Hoffman Estates High School
Hoffman Estates, Illinois, USA
2021 MATE INTERNATIONAL COMPETITION

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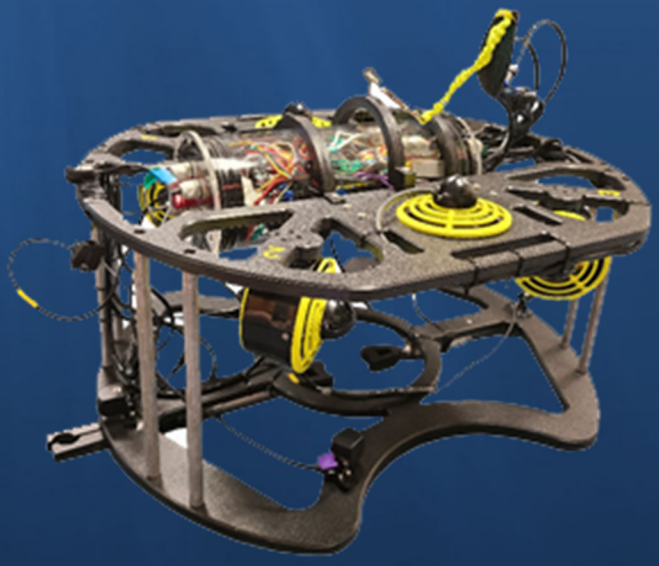
Sindhuja Bonagiri: CFO, Software Engineer, Co-Pilot

Wayne Oras, Jr: Mentor

Amber Dellacqua: Mentor



## *Abstract*

HAWKS Engineering is a company of three female students located in Hoffman Estates, Illinois in the United States of America. HAWKS Engineering has been designing and manufacturing Remotely Operated Vehicles (ROVs) for seven years.

This year, the Marine Advanced Technology Institute (MATE) has asked for an ROV that can clean up the plastic found in oceans, help monitor and nurse coral reefs back to health and analyze contaminants found in waterways. HAWKS Engineering has created an ROV that can effectively accomplish all of the mission tasks that MATE has requested.

The resulting vehicle, J.O.S.H. (Joystick Operated Subsea Helper), is built with a hydrodynamic frame that is used to maintain thruster alignment and secure the electronics dry housing. Inside the electronics housing is a microcontroller that translates joystick positions into vehicle directions accomplished by six thrusters. The ROV is equipped with six cameras, three manipulators and a Micro ROV that allow the pilot to complete the mission specific tasks.

*(Micro ROV)*

## *Design Rationale*

HAWKS Engineering had to consider numerous factors in order to deliver an ROV for waterways and oceans. J.O.S.H. is equipped with three manipulators and a Micro ROV that allow the pilot to retrieve, release and replace mission objects while keeping the surrounding area and marine life undisturbed. In order to enhance mission performance, a major focus was directed towards developing manipulators and a Micro ROV. The first manipulator is located at the bottom front of the vehicle which was designed to replace and release the power connector from the seabin's power port. The second manipulator is located at the bottom center of the vehicle which allows the pilot to efficiently retrieve and release the eel trap, mesh catch bags, coral fragments, sea star injection devices, and bottom debris. The third manipulator was specifically designed to aid the pilot in retrieving the surface debris. The Micro ROV was designed to retrieve the sediment sample located in the drain pipe.

## *Mechanical*

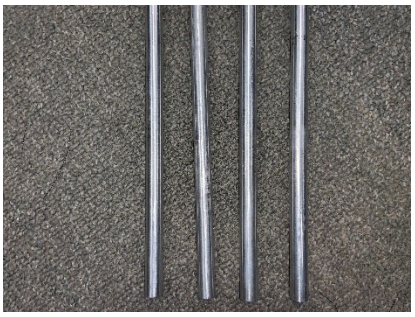
### Frame

The company designed J.O.S.H.'s frame keeping in mind quick access to payload tools, specific thruster alignment and the ability to manufacture components in the workshop. The final frame dimensions are 58.42 cm in diameter and 25.4 cm in height, which allows the user to place manipulators and cameras in accessible areas of the vehicle.

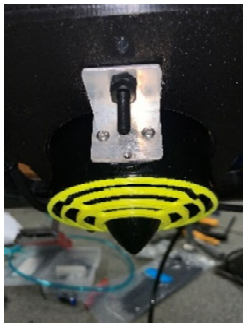
The frame was constructed using High Density Polyethylene (HDPE), which is slightly positively buoyant, recyclable and an environmentally safe material that does not emit toxins. The top of the frame has handle cutouts that allow users to safely pick up the ROV, while the bottom has specific cutouts which allow water flow from the vertical thrusters. Housing holders were created to secure the electronics housing in place while allowing the user to access and remove the housing from the frame.

*(Frame)*

The ROV's frame is held together by aluminum rods which provide stability to the frame. Aluminum L-brackets were used to securely hold the vertical thrusters in place. Aluminum was selected due to its lightweight, non-corrosive properties, malleability, durability and infinite recyclability.



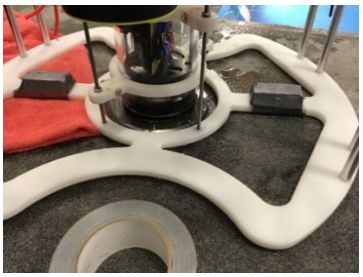
*(Aluminum rods)*



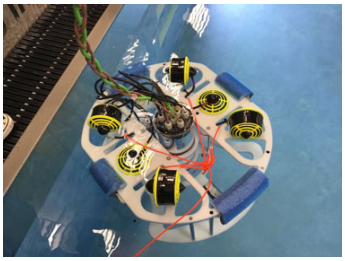
*(Aluminum L-brackets)*

## Buoyancy

The company performed multiple tests in the pool using weights, buoyancy foam, old frames and an acrylic housing. The ROV was negatively buoyant due to the electronics in the acrylic housing, aluminum rods, pneumatic pistons, thrusters and bolts. Floatation devices are attached to the frame making it neutrally buoyant.



