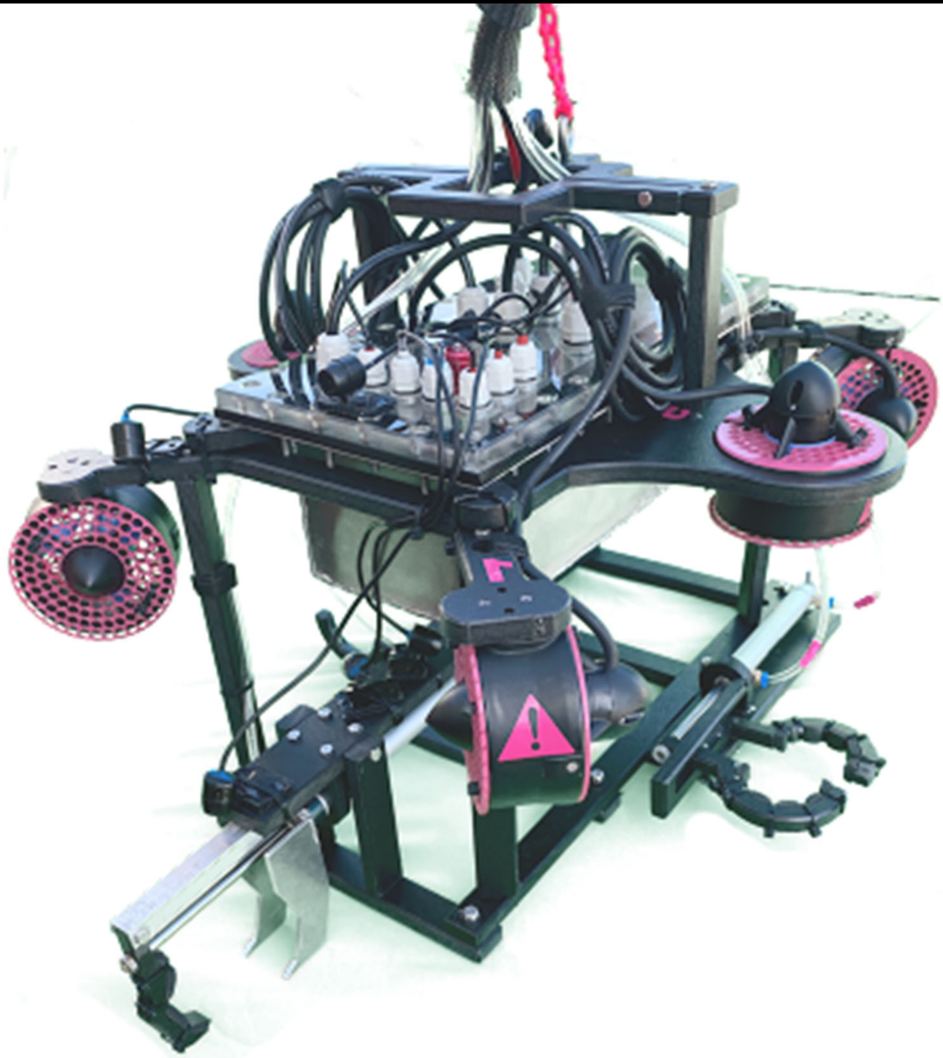
2022 MATE ROV WORLD CHAMPIONSHIP TECHNICAL DOCUMENTATION



COMPANY MEMBERS

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1. Abstract

HAWKS Engineering is a four-student company attending Hoffman Estates High School located in Hoffman Estates, Illinois, USA. The company was established in 2014 to assist in underwater exploration and perform tasks that humans cannot safely or realistically accomplish underwater. The MATE ROV Competition is taking this opportunity to highlight the United Nations Decade of Ocean Science for Sustainable Development and aligning its mission tasks with one or more of the 17 U.N. Sustainable Development Goals. We are responsible for installing and performing maintenance inspections on offshore wind turbines and their impact on the surrounding environment by deploying instrumentation and sensors, such as hydrophones. Additionally, we will be inspecting fish pen nets for damage, removing fish mortalities, and exchanging an old seagrass bed for a new bed. We must also recover a GO-BGC float to conduct diagnostics of ocean health and deploy a vertical profiling float to monitor ocean health. Lastly, we must locate and create a photomosaic of the Endurance shipwreck. In order to accomplish all of this, we use a Remotely Operated Vehicle (ROV). Our ROV, H.U.E.R.T.A., has features tailored to coincide with U.N. goals and the global community. Features include: two pneumatic and two stationary manipulators; six cameras; a hydrodynamic frame; and a robust electrical system. Some of the many safety features include a main power cutoff switch and a current detection system. Ultimately the capabilities and features of this ROV not only assist the company in solving real-world problems brought to attention by MATE's competition, but also give insight into the role that robotics can take on in helping humanity clean up the environment for a better future.

HAWKS Engineering
Armando Huerta, Vanessa Huerta, Justin Du, Melanie Rodriguez-Huerta

2. Design Rationale

HAWKS Engineering's primary focus when drafting the design for H.U.E.R.T.A. was to accommodate the various manipulators needed to accomplish the tasks MATE has stated in the Request for Proposal. We took advantage of a previous frame by utilizing it as a base to determine the proper positioning of the manipulators during underwater testing. The company narrowed down the options to one vertically placed claw on the front of the ROV to clamp onto objects lying flat on the ground, coupled perpendicularly with a horizontal facing claw to grasp objects sitting straight up. In addition to these payload tools, an aluminum handle that spans the entire ROV's rear was needed due to the excessive time it would take to pull repetitive items, like the pins in the pipeline. This simple tool gives the pilot the ability to accomplish this task in a shorter amount of time and with less effort.

Electronics were the next pivotal step in designing the ROV. Third-party components were inadequate for our use primarily because of their unreliability concerning troubleshooting. With this in mind, HAWKS Engineering decided to develop custom printed circuit boards. By doing so, team members are broadening their understanding of how the ROV operates and are more prepared to solve complications within our system should they arise.

