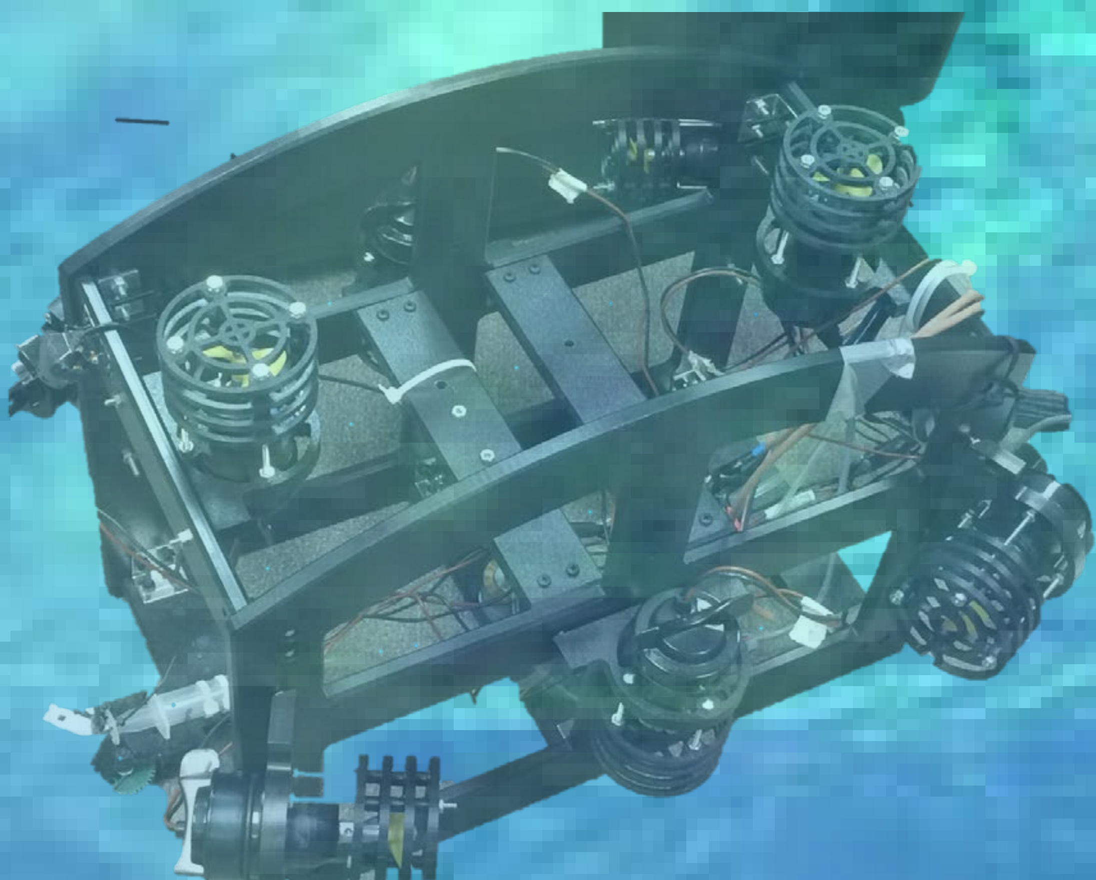
HAWKS Engineering 2014-15

Hoffman Estates High School, Hoffman Estates IL, USA

SeaHAWK



Company:
D. Vadgama- CEO, Pilot
G. Wilkins- Vice President, CFO
M. Shah- Safety Manager, Tether Engineer
L. Turf- Payload Tools Specialist
Mentor:
W. Oras