*(frame with weights)*



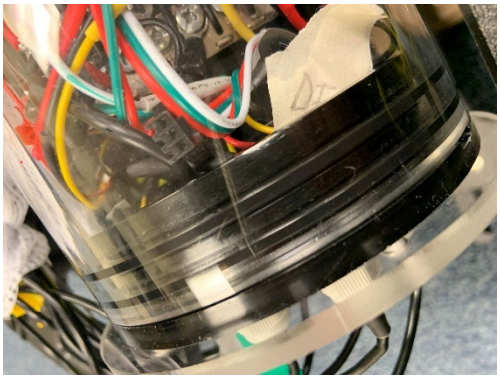
*(frame with buoyancy foam)*

## Electronics Housing

The electronics housing is an acrylic tube that is lightweight and impact resistant. The tube has an aluminum flange at each end that creates a watertight seal using three O-rings. A custom made acrylic end cap is attached to each flange that allows cables to enter and exit the housing at both ends. These cables are held in place by adjustable waterproof penetrators.

*(Front endcap)*

*(Back endcap)*

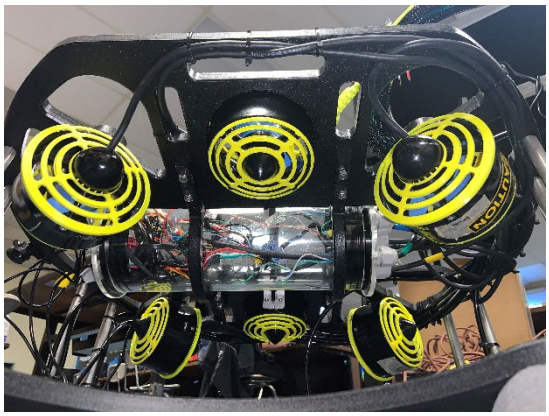


*(O-rings)*

## Propulsion

The ROV is equipped with six Blue Robotics T100 thrusters which are specifically designed for marine robotic use. Their high performance provides up to 22.24 Newtons of thrust, allowing J.O.S.H. to efficiently move through the water. Four of the six thrusters mounted at 45 degree angles provide cardinal, ordinal and rotational mobility. The two remaining thrusters are mounted horizontally on the frame which allow the vehicle to move up and down.

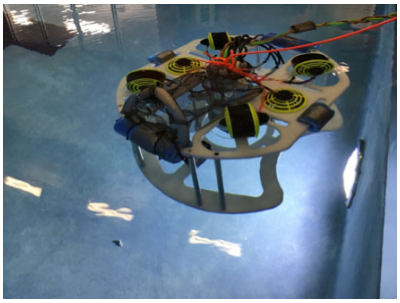
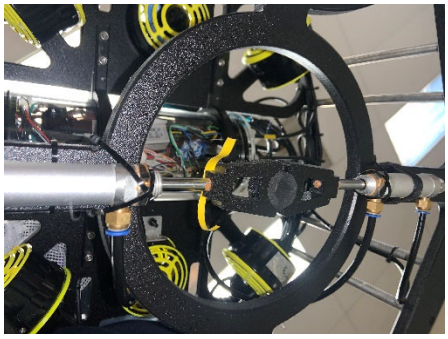

(Top view of thruster orientation)



(Bottom view of thruster orientation)

## *Mission-Specific Tools*

HAWKS Engineering designed two pneumatic manipulators, mesh catch bag, Micro ROV and basket which allow the pilots to efficiently complete mission tasks. The pneumatic manipulator located at the front of the vehicle is designed to disconnect the power connector from the seabin power port. The mesh catch bag manipulator is designed to retrieve surface debris. The second pneumatic manipulator located at the bottom center of the vehicle allows the pilot to efficiently retrieve, replace and relocate the eel trap, mesh catch bags, coral fragments, sea star injection devices and bottom debris. The basket allows the pilot to carry mission tasks such as the power connector and old mesh catch bag from the seabin, bottom debris and sponge sample while reducing the number of trips spent returning to the surface. Lastly, the Micro ROV is designed to retrieve the sediment sample located in the drain pipe.

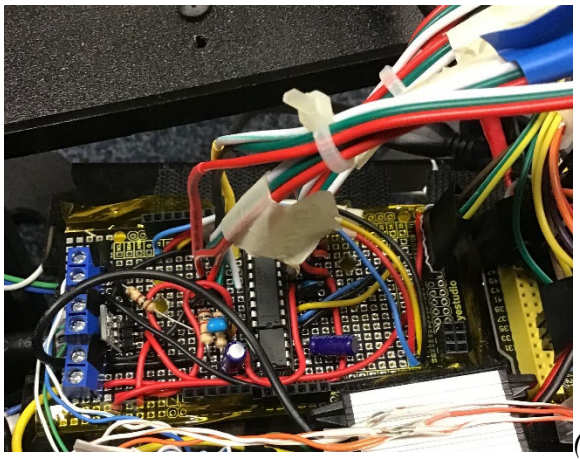




*(Mesh catch bag manipulator) (Manipulator at the bottom center) (Front Manipulator)*

## *Electrical*

Custom Camera Board

The company designed a custom board that is composed of a CMOS video Multiplexer/Amplifier and a DC-TO-DC voltage converter. The custom camera board communicates with the Arduino allowing the pilot to select one of eight analog channels that provide video feed. The DC-TO-DC voltage converter provides positive 5 volts and negative 5 volts to the camera board.



