WhiteWater has a gripper assembly, known as Talon as seen in figure 23, which is able to turn 90 degrees which is completed in 45 degree increments. Talon would allow for WhiteWater to help maintain a structure such as the Merganser by removing biofouling and other debris necessary. WhiteWater also contains three high definition cameras which are mounted to give a near 360 degree view of the surroundings. The orientation of the cameras would allow for easy identification of damaged areas and biofouling.

Multiple ESG factors have been identified throughout this short section. This includes climate change, environmental effect on the solar panel array, limited availability of land, public awareness of these environmental issues, and government funding which directly influence this topic.

Health Environments from the Mountains to the Sea

UN Sustainable Development Goal(s): [3]

- #13 Climate Action
- #14 Life Below Water

Lake Dillon, Colorado, known as the Dillon Reservoir, contains an interesting history. To briefly explain, Flooding was a large issue in the town of Dillon. Many homes would be damaged due to the flooding that would occur. "In the late 1950s, the Denver Water Board voted to build a dam to secure the water..." [3] of Lake Dillion. Funding from different county's allowed for the construction of the dam that created the Dillon Reservoir. The dam contains intakes allowing water to flow through turbines to produce electricity. The intakes are marked with buoys secured by ropes. This is where ROVs come into play. ROVs can be used to inspect these ropes to maintain the safe environment for citizens and tourists. ROVs can also be used to remove debris and biofouling that may be damaging the ropes.

WhiteWater could be used in multiple ways to complete useful tasks. As mentioned previously the Talon can be used to remove debris/biofouling. Out of the three existing cameras on the ROV, two of them are forward facing. The orientation of the cameras allow for depth perception of the pilot allows for easy removal of small pieces of debris. The camera systems also allow for a clear view of potentially damaged areas.

A handful of ESG factors were mentioned throughout these sections: flooding impacting the town of Dillion, the construction of a large dam to create a reservoir required the manipulation of the environment, and the county funding the created said dam.

Autonomous Underwater Vehicles - Floats

UN Sustainable Development Goal(s): [3]

- #13 Climate Action

Many mainstream global issues are affected by the earth's oceans. A significant global phenomena that is impacted by earth's oceans is climate change. The currents of earth's oceans "currents regulate global climate by helping to counteract the uneven distribution of solar radiation reaching Earth's surface." [8] To be able to innovate solutions to this global problem we must learn and understand earth's oceans. Currently, a wide array of AUVs across earth's oceans provides a large sum of data of various types. This includes "sonar, magnetometers, fluorometers (chlorophyll sensors), dissolved oxygen sensors, conductivity, temperature, depth sensors, pH sensors, and turbidity sensors." [7] AUVs contain various different sensors, but not all of which are incorporated into a single AUV. The possible innovations created from data collected by AUVs could drastically impact climate change and other environmental and social issues.

Cetacea is an AUV we designed and created for 2023's MATE ROV Competition. Cetacea is an AUV which transmits data to a server on the surface every second. This includes the current date, time, and depth. With this transmission time the incorporation of new sensors could allow Cetacea to be useful in real world situations to gather specific data. WhiteWater may also be used to monitor and deploy Cetacea depending on the circumstances.

A handful of ESG factors were addressed throughout this short section: the mainstream social issue of climate change and the social and environmental impacts of potential innovations.

Endnotes

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- The Richland Fire Department for helping us at a few outreach events and activities
- Emmett’s Print Shop for fabricating many of our custom parts
- Chris West, for being an amazing coach and mentor.
- Virginia Daubin for providing outreach opportunities

Figure 24: Suppliers and vendors.

We also would like to show our gratitude and appreciation to our parents for their financial aid as we as their moral support on our journey to the competition, including: serving as transportation, enduring the outreach days in extreme climates, and volunteering to help wherever they can like building mission models, reviewing documentation, bringing and making food for us, and providing opportunities for outreach events. Thank you again for all your support in this endeavor!

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