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2. Abstract

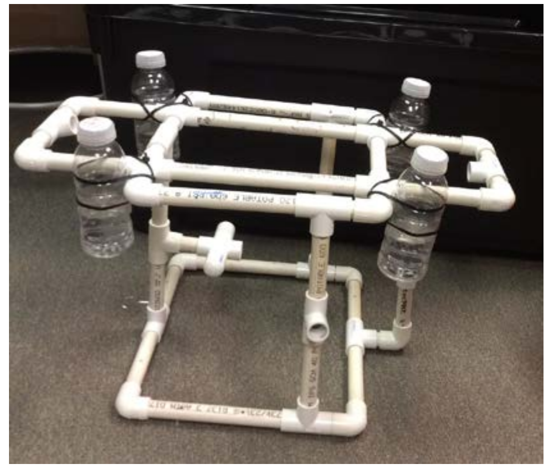
HAWKS Engineering is a company that is newly formed and highly ambitious. Consisting of five students ranging in grades from sophomore to senior, we set out at the beginning of September of 2014 to create a ROV that can accomplish the many tasks the MATE competition entails. To remove the piece of corroded pipeline a lift line was constructed to be attached to the claw before being transferred over the pipeline. In general the ROV is operated by an app, designed by the CEO of our company, which allows the pilot to control the ROV from a tablet. This feature is key due to the fact that the ROV can be operated from a range of around 36 meters away from the Bluetooth module. ROVs ensure safety for any number of things. Through the calculating of volume for an iceberg the threat level can be determined and that will ensure safe waters. Other tasks relate to how we learn more like the picking up the sea urchin or collecting algae and others still keep the waters clean and safe for the underwater inhabitants like the closing of pipes and the removal of them. All these missions and important detections will keep the waters safe for humans, urchins, any number of creatures who inhabit the water.

HAWKS Engineering Members from left to right:
Laura Turf, Grace Wilkins, Dillon Vadgama, Miraj Shah
Photo Credit: Wayne Oras

3. Design Rationale

a. Frame

As a first year team, HAWKS Engineering decided to begin with the classic structure of PVC pipe due to the low cost and ease of manipulation to test out numerous design types. Originally the ROV was built as a pentagon shape. This design with the angle at the front aided in being able to cut through the water quicker helping to speed up the tasks; however, due to extensive research on other designs a more compact box-like frame was decided upon and the team set to work to build this ROV. The ROV was the design that allowed us to decide on the placement of motors with the two outside motors for going left, right, forward, and back. The two remaining motors were placed at the top, propellers facing down, on the front and back of the ROV to ensure that the ROV could go up and down, but also tilt if the claw needed to be utilized at an angle. This was the design of the ROV for months and it was a design that HAWKS Engineering felt was well done but the actual material that the frame was created out of PVC pipe could be a material that would aid the ROV in performing better. As it turns out a better frame for the ROV would be something that nearly neutrally buoyant, a material that is not effected by cold temperatures, and a material that itself is structurally sound and very difficult to break. This is how the team decided on HDPE.