The next step in the design process was geared towards the frame. Based on the need to hold the aluminum electronics housing, the specific placement of our payload tools, and the thruster supports, the company decided that a rectangular profile would be best suited for H.U.E.R.T.A.. When It comes to the frame's buoyancy, the team determined its best option would be to use materials to keep it positively buoyant. This would allow for more flexibility to ensure the entire ROV could be neutrally buoyant by adding specific mass as needed. Also in order to keep in line with the theme of being environmentally friendly, all members desired a recyclable material. This led the company to conclude that High-Density Polyethylene (HDPE) would be the best choice of material since, in addition to all those attributes, it has the benefit of being easily machinable.

Thrusters were next in the design process of the ROV. The previous year's T-100 thrusters were no longer available for consumers which meant that by using them on our new ROV, we ran the risk of having no replacement for them if they were to fail. Taking this into account, combined with the fact that this year's ROV is the largest and heaviest yet for our company, this provides us with enough justification for upgrading to the more powerful T-200 thrusters. By incorporating the upgraded thrusters, our ROV was engineered for quicker underwater operations all the while being more reliable.

3. Innovation

There were many structural innovations that made our ROV's vast capabilities possible. The most important of these innovations was the aluminum electronics housing. That has been manufactured by our company, and was specifically designed to fit the entirety of the ROVs custom electrical hardware. The further use of aluminum can be seen on the front manipulator, where it is the best candidate to acquire our desired design, due to its malleability, recyclability, and non-corrosive properties.

Several developments in the electrical system were made. We switched from USB to RS-485 serial communication between the ROV and control station. This form of serial communication reduces the interception of other electrical signals, making it far more reliable in an electrically noisy environment when compared to USB. We have designed our own printed circuit boards (PCBs), which allows us to easily troubleshoot and replace boards if an issue were to arise.

In terms of our software system, HAWKS Engineering has interfaced Python software from the control station with Arduino software on-board the vehicle. At the control station a computer is being used to translate joystick positions and send out speed values as well as receive sensor data. On-board the vehicle, Arduino code is being used to send out pulse-width modulation (PWM) signals to thrusters, select cameras, control and gather sensor data. This has resulted in an organized form of communication between the control station and the vehicle.

4. Problem Solving

When attempting to solve the tasks that MATE has challenged us to complete, we would consider many factors pertaining to the specific nature of each task and derive a solution, such as the placement or number of manipulators, to accomplish the mission. From there we would need a placeholder to test this. HAWKS Engineering, again, utilized the previous year's ROV to first test such concepts before moving on to any drastic changes such as an entirely new frame to accommodate the tools. This keeps in line with our philosophy of doing more initially in order to save time in the long run.

5. Systems Approach

Throughout H.U.E.R.T.A.'s construction, HAWKS Engineering has always held on to the belief that the ROV's behavior in the water, regardless of how well the electronic or propulsion systems were built, would all depend on how well we balanced functionality with physical characteristics. The placement of thrusters, for example, are all positioned on the same plane in order for the ROV to move more uniformly through the water. Furthermore, the company distributed weight more evenly by adding manipulators on both sides of the ROV in order to minimize pitch. This philosophy even extends to the arrangement of the PCBs in the aluminum housing. Rather than locating the vertically facing boards against one side, they are all facing parallel to the front of the ROV in order to maintain a favorable center of mass. The company's strict policy of symmetry and cohesive design has proved to be crucial in determining the success of a mission.

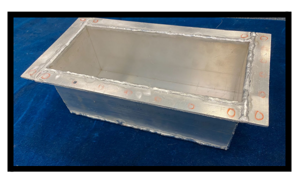
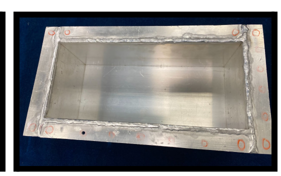
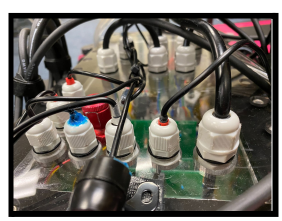
6. Vehicle Structure

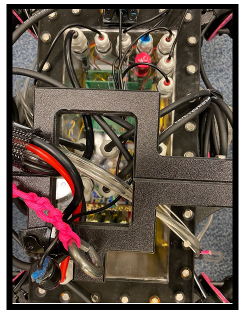
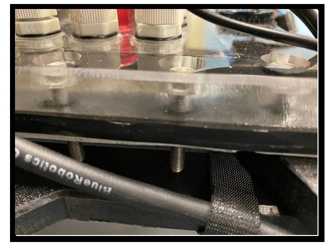
6.1 Frame

High-Density Polyethylene (HDPE) was selected as the primary material for H.U.E.R.T.A. 's frame. The non-brittle nature of these sheets has the additional benefit of being easily machinable and this attribute was taken advantage of when we utilized our CNC router to give precise tolerances to each individual component. The ROV's top and bottom frames are bolted together. Bolting everything together provides structural integrity and stability. The vehicle uses an open design to create as little drag as possible in the water. Despite this, it still retains many surfaces for the mounting of tools. This allows for the use of custom tools onboard the ROV. The ROV's profile was designed and digitally assembled on Autodesk Inventor to ensure any mistakes could be caught beforehand to be easily corrected before physically cutting anything.

6.2 Electronics Housing

H.U.E.R.T.A.'s electronics housing has been constructed from 0.3175 cm thick aluminum sheets. We chose to construct our housing from aluminum due to its non-corrosive properties and the material's ability to disperse heat. In order to create a structurally sound housing, we welded each piece together. These welds can withstand high pressures and are not prone to leaking.

Aluminum Housing ● Welding form: TIG ● Material: Aluminum ● 2.54 cm lip used to create seal. ● Dimensions: 30.48 cm (length) x 13.97 cm (width) x 13.34 cm (height).	 
Acrylic Cover ● Adjustable watertight penetrators are used to feed external cables into housing. ● The penetrators are screwed to the acrylic cover to create a seal to the housing and provide strain relief to the external connections. ● The cover was cut using a CNC router.	

Watertight seal ● A watertight seal is created by a rubber gasket coated with silicone grease that fits between the top of the box and acrylic cover. These components are bolted together which effectively waterproofs the electrical components.	 

7. Mechanical Systems

7.1 Propulsion

H.U.E.R.T.A. is propelled by six Blue Robotics T200 thrusters. T200 thrusters are being used due to the thrust they provide. Four thrusters are used for horizontal movement and are vectored at 45° to allow for cardinal, ordinal, and rotational momentum. The remaining thrusters are mounted vertically which allows for ascending and descending movement. The vehicle has four degrees of freedom which allows the pilot to complete tasks in a timely manner.