*(Custom Camera Board)*

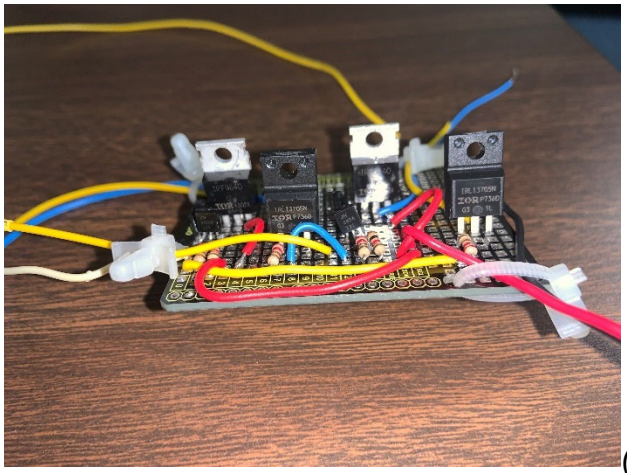
## Cameras

J.O.S.H. is equipped with 6 NTSC resolution cameras that are strategically placed on the vehicle to allow the pilots to see their surroundings and aid them in successfully completing tasks. The 1st camera is placed on the front allowing the pilot to see in front of the vehicle. The 2nd camera is placed inside of the ROV's frame providing feed from each side and back of the vehicle. The 3rd camera is positioned on the bottom of the frame pointing down toward task locations. The 4th camera is placed inside of the mesh catch bag manipulator which allows the pilot to locate the surface debris. The 5th and 6th cameras are positioned to provide video feed of each pneumatic payload tool.

*(NTSC resolution cameras)*

## Custom Micro ROV Board

In order for the pilot to control the Micro ROV, a custom made H-bridge circuit board utilizing MOSFET technology is designed to switch the polarity of the bilge pump motor allowing the Micro ROV to propel forward or backwards.



*(Micro ROV custom board)*

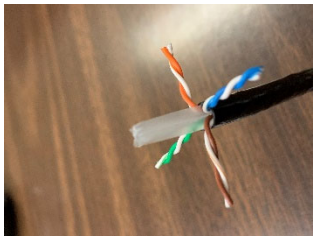
## Tether

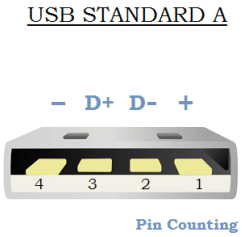
J.O.S.H.'s neutrally buoyant tether is attached to the top of the vehicle to increase mobility while satisfying MATE's safety regulations. The ROV's cables are encased in mesh to avoid tangling and unnecessary stress to the tether. Strain relief is included outside of the mesh jacket which allows the tether manager to safely remove the vehicle from the water without pulling on the cables.

*(Strain relief)*

The ROV's tether is composed of two cables and four pneumatic lines which make the tether positively buoyant. A 14/2 AWG power cable provides power to the onboard electronics. The Cat6 cable allows for communication. The four pneumatic lines within the tether are connected to manual 5/2 lever valves which control both pneumatic manipulators.

The company is using Cat6 cable for communication between the control station and the ROV while also providing video feed to the monitor. The team is also using USB Extenders as they provide reliable communication over long distances. The Cat6 wires are grouped into three conductors that go to complementary USB Extenders to provide DATA IN, DATA OUT and common ground. One pair of corresponding USB Extenders allow communication between the computer and the Arduino while a second pair allows for communication between the joystick and the USB Host shield.





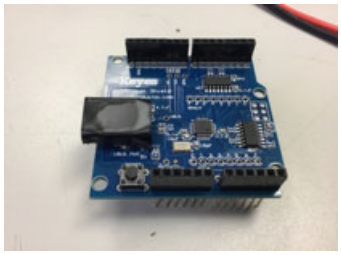

*(USB Extender)* *(Cat6 twisted pairs)*

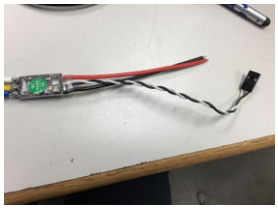
## Control System

A Logitech Extreme 3D Pro Joystick is used to control the ROV's movements by gathering data using the potentiometers and buttons pressed on the joystick. The data from the joystick is read using a USB host shield, which runs on an Arduino MEGA 2560

board. The thrusters are controlled by BLHeli_32 electronic speed controllers (ESCs) which were programmed by the company. The ESCs are driven by the Arduino which sends out pulse width modulation (PWM) signals that control the speed and direction of each thruster.


*(Arduino MEGA 2560)*


*(USB Host shield)*


*(BLHeli_32 ESC)*

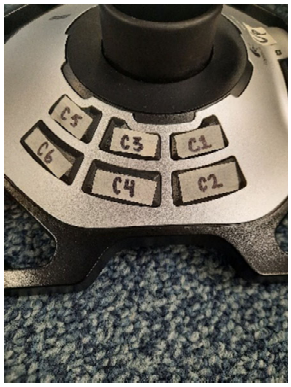

*(Joystick)*

## *Software*

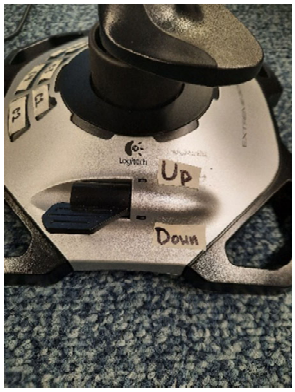
A Logitech Extreme 3D Pro Joystick is used to control speed and direction of the ROV's thrusters. Data is gathered through the potentiometers and buttons on the joystick and read using a USB host shield running on an Arduino MEGA 2560. The Arduino is programmed with C++ based Arduino coding language and uses downloaded Arduino library LE3DP as well as several other commonly available libraries.

The basic directions that J.O.S.H can move are cardinal, ordinal, rotational, and vertical. This was made possible by adjusting the speed and direction of each thruster. Speed and direction are set by Pulse-Width Modulation (PWM) signals using a range of 1100 to 1900 microseconds. At the extreme ends of the range, the thrusters rotate the fastest in opposite directions. As the PWM value is closer to 1500, the thrusters slow down. Additional functions will be further explained in the following figures.