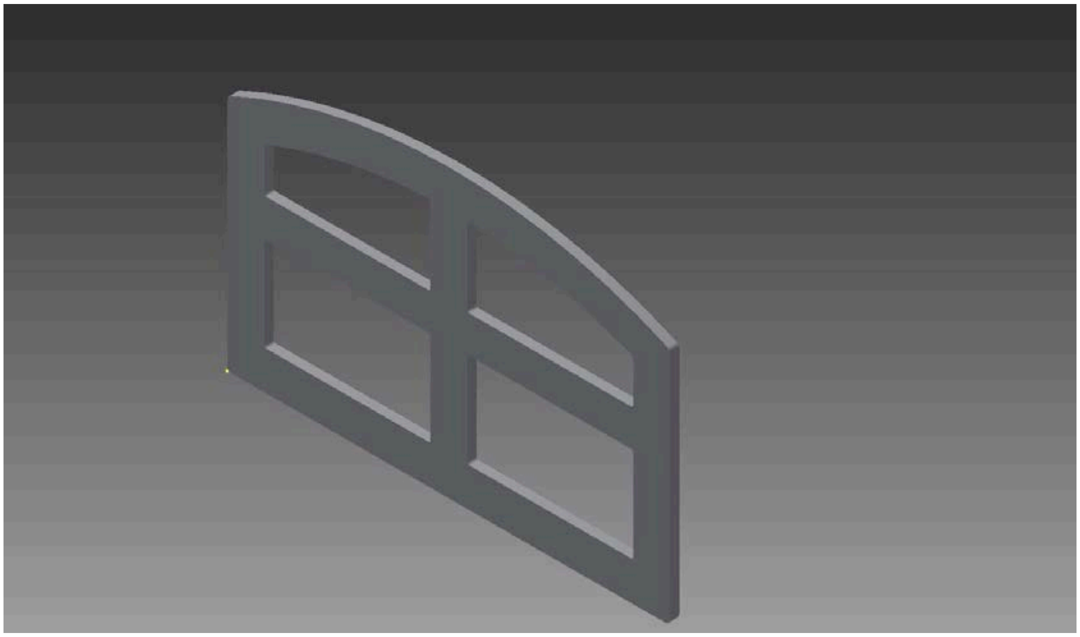
ROV-erto
Photo Credit: Grace Wilkins

High-density polyethylene, HDPE, meets those requirements for HAWKS Engineering. It has a density of 970 kg/m^3, which makes the frame slightly, positively buoyant. This buoyancy is what allows HAWKS Engineering to have very limited additional buoyancy providing equipment. The material, in conjunction with the two addition motors that are used with the two original in vertical directions, increases both the speed of the ROV and the stability in the water. With the material the design was altered slightly. Instead of being almost sandwich style with the main structures being on top and bottom, the new design allowed for the sides of the ROV to be the main structures with braces to hold the ROV together and also hold the majority of the motors, payload tools, and cameras. These pieces were designed in CAD then cut out with the use of a ShopBot, a CNC Machine, to exact specifications. This device was used to save both time, and eliminate a lot of worries about human error. The frame

ShopBot
Photo Credit: www.talkshopbot.com

SeaHawk
Photo Credit: Grace Wilkins

has curved tops. The curvature saved the team unnecessary material making the ROV lighter and also better looking. Another way that waste was eliminated was the four cut outs on the main structures; these cutouts were then used to create most of the motor mounts that are now attached to the ROV. This reduced waste of material and in addition money. Originally the motor mounts were screwed in flat against the frame however with only the four motors, HAWKS Engineering found it hard to turn the ROV left or right and has since made modifications to correct this. Now the motor mounts are at an angle that allows for ease of rotation and additional force when going forward or backward. The frame is black and 1.27 cm thick. Though the entire frame is securely put together with stainless steel screws, the material itself is incredibly tough to break with a tensile strength at the breaking point of 2,250,000 kgf/m^2 3,164,000 kgf/m^2. This new design was given the name of SeaHAWK.