Each thruster provides up to 18.14 N of thrusting force, leading to the following thrust calculations:

Vertical Thrust: 18.14 N • 2 thrusters • sin 90° = 36.28 N

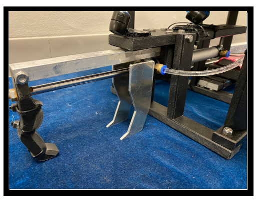
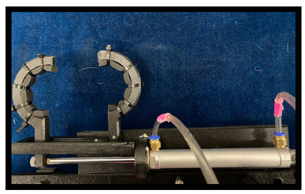
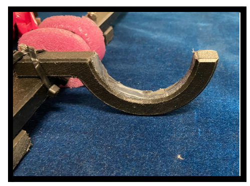
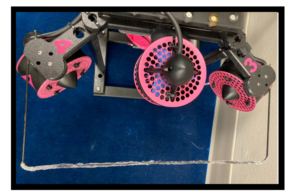
Horizontal Thrust: 18.14 N • 4 thrusters • sin 45° = 51.31 N

7.2 Buoyancy

Without any additional buoyancy, H.U.E.R.T.A. is positively buoyant. In order to counteract this upward force, 5 newtons of weight have been attached to the bottom of the ROV's frame to make it neutrally buoyant. This prevents interference with the vehicle's propulsion system.

8. Payload and Tools

Before committing to a manipulator design, the team spent many days by the pool testing a multitude of prototypes before coming to a final decision. All manipulators are multi-purpose and have a simple design with variable width of closing which allows them to retain a firm grip on objects of varying sizes from mission-specific tasks. Four manipulators have been designed and incorporated onto H.U.E.R.T.A. 's frame in order to efficiently perform tasks and cut down the number of trips taken to and from the surface. Below are the payload tools and their capabilities.

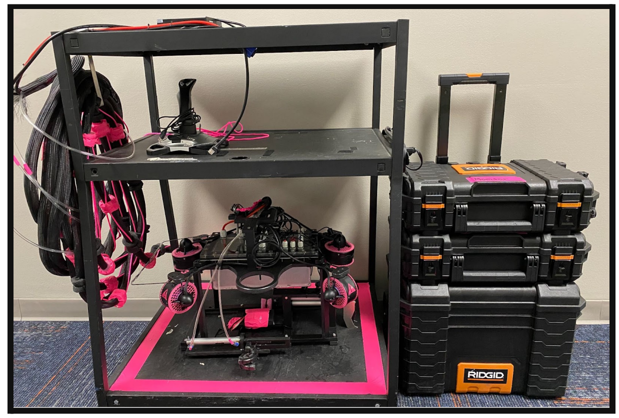
Front claw (pneumatic)	Side claw (pneumatic)	Hook (stationary)	Pin hook (stationary)
			
Material used: Aluminum and HDPE	**Material used:** HDPE	**Material used:** HDPE	**Material used:** Stainless steel rod.
Mission-specific tasks: ● **1.1:** Installing a new section of cable & securing the new section of cable in place with wet-mateable connectors. ● **1.3:** Recovering hydrophone. ● **2.1:** Removing marine growth. ● **2.2:** Collecting a mort and inserting into a collection tube. ● **2.4:** Pruning seagrass bed. ● **2.4:** Planting seagrass bed.	**Mission-specific tasks:** ● **1.2:** Releasing and recovering a damaged buoyancy module. ● **1.2:** Attaching and securing a new buoyancy module. ● **1.3:** Deploying hydrophone. ● **3.1:** Recovering GO-BGC float. ● **3.1:** Deploying profiling float.	**Mission-specific tasks:** ● **1.1:** Removing damaged section of cable.	**Mission-specific tasks:** ● **1.1:** Cutting the cable on both sides of the damaged section ● **1.3:** remove ghost net from wind turbine's substructure. ● **1.3:** Pulling ghost net pin. ● **1.3:** remove ghost net from water.

The company's primary focus this year was the mechanical aspects of H.U.E.R.T.A. which resulted in no implementations of artificial intelligence or external sensors.

8.1 Fluid Power SID

View appendix C.

9. Control station

Control Box	Cart
	
The ROV is controlled from the surface by a transportable control box. This box contains an RCA to VGA video converter, a 120 VAC power strip, two USB to RS-485 converters, a killswitch on the powerline of the vehicle, and a monitor. The control box allows the entire ROV system to be moved anywhere with ease, and also provides a modular area from which to control the ROV.	The ROV is transported by a cart, the vehicle's tether is attached onto an aluminum hook that is bolted to the cart's frame. Using a cart allows us to safely and efficiently transport the vehicle.

10. Software System

The team is using pySerialTransfer software that was created by PowerBroker2, which transmits and receives Python and Arduino packages in a fast, reliable, and packetized form. Software that is used to read joystick positions, select cameras, and control sensors has been developed by the team. Due to the company's basic coding experience, we are primarily using PowerBroker2 pySerialTransfer code to send packets of data.

The control station is using python code to read omni-directional joystick positions and send out values as well as receive sensor data from the robot. The robot is using Arduino code to receive speed values and send them out to our electronic speed controllers (ESC) as pulse-width modulation (PWM) signals as well as transmit sensor data to the control station.

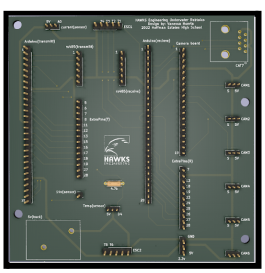
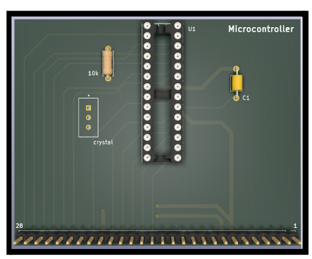
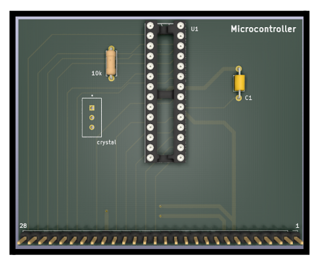
Two buttons have been programmed to allow the pilot to decrease and increase the vehicle's speed. Incorporating these buttons allows the pilot to have control of the vehicle while inspecting the offshore aquaculture fish pen, flying a transect over the Endurance22 wreck, and mapping the wreck.