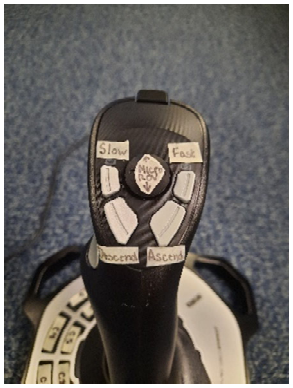
*(Figure 1)*



*(Figure 2)*



*(Figure 3)*



*(Figure 4)*

Figure 1: The buttons labeled on the joystick are functions that have been programmed by the company. Each function controls the ROV's movements.

Figure 2: Each button has been programmed to switch between one of six analog channels.

Figure 3: The throttle switch has been programed to move the ROV up and down.

Figure 4: The hat switch on the joystick has been programmed to control the Micro ROV. The 4 remaining buttons have been programed for specific functions such as slowly ascending and descending as well as increasing and decreasing all thruster speeds.

## *Company Information*

HAWKS Engineering was founded in 2014. The company attended MATE's International ROV Competition in 2015 at St. John's, Newfoundland and Labrador, Canada after coming in 1st Place at the Shedd Aquarium Midwest Competition. This accomplishment was a successful stepping stone in the company's future as well as an inspiration for future team members. In 2019, the company again qualified for MATE's International ROV Competition in Kingsport, Tennessee after coming in 2nd Place at the Shedd Aquarium Midwest Competition.

This year's CEO was a crucial member of the 2019 team, which motivated her to be more successful at the International Competition. In 2019, the company had its first all women's team which has continued through the present. This is the second all women's team HAWKS Engineering has sent to MATE's International Competition. Being an all women's team has inspired the company to work hard and succeed in a traditionally male dominated setting.

Vanessa Huerta (left) is a rising senior at Hoffman Estates High School and this is her third year on the team. She serves as the CEO, Electrical Engineer, Pilot and Documentation Manager.

Sindhuja Bonagiri (middle) is a rising junior at Hoffman Estates High School and this is her first year on the team. She serves as the CFO, Software Engineer and Co-Pilot.

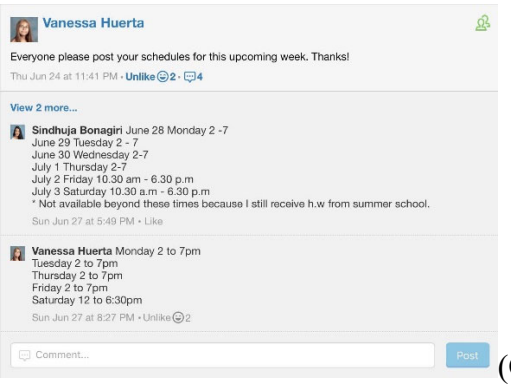
Julia Chom (right) is a rising senior at Hoffman Estates High School and this is her second year on the team. She serves as the Safety Manager, Tether Manager, Fluid Power Engineer and Mechanical Engineer.

## *Project Development*

HAWKS Engineering began the construction of J.O.S.H. in 2019 but due to COVID-19, the finalization of the ROV was delayed. The company was able to assign specific roles that aligned with the members' experiences and encouraged each member to challenge their capabilities by exploring new fields.

### Scheduling

The CEO of HAWKS Engineering emails members every week to provide their schedule in the following format: 06/12 Saturday: available at 1:00pm until 7:00pm. This format made it easy to create a meeting schedule. Additionally, this process eliminated any possible communication issues. Once a schedule has been decided upon, the CEO would relay it to the company's mentor to gain permission to meet during those times. The company meets at least three times a week for a duration of 5 hours each.



(Online school platform)

### Organization and Communication

Organization is an integral part of HAWKS Engineering as it ensures safety and simplicity within every aspect of the company. To organize meetings, all the members of the company state their available times and determined meeting times for each week. In order to stay on track, the team created deadlines at the beginning of each week for the completion of the vehicle. Monthly deadlines were also set for major ROV innovations such as cameras, custom boards and manipulators.

### Interpersonal

HAWKS Engineering knows that it is easy to procrastinate when there is still time until deadlines arrive. The team knows that it is difficult to step up when there are only a few people to shoulder the load. HAWKS Engineering was originally a team of five. However, as time passed and urgency increased, the numbers reduced making it difficult to accomplish the company's goals. These challenges were overcome through an increased meeting schedule and work ethic. Occasionally, when there were disagreements among the team members, they would discuss their perspectives with each other and eventually come to an agreement.

## *Accounting*

### Budget

The budget that HAWKS Engineering enforced was to make meaningful and useful purchases. At the beginning of the year, our company decided on a budget of $3,000 for J.O.S.H. The company firmly believed that the items that were being purchased had extreme benefits and could not be reproduced by the team. (Reference Appendix A-Budget)

### Build vs. Buy

HAWKS Engineering bought from companies that specialize in the construction of components that could not be recreated with the machines in the workshop. Examples of this include Blue Robotics thrusters, bilge pump motors, watertight penetrators, pistons, pneumatic lines and other components.

### New vs. Re-used

This year, HAWKS Engineering was able to reuse many materials that previous teams had used. The company reused Blue Robotics thrusters, pneumatic components and bilge pump motors which have been successfully integrated onto the ROV's frame.

## *Safety*

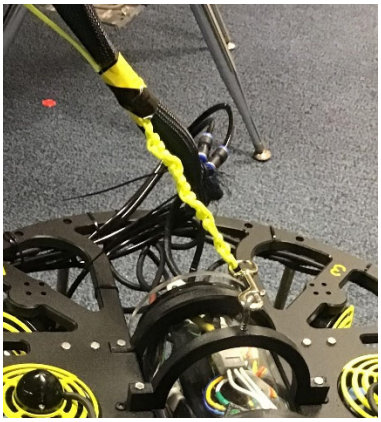
### Safety Philosophy

HAWKS Engineering enforced protocols and procedures to ensure safety amongst team members in the workshop and the pool. Recognizing safe behaviors foster better understanding of protocols, philosophy and practices. The company designed the ROV to have specific safety features that protect marine life, team members, the vehicle and people in the surrounding area.