Frame
Creation Credit: Miraj Shah

b. Electronics/Control Systems

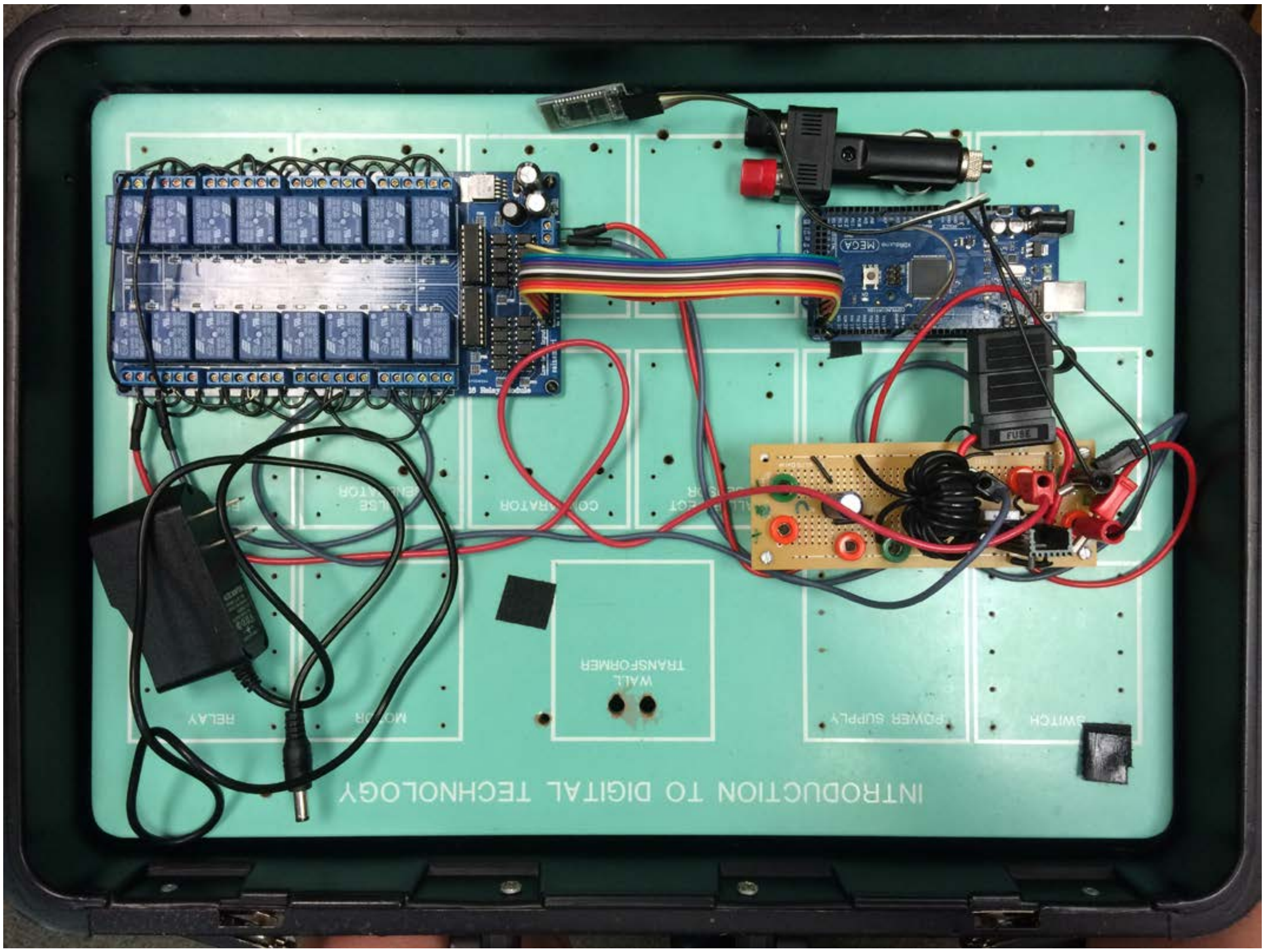
The primary processing unit for the SeaHAWK is the Arduino Mega 2560. This electronic device is a computing platform based on the ATmega2560 microcontroller. Generally, the Arduino receives information from an external sensor/system, and, through its uploaded internal programming, processes the input and creates a corresponding output. For our particular situation, the Arduino is used to control the relay board that all eight motors are attached to. In total, there are sixteen single pole-single throw relays, two relays per thruster, that allow the bilge pump motors to be turned on/off and change directions.

On the input side of the Arduino Mega is the HC-06 Bluetooth Module. This sensor receives information from the HAWKS Engineering mobile application, which can be installed on any Android device with WiFi and Bluetooth capabilities. The HC-06 converts the wireless information received from the mobile device to serial data that the Arduino can read and process.

When downloaded to a mobile device, such as a tablet, the controller application establishes communication to both the HC-06 and a surface laptop. When buttons such as “up” and “down” are touched, information in the form of text is wirelessly transmitted to the Bluetooth module indicating the desired ROV movement. As mentioned previously, the HC-06 converts this information to serial data and the Arduino outputs the proper combination of digital I/O pins to allow the relay board to turn on the specified motors in the correct direction.