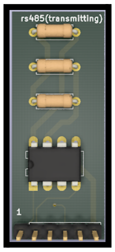
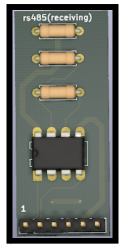
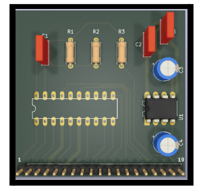
11. Electrical System

11.1 Onboard Electronics

The implementation of the onboard electronics system was done this year to remedy the unreliability of the previous year’s ROV electrical system. The circuitry for H.U.E.R.T.A. had been tested and gone through extensive troubleshooting four months prior to the design of the printed circuit boards. Our company had multiple unknown electrical issues last year which has encouraged the team to test and troubleshoot all electrical components individually to avoid human errors and identify unknown variables in our system. One of our biggest issues was electrical noise on our power line that was caused by our electronic speed controllers (ESC). We fixed these issues by adding six 10,000uF capacitors to our power line. This solved all the other issues caused by the electrical noise in our system. Due to these tests, our team has successfully designed a robust and reliable electrical system.

HAWKS Engineering designed six custom printed circuit boards, a description for each board is provided below.

Passive Backplane board	**Receiving microcontroller**	**Transmitting microcontroller**
		
This board was designed to make connections between electrical components and house bus connectors. These connectors allow the team to easily remove each board for troubleshooting and maintenance. Due to this design, if an issue were to arise these boards can be easily replaced, which cuts down the amount of time and labor needed to solder new boards.	This board is equipped with an ATMEGA328 IC. We have uploaded code to this IC which allows us to select cameras and send PWM frequencies to our ESCs as well as decipher data packets sent via python code from the control station. ● Six ESC signals are connected to the PWM pin outputs. ● Camera selectors are connected to the digital outputs.	This board is equipped with an ATMEGA328 IC. We have uploaded code to this IC which allows us to control the vehicle's sensors and collect their data as well as transmit data packets that can be deciphered by Python code at the control station. **Sensors** ● The current sensor connects to a digital input. ● All voltage sensors connect to digital inputs. (**3.3v, 5v, and 12v**) ● The temperature sensor connects to a digital input.

Transmitting RS-485 module	Receiving RS-485 Module	Camera board
		
This board is equipped with an RS485 IC, connecting this IC directly to 5 volts gives us the ability to transmit data.	This board is equipped with an RS485 IC, connecting this IC directly to ground (GND) gives us the ability to receive data.	This board is equipped with a MAX455cpa (video multiplexer/amplifier) and a voltage pump provides -5 volts which are critical to the video multiplexer functionality. This video multiplexer has the ability to provide video feed for 8 cameras. • Six camera signals are being sent to the camera board and only 1 camera is being displayed on the control station monitor.

11.2 Main Electrical SID

View appendix B.

11.3 Cameras

H.U.E.R.T.A. is equipped with 6 cameras that have been securely mounted on areas of the vehicle that allow the pilot to have the most insightful view of the payload tools and their surroundings.

11.4 Tether

The ROV's tether consists of an 8 gauge power and ground cables, shielded CAT 7 cable, and four pneumatic lines. Buoyancy foam has been attached to the tether making it slightly positively buoyant which prevents interferences with tasks. The four pneumatic lines are connected to manual lever valves that allow the pilot to control the pneumatic manipulators from the control station. The CAT 7 cable is used as a communication line between our control station and ROV. Shielded CAT7 is being used because it significantly improves noise resistance and prevents signal interference. All cables are neatly encased in a black Flexo PET braided sleeve which can be coiled around the frame of the ROV, making transportation easy.

12. Build vs. Buy

Building custom parts offers many advantages including cost-effectiveness and customizability. This can be seen in the design of the company's manipulators. These manipulators were welded out of aluminum or cut out of HDPE which gave the company freedom over the design. These manipulators were relatively cheap to manufacture and have been tailored to fit this year's mission tasks.

Another custom-fabricated part of the ROV is the frame, which was milled out of sheets of High-Density Polyethylene (HDPE) using a CNC router. This process gave the team a great degree of freedom while designing.

Buying commercial components is also sometimes necessary, as it can offer a fast and often more reliable solution to any problem. For example, the vehicle's pneumatics system is composed of commercial products as it is far more time and cost-effective. This yields dual advantages: the pneumatic system has the reliability of commercial components while still allowing for the flexibility of a custom-built part.

13. New vs. Re-used

In determining which parts would be bought new and which parts would be reused from previous designs, the team had to carefully consider both cost and ROV performance. The team opted to buy new in areas that were critical to this year's contract and overall ROV performance while reusing what we could to reduce both costs and the company's impact on the environment.

Six T200 thrusters were purchased from Blue Robotics. These are extremely popular, high-performing, and reliable thrusters that the team felt were worth the relatively high cost. Also purchased new were two Aikon 4 in 1 ESC which uses a variety of bleeding-edge technologies in hardware and firmware that allow the pilot to control four thrusters with one ESC; the benefits of using these electronic speed controllers allow for saving space, money, and time programming.