Shrouds: Protect marine life and team members from the thruster blades.


*(Custom made 3D printed shrouds)*

Strain relief: Allows the team to pull the ROV out of the water without putting strain on the vehicle's cables.


*(Neon yellow rope is strain relief)*

Caution stickers: Alerts people in the surrounding area to take caution when approaching the vehicle and control station.

*(Custom made caution stickers)*

Hard hats: Team members use hard hats when entering the pool in case of falling objects.

Safety vest: Alerts people in the surrounding area to proceed with caution.

Safety goggles: Used to protect the eyes from particles, water or chemicals.

*Safety Rules and Procedures*

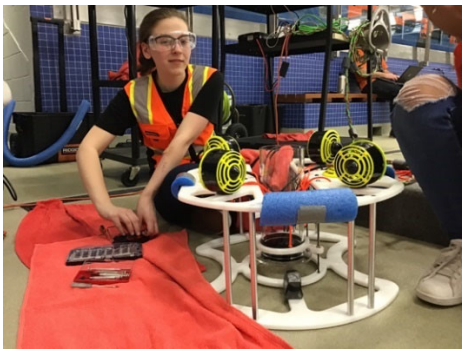
Workshop

1. Team members shall wear safety goggles while using machines and power tools.
2. Team members shall tie up hair before using machines and power tools.
3. Team members shall pull up long sleeves and remove any jewelry before using machines and power tools.
4. Team members shall ask for assistance with machines and power tools when confused.
5. Team members shall wear safety goggles while soldering and keep the work area clean.
6. Team members shall wear safety goggles when pressurizing the pneumatic system.


*(Safety manager cutting HDPE)*

On deck

1. Team members shall wear safety goggles, safety vests and hard hats before entering the pool.
2. Team members shall prevent tripping hazards from being present on the pool deck.
3. Safety manager shall check that every manipulator is secured in place.
4. Pilot shall communicate the status of the ROV to the tether manager.
5. Pilots shall communicate what tasks they will be attempting to the tether manager.
6. Team members on deck shall perform a dip test before launching the ROV.



Emergency procedure

1. The pilot shall communicate the emergency type to the tether manager and the judges.
2. The tether manager shall remove the ROV from the pool using the strain relief.
3. Team members shall stay composed when dealing with the emergency.
4. Team members shall be ready to assess the emergency and fix it.

## *Critical Analysis*

Testing and troubleshooting

The company has had their fair share of problems and are prepared to solve any issue that arises. Due to J.O.S.H.'s unique electronic system the team has become accustomed to problems they have encountered. With these experiences, the team has specifically and thoroughly documented each issue and the troubleshooting process. Depending on the issue that occurs, different troubleshooting processes are implemented. For example, the company has had a large amount of electrical issues that have occurred due to a broken wire, missing connection or human error. The approach to each problem has been the same; eliminate variables and retreat back to what is known to function. There have been many steps and branches to troubleshooting; however, it can be summarized through these steps: isolate and analyze the problem, determine a solution, test and if necessary repeat this process.

Electrical Troubleshooting Process

Broken wire/connection: Test with a multimeter for continuity between connections and resolder or replace connections.

Communication issue: Disconnect joystick or anything that can be disconnected and reconnect the components. If this doesn't work, do research on different troubleshooting methods.

Pneumatic Troubleshooting Process

Leak in the system: Listen closely to each connection and component from a safe distance. When the leak is found depressurize the system and fix the leak.

## *Community Outreach*

In 2019, HAWKS Engineering attended multiple community events ranging from small guided presentations for young aspiring engineers to representing Hoffman Estates High School at GCAMP's regional business meeting. The team sponsored a coding event for young children within our school's boundaries using Sphero robots. The company used this opportunity to inform the Hoffman Estates Committee Board of the purpose of underwater Remotely Operated Vehicles (ROVs) and allowed the company to create a relationship with the town's leaders.

In 2020, the HAWKS Engineering program hosted the regional Purdue National Chain Reaction Competition at Hoffman Estates High School. Approximately 200 elementary and middle school students along with their parents and mentors were able to observe the company's presentation and demonstration about the abilities and uses of ROVs.

*(Sphero coding event)*

*(Meeting with Hoffman Estates Committee Board)*

## *Future Developments*

In the future, HAWKS Engineering wants to expand into hydraulics, different methods for buoyancy, frame designs and control systems. Additionally, the company would like to recruit more young women to encourage them to pursue STEM fields as well as providing a unique experience that can't be obtained in a normal classroom setting.

## *Acknowledgments*

HAWKS Engineering would like to thank the following people:

Mr. Josh Schumacher, Principal for his support and enthusiasm.

Mrs. Kathleen Burley from GCAMP for sponsoring HAWKS Engineering
Previous team members for supporting the company.

Ms. Britney Thomas from the Art Department for screen printing the company's shirts.

Mr. Oras for dedicating his time towards the company and for hosting this year's regional MATE ROV Competition.