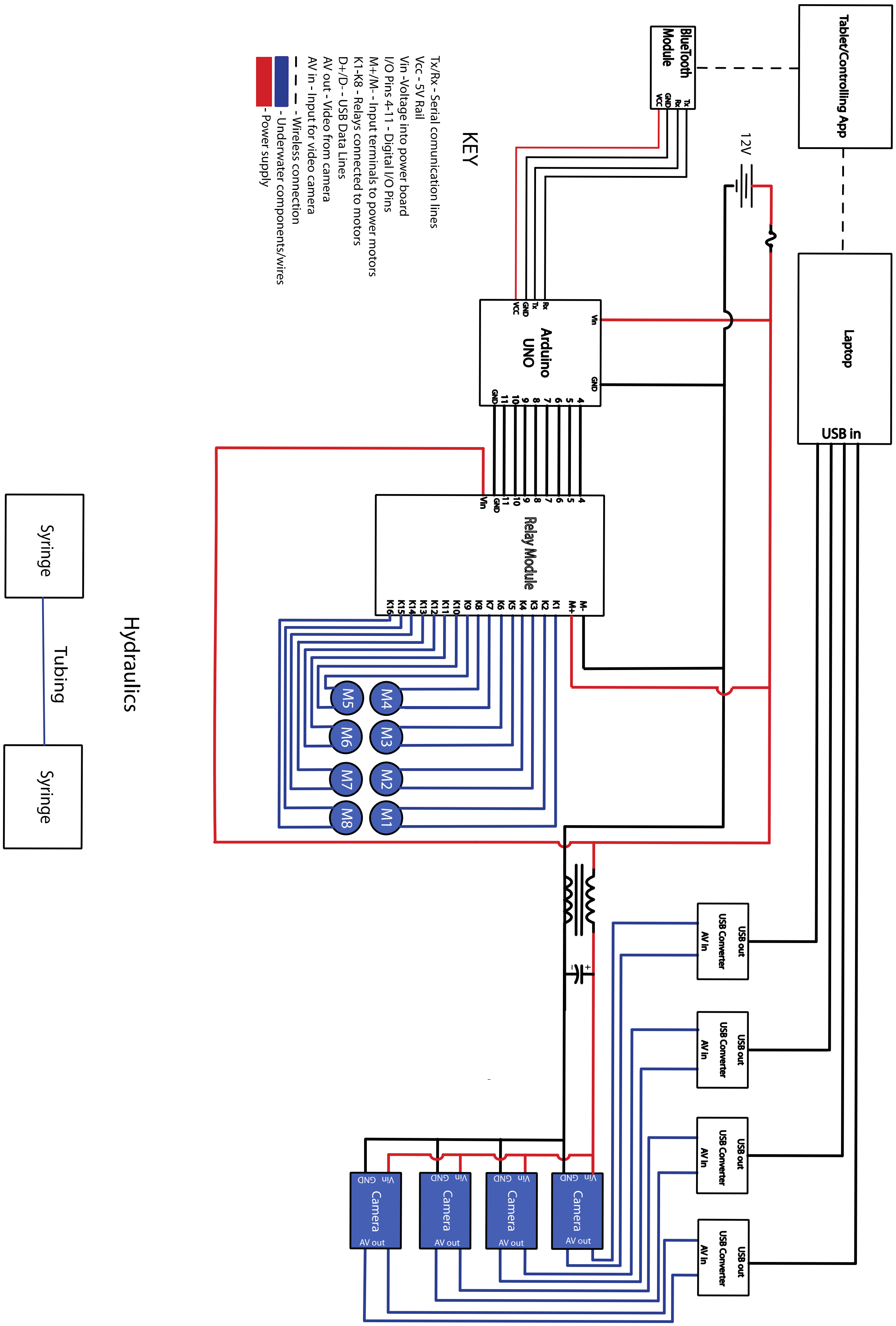
The mobile application also contains a window placed in the middle of the lateral and elevation buttons that is used to display the video feed from the four onboard cameras. Each rear-view backup camera is wired from the ROV through an AV-to-USB converter to the surface laptop and assigned a unique IP address. The laptop has been configured to act as a wireless router to send these four channels of information to the tablet. The table is required to enter the IP addresses of the cameras when it connects with the laptop. The application assigns each IP address to a button, “Camera 1” through “Camera 4”, that the pilot can easily switch perspectives upon touching the button. In addition to the Bluetooth connection, the video transmission allows the pilot to be completely detached from SeaHAWK (there is no tether connected from the tablet controller to the ROV) while still being able to navigate and observe the ROV's surroundings underwater.