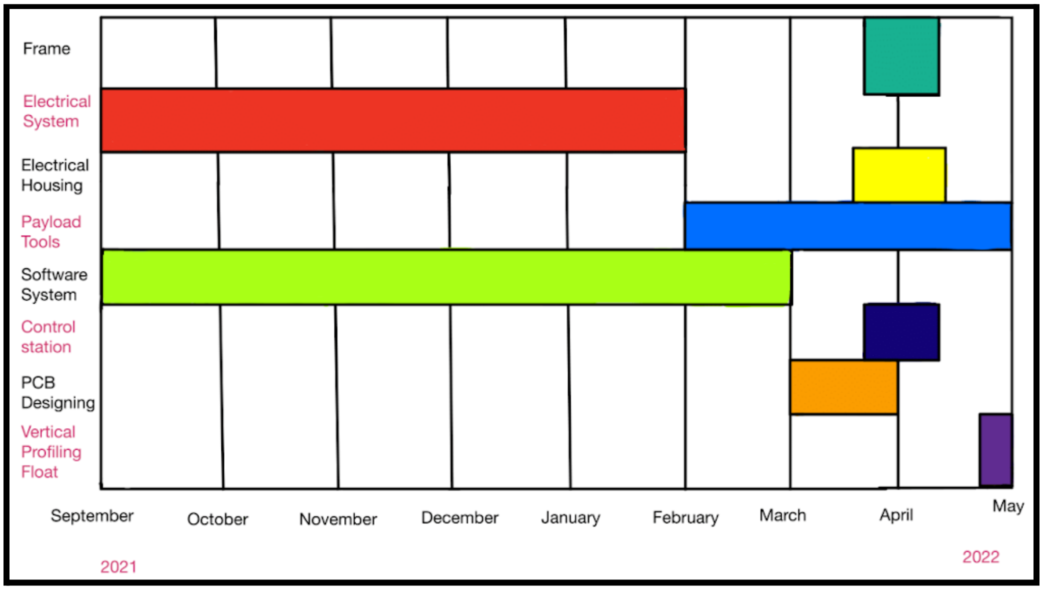
Re-used components for this year's ROV include the monitor, pneumatic system, joystick, and adjustable penetrators, among other things. These were all high-cost items, where buying new offered no real performance advantages.

14. Project Management and Teamwork

14.1 Scheduling and Planning

To tackle such a large operation, the CEO kept an itinerary to get the most done in the team's time together. In order to create an itinerary, the CEO would communicate with her employees through the team's personal group chat and ask them for their weekly schedule. Once the team was aware of each other's availability, they would decide on what days to meet as well as what should be accomplished on those days. This weekly procedure allowed the company to have an extremely successful production of H.U.E.R.T.A.

14.2 Project Timeline



14.3 Organization

Even though this project consisted of several moving parts, HAWKS Engineering was able to stay organized through it all. The team credits this success to the CEO's ability to keep a strict agenda as well as each member's full commitment to the team.

In terms of resources, Imessage and Gmail were our company's primary applications for communication. To complete our work, the team utilized Google Docs to be able to collaborate on the same document simulationaly. Additionally, a Google Drive containing files and data accumulated from the company's history is made accessible to every member. This ensured a reliable source of information members could access when producing documentation or troubleshooting systems.

14.4 Problem Solving - Interpersonal

Like all other companies, HAWKS Engineering would constantly encounter obstacles over the course of this project. The team would deal with these occurrences by taking a moment to identify the type of issue along with its cause. Once the company had a firm understanding of the situation, employees would brainstorm potential solutions. Time and resources were indispensable, therefore members would have to take this into account when evaluating the ideas given by their peers. Whichever solution proved to be the most promising would be selected by the team and implemented in the ROV. Following these steps led the company to a swift and efficient resolution.

14.5 Team Composition

Due to the fact that this is most members' first year on the team, roles were assigned with respect to the CEO's observations. The CEO observed members as they took on different responsibilities and evaluated their performance. Once she had a good grasp on their strengths and weaknesses she entrusted them with different tasks that they would be comfortable with. Team members relied on each other to check their work and confirm it meets company standards. Each employee takes their job seriously and puts in the effort it takes to produce the best results for HAWKS Engineering.

15. Safety

15.1 Safety philosophy

HAWKS Engineering is a company dedicated to not only ensuring the stability and safety of the environment but also the individuals performing that effort. While constructing H.U.E.R.T.A., all members were made aware of safety protocols and routinely practiced safe habits like tying back any long hair, wearing safety glasses while operating machinery, and maintaining a close watch of operational tools in the workshop until they are completely shut down. Any members seen incorrectly handling tools are promptly addressed and shown by a more experienced member of the proper methods necessary so as to not repeat the mistake again.

During the initial and concluding phases of the ROV's operation, members of the company can be seen wearing hard hats and safety vests to ensure clear visibility to others in the area. Additionally, when entering a work environment, a designated safety manager steers the team clear of any potentially hazardous objects that would otherwise hinder the company's ability to accomplish missions successfully and safely.

HAWKS Engineering's commitment to safety is further indicated by the numerous safety features implemented in the ROV itself. All easily accessible and visible edges of H.U.E.R.T.A. have been sanded and filed down so that individuals handling the ROV cannot accidentally cut themselves. The tether cable has been strategically placed on the very top of the ROV rather than on any of the sides to mitigate the chances it gets caught under or in the thrusters. Additionally, the tether is encased in mesh to avoid unnecessary entanglement and complications. Thruster shrouds were manufactured in-house out of acrylic to be positioned on both open ends of the thrusters to not only prevent user injuries but also to ward off stray objects in the water from getting sucked in and potentially obstructing the ROV's only source of propulsion. Vibrant pink hazard stickers can be found around the ROV to let users know to proceed with caution whenever handling moving components such as the thrusters. Concerning our control station, there is a kill switch to quickly cut power in case of an emergency with our systems. A 25 Amp fuse is hooked up between the MATE 12VDC power supply and our control station to prevent fires, electrical shock, and damage to our control station from an overload of current.

15.2 Safety checklist

Performing a safety check prior to every product demonstration is vital to ensure that all safety measures are followed by our company members. View appendix A for checklist.

16. Critical Analysis

16.1 Testing and Troubleshooting

Electrical and Software system	Identify issues and remove variables. Once the issue is resolved, add new variables and test until the system is satisfied.
Payload tools	Create a simple design and test this design until it is proven to be functional. If it isn't functional repeat the process above.
Thrusters	Run the thruster cycle in water and identify which thruster is non-functional. Turn off power and open the thruster housing to perform a visual inspection. If the thruster is damaged, replace the component and test again.
Leak in housing	Perform a vacuum test and document how fast the leak is. Once this is done, remove electronics from housing and pressurize the housing to 3 psi. While doing this, submerge underwater and watch for air bubbles, locate faulty connection and replace it. After replacing components, perform a vacuum test of 11in-hg for 30 minutes.

17. Accounting

17.1 Budget

HAWKS Engineering did not want to spend more than $4000.00 on this project. To make sure the company respected this budget any purchases had to be approved by the CEO. Each purchase was planned and had a good justification. Additionally, to keep costs down HAWKS Engineering asked for donations. Thanks to supportive community members the company was able to benefit from free welding lessons and materials that contributed to the creation of our electronics housing. The company was also able to receive our PCBs free of charge.