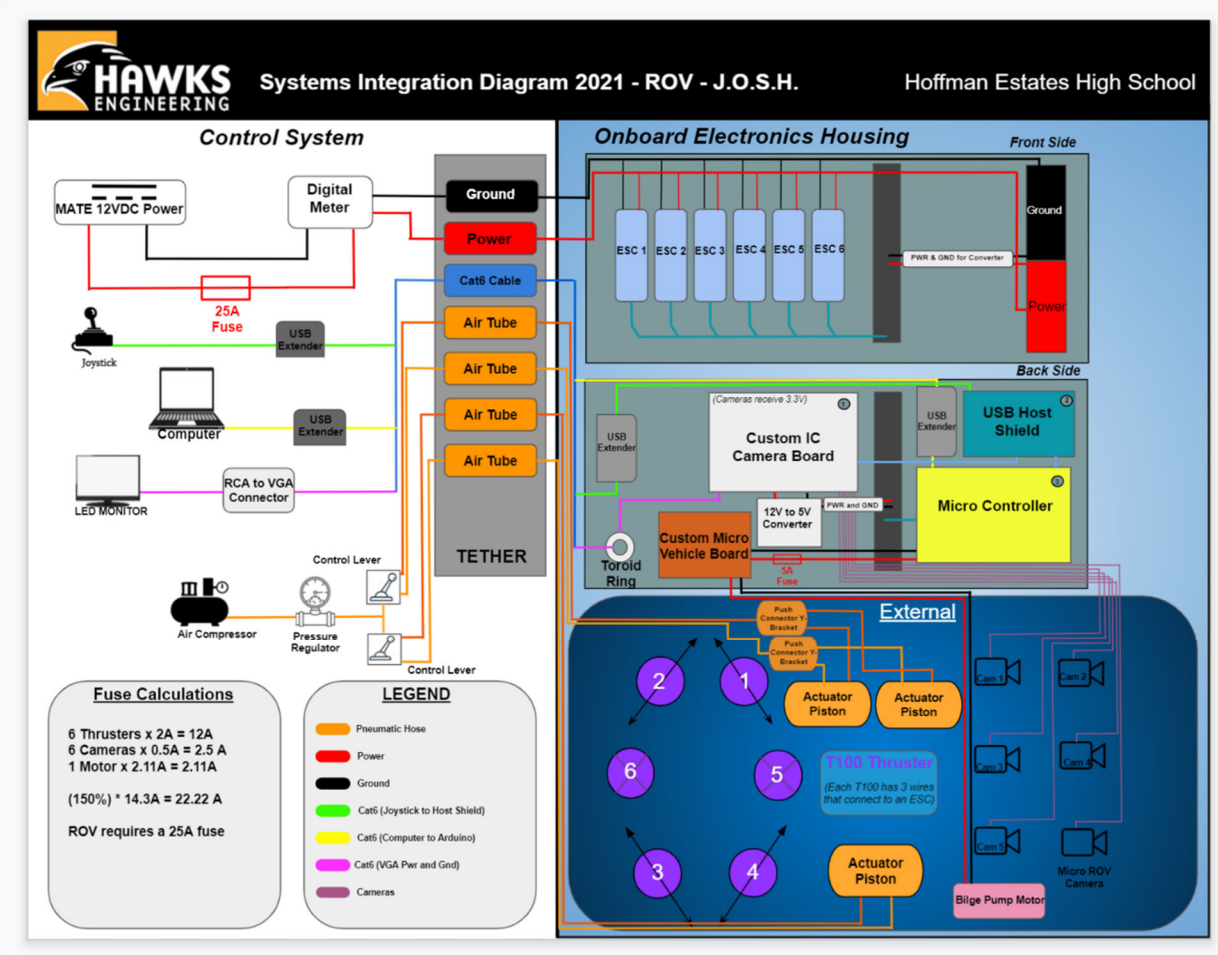
Mr. Miro hodyl for donating electrical components.

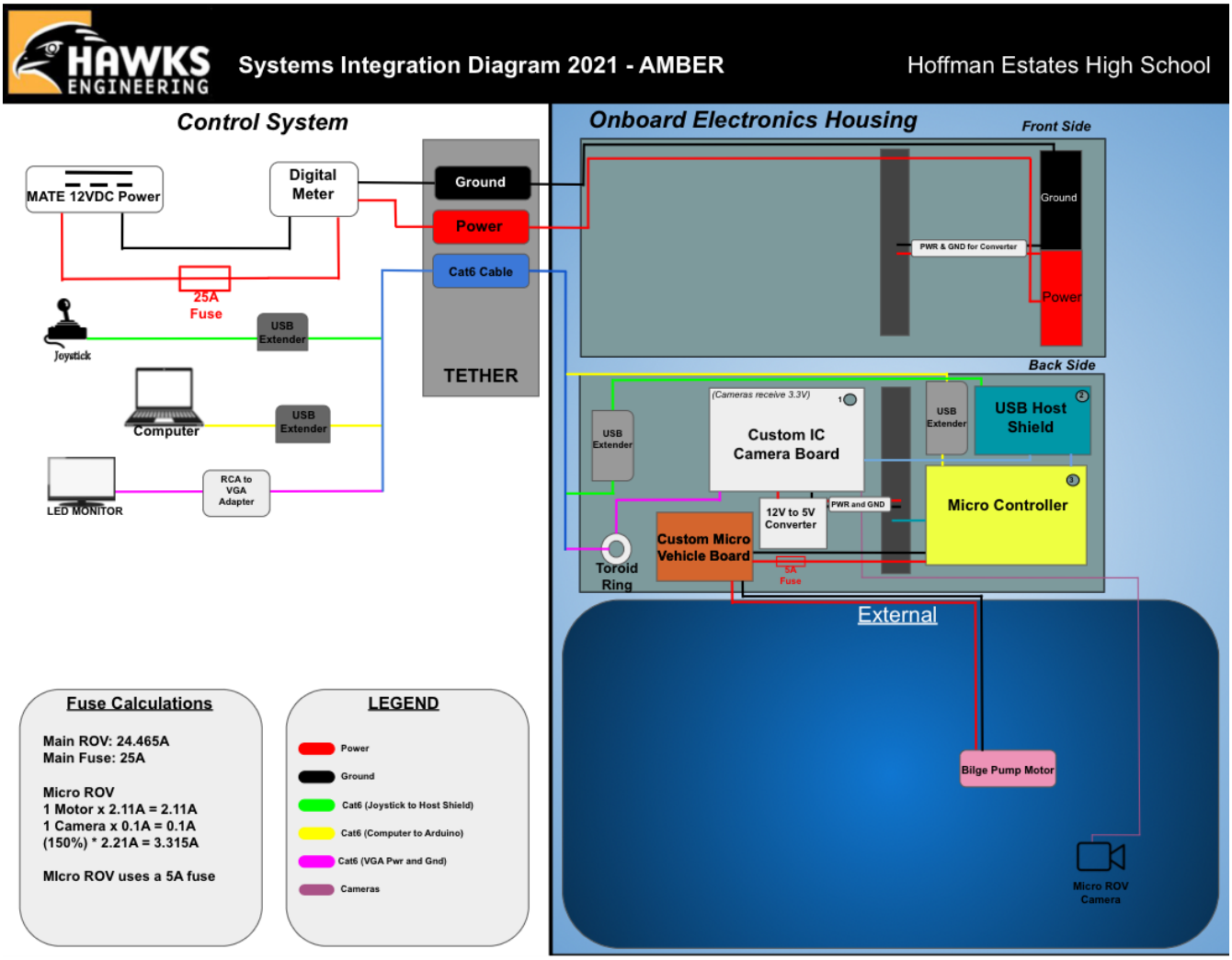
# Appendix A:

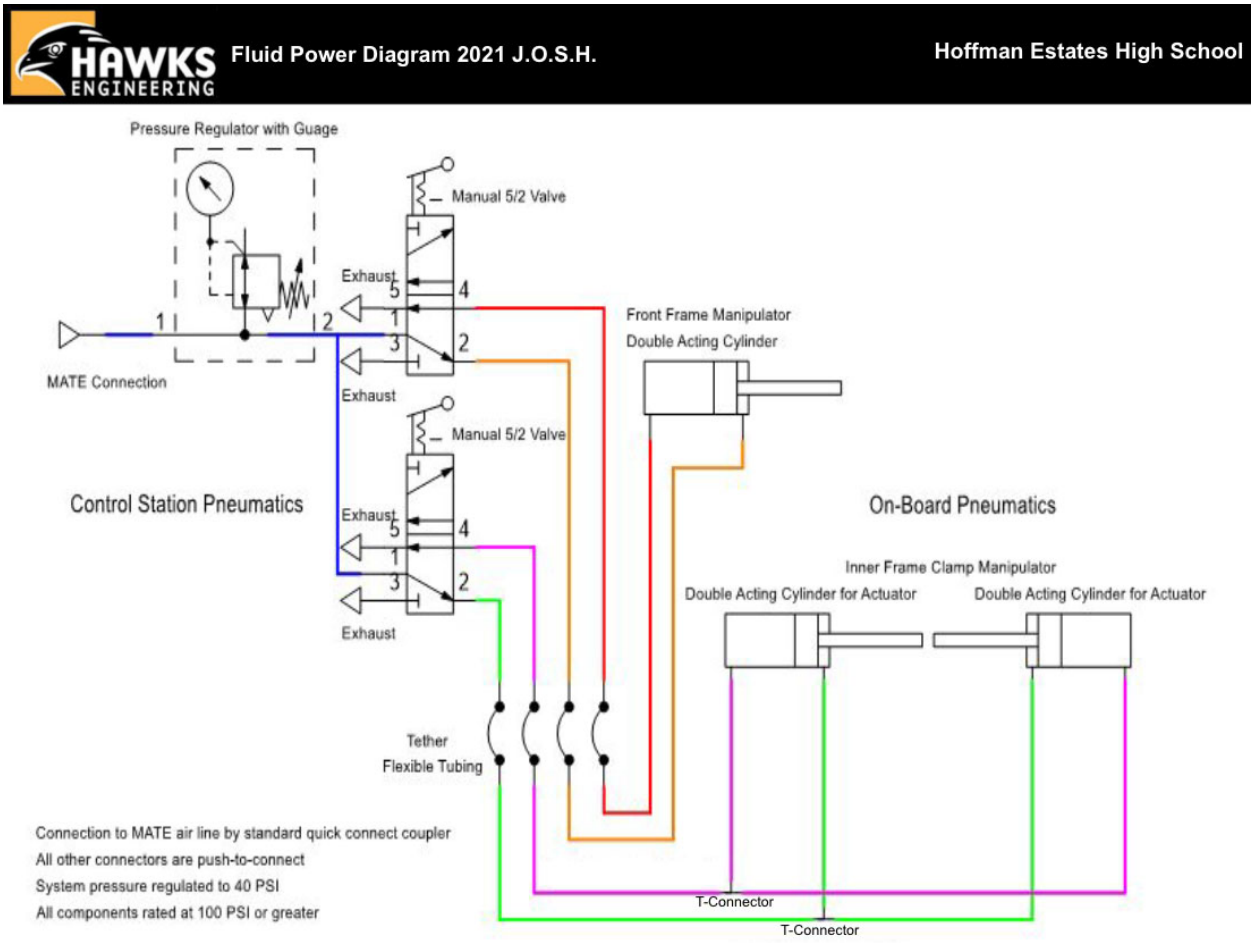
| Category | Amount Spent | Reused | Market Value |
|---|---|---|---|
| 6 HAKRC BLHeli-32 35 A ESCs | $69.00 | N/A | $69.00 |
| 2 Blue Robotics T200 Thrusters | N/A | $338.00 | $338.00 |
| 4 Blue Robotics T200 Thrusters | $676.00 | N/A | $676.00 |
| Blue Robotics Electronics Tray | $49.00 | N/A | $49.00 |
| LED Monitor Ultra Slim Pro Series 20 | $70.00 | N/A | $70.00 |
| 3 NOAUKA Waterproof IP68 Cameras | $45.00 | N/A | $45.00 |
| 1 KEYESTUDIO PCB Prototype Board Shield | $13.99 | N/A | $13.99 |
| 4 IC MAX455CPP+ | $48.24 | N/A | $48.24 |
| 500 ft navepoint Cat6 Cable | $44.77 | N/A | $44.77 |
| 2 iGreely USB Extenders | N/A | $15.98 | $15.98 |
| 2 iGreely USB Extenders | $15.98 | N/A | $15.98 |
| MEGA 2560 prototype PCB Circuit Board | $17.99 | N/A | $17.99 |
| 1 Logitech Extreme 3D Pro | $46.99 | N/A | $46.99 |
| MEGA 2560 R3 | $15.99 | N/A | $15.99 |
| 12v to 5v buck inverter | $9.99 | N/A | $9.99 |
| 4 1/8 Router Bit | $12.72 | N/A | $12.72 |
| 120pcs male to male breadboard jumper | $8.99 | N/A | $8.99 |
| 3 IP68 Rearview Car Cameras | $49.50 | N/A | $49.50 |
| USB Male to Male Connector | $6.89 | N/A | $6.89 |
| USB C Short Connector | $3.99 | N/A | $3.99 |
| Universal Servo Connector Housing | $16.19 | N/A | $16.19 |
| 10 P-Channel MOSFET Transistor, 3-Pin | $8.49 | N/A | $8.49 |
| Basesailor USB Female to Female Adapter | $7.99 | N/A | $7.99 |
| 4 LDO Voltage Regulators 3.3V 1.0A Positive | $2.32 | N/A | $2.32 |
| 25ft Power Cord | $26.40 | N/A | $26.40 |
| TC1044S IC Voltage Charge Pump dc to dc | $3.50 | N/A | $3.50 |
| 3 Wireless Chargers - 5V/12V 1.5A | $6.90 | N/A | $6.90 |
| STMicroelectronics 3.3V. Voltage Regulator | $6.85 | N/A | $6.85 |
| Dell Latitude 5490 | N/A | $1,000.00 | $1,000.00 |
| 2 USB Host Shields | $22.00 | N/A | $22.00 |
| Electrical & Software | $1,305.67 | $1,353.98 | $2,659.65 |
| 4 Aluminum Rods | $32.00 | N/A | $32.00 |
| 4" Acrylic Tube | $190.50 | N/A | $190.50 |
| 54 cm x 96 cm Black HDPE | $105.00 | N/A | $105.00 |
| 1/2 inches Cast Acrylic Sheet | N/A | $234.00 | $234.00 |
| 10 5mm Plastic Penetrators | $40.00 | N/A | $40.00 |
| Bilge Pump Motor | N/A | $20.99 | $20.99 |
| Stainless Steel Eye Bolt | N/A | $3.69 | $3.69 |
| Fluorescent Yellow P430 ABSPlus Cartiladge | $136.00 | N/A | $136.00 |
| Compact Splicing Wire Connectors | $13.99 | N/A | $13.99 |
| SP13 Aviation Connector | $13.99 | N/A | $13.99 |
| Vent and Plug | $8.00 | N/A | $8.00 |