Power distribution is handled entirely by a splitter board that branches off the battery's 12V between the cameras, Arduino, and the output of the relay board (connected to the thrusters). Due to the motors causing feedback interference to the cameras, a low pass filter is employed, dampening any high frequency signals and reducing the noise of the DC power rail. This is not an issue for the Arduino because it contains an internal voltage regulator, which eliminates any variations in voltage.



Control Box
Photo Credit: Grace Wilkins

System Integration Diagram May 2015



c. Propulsion

HAWKS Engineering uses the Johnson Pump 500 GPH Motor Cartridge that has been modified to act as our motors. FunRCBoats ROV Propeller Couplers are then added to the ends to spin and propel the ROV through the water. In total HAWKS Engineering purchased five of these motors and their propellers and the Shedd Aquarium donated three.

The final ROV design is one that allows for eight bilge pump motors. These eight bilge pump motors increase efficiency and aid the team in all aspects of the missions. On the original design there were only four bilge pump motors, two for vertical, and two to go forward and backwards however due to the additional purchase of bilge pump motors for next year and a discussion with Purdue University's own team, Purdue IEEE, the company felt that these changes would be for the best and so the design of the ROV was modified accordingly.

Johnson Pump 500 GPH Motor Cartridge
Photo Credit: Amazon.com

As SeaHAWK stands in the late weeks of May 2015 there are four bilge pump motors used for horizontal directions (left, right, forward, backward) and four for vertical propulsion (up and down). The horizontal bilge pump motors are actually at an angle of 23 degrees which allows for a better left and right movements without sacrificing too much of the forward motion. This angle allows for around 75% of the motion to be forward in the event that the ROV must move forward or backward. This is how SeaHAWK will be propelled in the water. As a last note to the propeller to protect living creatures, as well as the propellers, HAWKS Engineering designed their own shrouds. These shrouds were then 3D printed out of plastic and attached around the propellers.

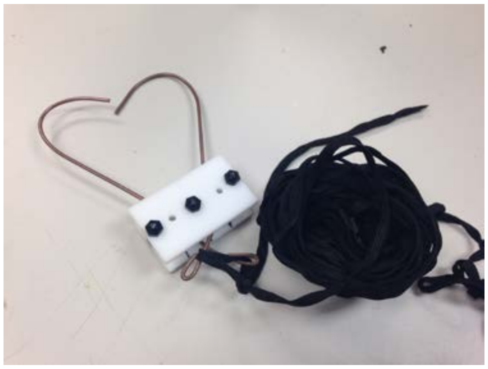
Shrouding
Creation Credit: Miraj Shah

d. Payload tools

The measuring device consists of a 6.096 meters measuring tape, welder's rod, and stainless steel screws. The 6.096 meters of tape measure has been modified to be of better use to HAWKS Engineering. This modification was done by inserting two larger, stainless steel screws that now allow the tape measure to be secured to the frame of the ROV. The welder's rod was shaped into a hook and attached to the metal clip of the tape measure. The hook is there so it can be attached onto the PVC pipe without slipping off. The measuring device operates by the hook being secured to the PVC pipe and a camera being focused on the numbers of the tape measure.