17.2 Project Cost

View appendix E.

18. Lessons Learned

18.1 Technical

When building the ROV, the company kept in mind the obstacles we've encountered in previous years to guide us. By taking time to reflect on past issues the team was able to comprehend where these problems were coming from. This strategy helped us anticipate the issues we would be facing before they even appeared.

18.2 Interpersonal

Having a team with so few and inexperienced people required each member to gain new insight when it comes to teamwork. As a company, each member learned to establish a solid team dynamic where everyone felt safe and respected. Throughout the project, the inexperienced members were able to transition from to fully contributing members of the company. On the other hand, the company's CEO was able to gain new experience as the overseer of this operation. By working with a completely new team she was able to acquire leadership skills that will be sure to come in handy in her future projects.

18.3 Skills

The manufacturing of the ROV gave new members the opportunity to pick up different sets of skills. First-year employees were introduced to equipment at our school that they had never interacted with. With the help of our mentor, members learned to properly use the machines and take the proper precautions to operate them safely. By having members acquire many different abilities, the team's skills are kept sharp.

19. Future Improvements

Although H.U.E.R.T.A. is the most reliable and innovative vehicle HAWKS Engineering has produced, the company would like to challenge themselves to add a ballast system, incorporate more sensors, and design a more robust software system. Along with all the system improvements we hope to accomplish, a goal we have set for ourselves is the recruitment of new members, especially people who specialize in the financial part of this operation. With our new members we hope to spread the joy of aquatic exploration throughout our community.

20. References

"T200 Thruster Technical Details." Blue Robotics, *www.bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster-r2-rp/*

"Tx for Arduino" PowerBroker2, *pySerialTransfer/tx_data.ino at master · PowerBroker2/pySerialTransfer · GitHub*

"Tx for Python" PowerBroker2, pySerialTransfer/tx_data.py at master · PowerBroker2/pySerialTransfer · GitHub

"Rx for Arduino" PowerBroker2, pySerialTransfer/rx_data.ino at master · PowerBroker2/pySerialTransfer · GitHub

"Rx for Python" PowerBroker2, pySerialTransfer/rx_data.py at master · PowerBroker2/pySerialTransfer · GitHub

21. Acknowledgments and Sponsors

HAWKS Engineering is very appreciative of the opportunity to participate in the MATE ROV Competition. We would like to acknowledge the following for contributing to the success of the company:

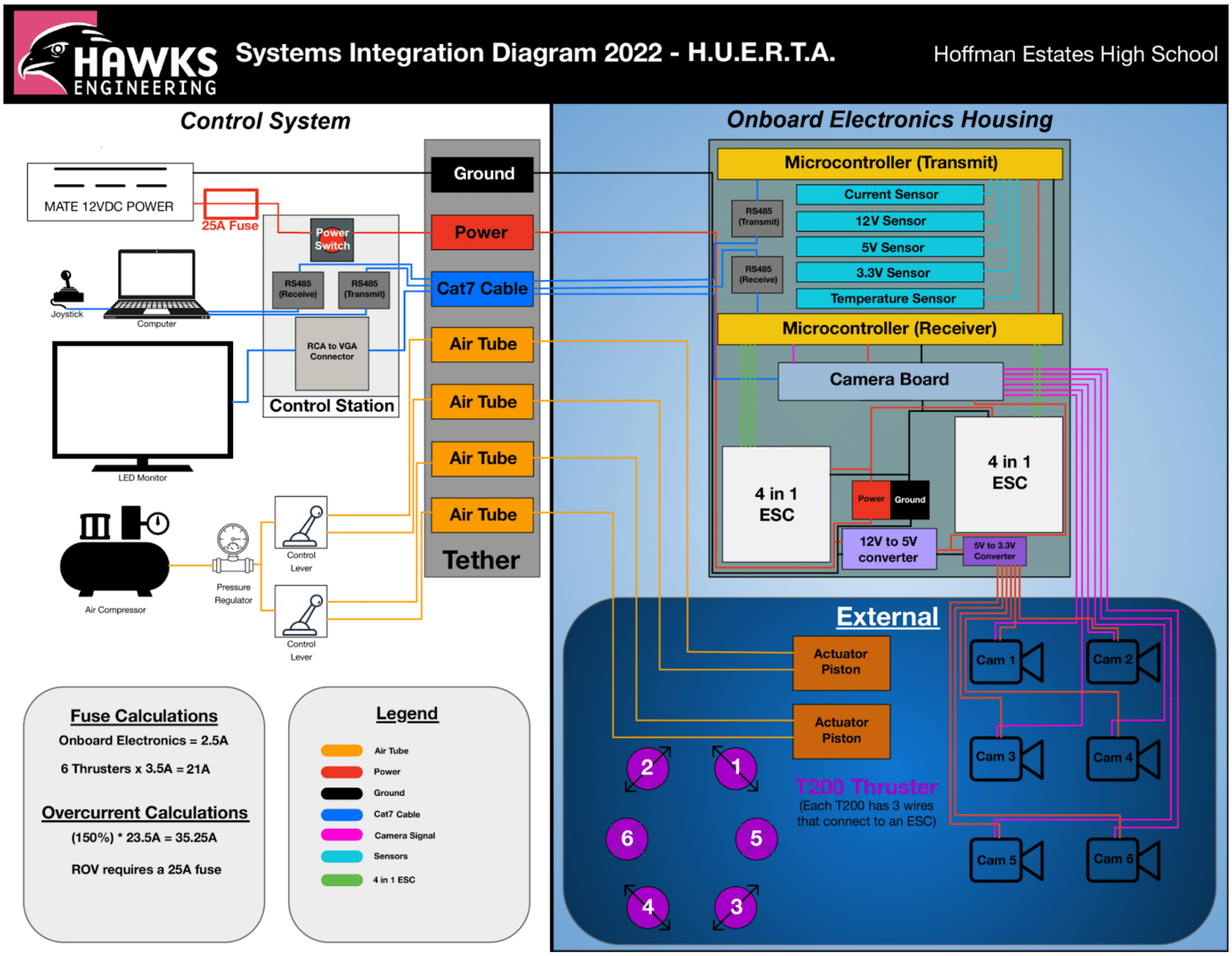
- Mr. Wayne Oras Jr., our mentor, has supported us with technical and non-technical advice throughout our design process.
- Mr. Carlos Guillen for teaching the company's CEO how to TIG weld aluminum.
- Mr. Miguel Cruz for donating aluminum.
- Mr. Jeff Bird for proof reading our technical report.
- Mr. Adam Long for providing the company with software advice.
- Pratish Patel and Sanjay Shah for manufacturing our PCBs free of charge.
- Long Beach City College for hosting the 2022 MATE International ROV Competition.
- The MATE Center - Jill Zande (Competition Coordinator), Matt Gardner (Competition Technical Manager), and all the MATE Center staff, volunteers, and judges for making the MATE International ROV Competition possible.