| | | | |
|---|---|---|---|
| Rigid 5 Box - Tool Cart Box | $185.95 | N/A | $185.95 |
| 2 Aluminum Flanges | $48.00 | N/A | $48.00 |
| Mechanical | $772.93 | $258.68 | $1,031.61 |
| 6 Hard Hats | $64.50 | N/A | $64.50 |
| Speed Care First Aid Kit | $13.99 | N/A | $13.99 |
| 3 Polo Shirts | $29.85 | N/A | $29.85 |
| Safety Vests | $132.00 | N/A | $132.00 |
| Safety | $240.34 | $0.00 | $240.34 |
| Team Registration | $100.00 | N/A | $100.00 |
| Lodging | $280.00 | N/A | $280.00 |
| Gas | $160.00 | N/A | $160.00 |
| Traveling & Boarding | $540.00 | $0.00 | $540.00 |
| Heat Shrink | $14.00 | N/A | $14.00 |
| Zip Ties (500 pcs.) | $10.99 | N/A | $10.99 |
| Miscellaneous | $24.99 | $0.00 | $24.99 |
| **Total** | $2,882.84 | $1,612.66 | $4.495.50 |

## *System Integration Diagrams*




HAWKS ENGINEERING
Systems Integration Diagram 2021 - AMBER
Hoffman Estates High School
Control System
MATE 12VDC Power
Digital Meter
Ground
Power
Cat6 Cable
TETHER
25A Fuse
Joystick
USB Extender
Computer
USB Extender
LED MONITOR
RCA to VGA Adapter
Onboard Electronics Housing
Front Side
Ground
PWR & GND for Converter
Power
Back Side
(Cameras receive 3.3V)
Custom IC Camera Board
USB Extender
USB Extender
USB Host Shield
Micro Controller
12V to 5V Converter
PWR and GND
Custom Micro Vehicle Board
5A Fuse
Toroid Ring
External
Bilge Pump Motor
Micro ROV Camera
Fuse Calculations
Main ROV: 24.465A
Main Fuse: 25A
Micro ROV
1 Motor x 2.11A = 2.11A
1 Camera x 0.1A = 0.1A
(150%) * 2.21A = 3.315A
MIcro ROV uses a 5A fuse
LEGEND
Power
Ground
Cat6 (Joystick to Host Shield)
Cat6 (Computer to Arduino)
Cat6 (VGA Pwr and Gnd)
Cameras




## References:


[T100 Thruster (Retired) (bluerobotics.com)]

[2021 Challenge | MATE ROV Competition Website]

[MAX452-MAX455.pdf (maximintegrated.com)]

[TC1044SCPA pdf, TC1044SCPA description, TC1044SCPA datasheets, TC1044SCPA view ::: ALLDATASHEET :::]