22. Appendices

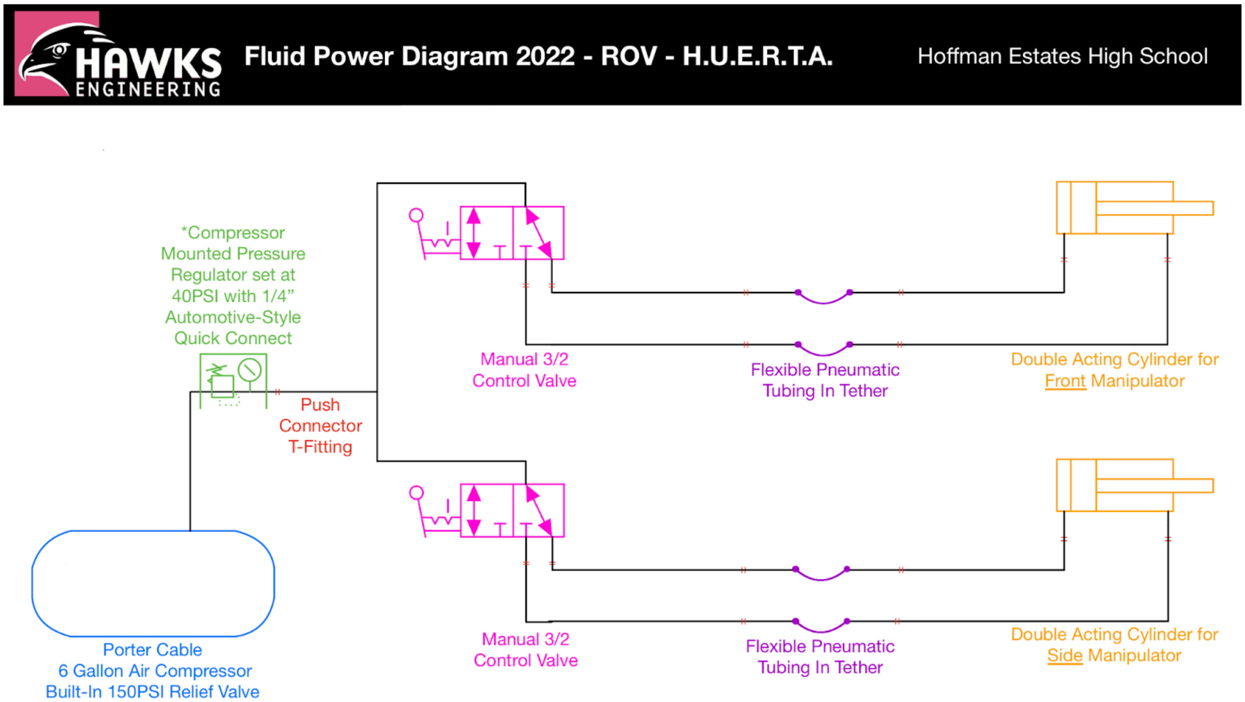
22.1 Appendix A - Safety Checklist

In Workshop	On Deck
General Precautions ● Keep a clear workplace ● Proper safety gear for specific situation is worn ● Equipment is kept properly ● Area clear of tripping hazards Soldering ● Wear safety glasses ● Work in a clear area ● Let others be aware you are soldering Using Power Tools ● Wear safety glasses ● Keep a clean workspace ● Let others be aware you are using power tools	Setting Up ● Clear the area ● Tether is attached securely and being managed ● All components are in power strip ● Power supply is off ● No exposed wires ● Attach the ROV's power supply ● Connect compressor to pneumatic system Power Up ● Ensure team members are attentive ● Communicate the power will be turned on ● Power on ● Monitor and control station up and running ● Perform thruster test ● Check video feeds ● Test pneumatic manipulators Launch ● Notify the team that launch is initiating ● Crew members handling ROV call out "ready" ● Deploy the ROV ROV Retrieval ● Pilot announces ascension ● Deck crew waits for thrusters to be stopped ● ROV is carefully lifted from the water Loss of Communication ● Restart ROV ● Check if there are any red lights on the board ● Restart program ● Resume mission if communication is restored Maintenance ● Check if the thruster propellers are spinning freely ● Check electronics are working properly ● Check if there is any damage to any of the components ● All cables are neatly secured ● Screws and nuts are tight

22.2 Appendix B - Main Electrical SID and Fuse Calculations



22.3 Appendix C: Fluid Power Diagram SID



NOTES:

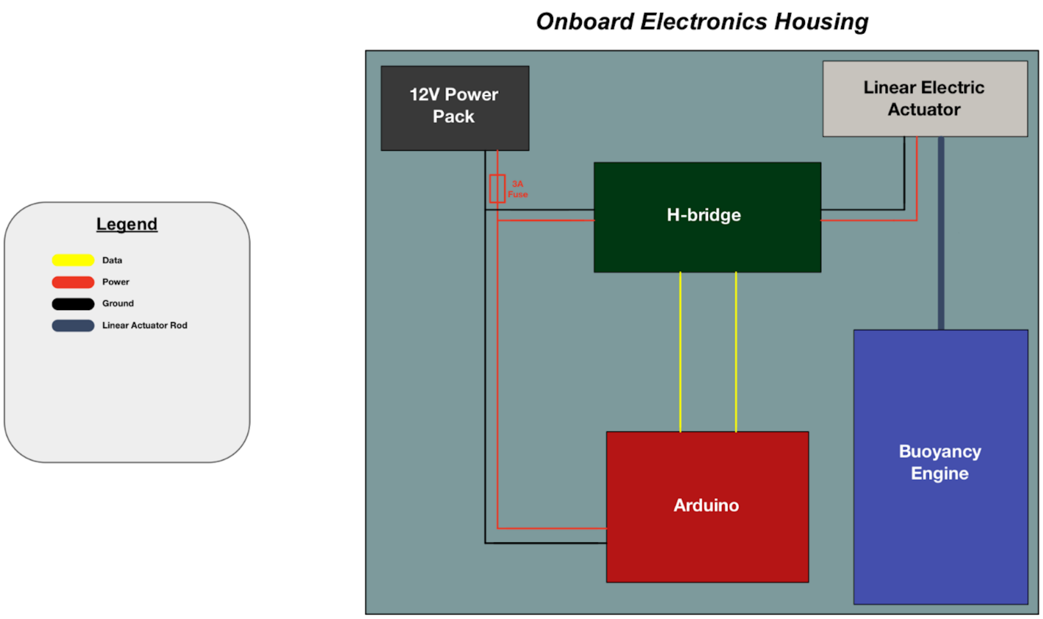
- Tubing, Push Connectors, Double Acting Cylinders, and Control Valves rated at 100PSI
- Push Connectors installed on Double Acting Cylinders, Control Valves and Automotive-Style Quick Connect

22.4 Appendix D: Finances

Category	Amount Spent (USD)	Reused	Market Value
Travel			
Hotel	N/A	$3,022	$3,022.00
Gas	$1,055	N/A	$1,055
Van Rental	$1,132	N/A	$1,132
Registration Fee	$200.00	N/A	$200.00
ROV & Profiling Float			
(6) Blue Robotics T200 Thrusters	$1,416.00	N/A	$1,416.00
(6) Electronic Interconnect Custom PCBs	$0.00	N/A	$400
25ft Power cord	N/A	$26.40	$26.40
(2) Balmain Mini Air Cylinders	$14.66	N/A	$14.66
Alex Tech 100ft Braided Sleeving	$16.99	N/A	$16.99
(2) Heraihe Hall Current Sensor Module	$25.99	N/A	$25.99
DROK Buck Volt Converter	$17.99	N/A	$17.99
(4) HGLRC 30A ESCs	$46.99	N/A	$46.99
(2) Aikon AK32 4-in-1 ESCs	$135.99	N/A	$135.99
DROK Micro Electric Buck Volt Converter	$11.99	N/A	$11.99
ELECFUN Terminal Connectors	$16.99	N/A	$17.99
Oracal Glossy Permanent Pink Vinyl	$6.95	N/A	$6.95
Paracord Planet 100ft neon pink paracord	$13.49	N/A	$13.49
(10) ANMBEST RS-485 Modules	$9.99	N/A	$9.99
smseace SPL-3 Connector Clamps	$15.36	N/A	$15.36
VUAOHIY SPL-62 Connector Blocks	$14.99	N/A	$14.99
Acer Racing 50ft 8 Gauge Copper Wire	$169.99	N/A	$169.99
VELCRO Mounting Tape	$19.99	N/A	$19.99
VELCRO Black Cable Ties	$11.40	N/A	$11.40
(5) PoiLee 1000uf Capacitors	$8.68	N/A	$8.68
beduan Clear Pneumatic Tubing Pipe	$68.99	N/A	$68.99
daier Jst Connector Plug with Wires	$8.59	N/A	$8.59
(2) Tnuocke Grounding Bus Bars	$11.99	N/A	$11.99
Comimark Current Sensor Module	$12.99	N/A	$12.99
Dahszhi Pin Header Connectors	$9.99	N/A	$9.99
(6) St !GIANTMAN camera lens	$78.00	N/A	$78.00
E&T Plastics 1/2" Thick Black HDPE	$210.00	N/A	$210.00
(2) Blue Robotics O-Ring Flanges	$70.00	N/A	$70.00
Eplastics 6ft Acrylic Tube	$440.16	N/A	$440.16
DasMarine Linear Actuator	$31.95	N/A	$31.95
mxuteuk nylon wire protector joints	$9.66	N/A	$9.66
WERTYCITY 500mL Large Syringe	$14.99	N/A	$14.99
Control Station			
(2) DSD TECH USB to RS485 Cable	$31.99	N/A	$31.99
Logitech G Extreme 3D Pro Joystick	N/A	$39.99	$39.99
(2) SNS Hand Valves	$29.99	N/A	$29.99
XXONE 200ft Cat 7 Ethernet Cable	$68.99	N/A	$68.99
Verbex Telecom Cat 6 Keystone Jack	$10.99	N/A	$10.99
YUANTUO Motor Plug Receptacle Set	$61.99	N/A	$61.99
Nilight Battery Disconnect Switch	$14.99	N/A	$14.99
BULVACK Power Connectors	$17.99	N/A	$17.99
W-NECTOUN RJ45 Cat 6 Plugs	$14.80	N/A	$14.80
Fosmon VGA to RCA Adapter	$15.99	N/A	$15.99
(2) ANMBEST Socket Plug Panel Mount	$14.49	N/A	$14.49
(2) UMLIFE RJ45 Cable Couplers	$11.99	N/A	$11.99
Miady Flanged Inlet Receptacle	$18.67	N/A	$18.67
(2) briidea Motor Plug Receptacle Sets	$55.99	N/A	$55.99
Conext Link 25A Fuse Holder	$5.99	N/A	$5.99
(2) RIDGID Black Organizer Box	$49.99	N/A	$49.99
RIDGID Black Gear Cart Tool Box	$59.97	N/A	$59.97
Sceptre LED Monitor	N/A	$66.98	$66.98
Overall cost			
ROV - H.U.E.R.T.A.	$9,369.92	N/A	$9,369.92

22.5 Appendix E: Vertical Profiling Float SID

Systems Integration Diagram 2022 - Profiling Float Hoffman Estates High School



NOTES:

- Linear Electric Actuator draws 0.81A during pool testing.
- 3A Fuse is the maximum current draw of the Linear Electric Actuator.
- 12V Power Pack is 8 x 1.5V AA Batteries in series.
- Buoyancy Engine is a 500mL syringe.