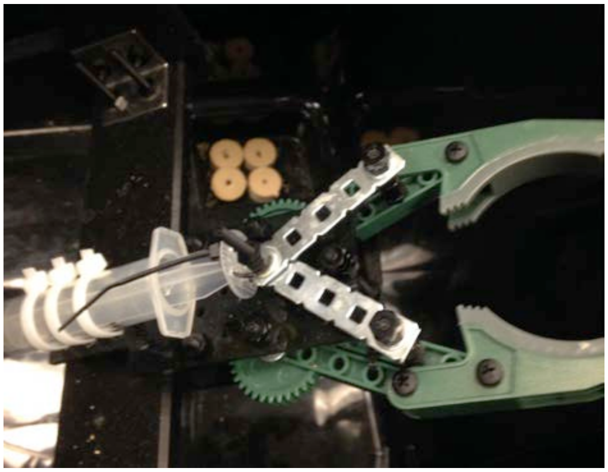
Measuring Tape
Photo Credit: Laura Turf

The lift line is constructed of Plexiglas, plastic screws and nuts, welder's metal, and string. The Plexiglas is being used as a base to hold the welder's metal and string together it is also an easy surface for the claw to grip onto, this base is being held together by the plastic screws and nuts so nothing will become undone. The welder's metal again is molded into two hooks and they are attached to the Plexiglas base facing each other. Finally the string is attached to both hooks on one end and the other of the string end will be on deck. The lift line works by having the claw grab onto the Plexiglas and have the hooks open. The claw will then push the lift line onto the corrode piece of pipe where once the claw releases someone on deck will then pull the string closing the hooks and locking the corrode pipe. The person on deck can then pull up the corrode piece of pipe and bring it onto deck.



Lift Line
Photo Credit: Laura Turf

The claw device that HAWKS Engineering makes use of is actually a modified VEX (a company that provided educational programmable tools) claw. These modifications were necessary to avoid rusting with the metal pieces however it was found that some of the metal would not rust for a very long time. The claw is held together by a Plexiglas frame. This frame was designed through inventor on CAD and cut out through the use of a CNC Machine. The metal screws and nuts were replaced with plastic screws and nuts that hold those pieces of Plexiglas together and two modified VEX 25 hole bars that were cut down in size were attached to the plastic gears located inside the Plexiglas frame are used to open and close the claw. The claw functions through the use of



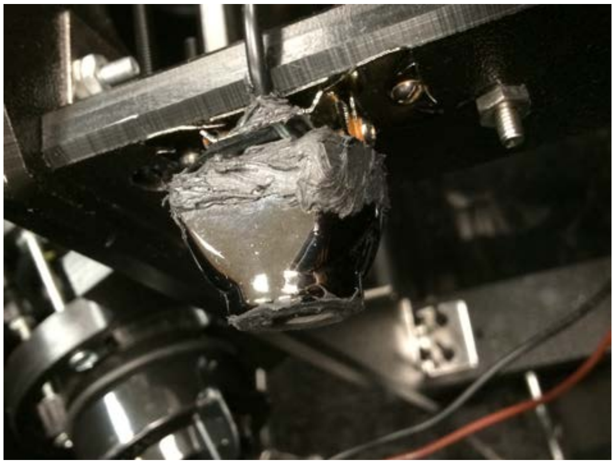
Claw
Photo Credit: Laura Turf

a simple syringe hydraulics system. The hydraulics system consisted of two syringes, tubing, and saltwater. One of the syringes is attached to the claw underwater and the other is on deck with the handler. The syringes are connected through a tube, one that runs through the tether, filled with saltwater. The claw works due to when one end is pushed in the other end expands out.

This year, the SeaHAWK has the capability of measuring the voltage between to electrically charged points. This feature is achieved through an analog input pin of the Arduino Mega. Without additional circuitry, the microcontroller is capable of measuring a test voltage up to 5V. To expand this voltage range to handle greater voltages, a voltage divider is attached to the input of the Arduino. With this modification (See schematic), the test voltage can exceed 5V while the voltage at the Arduino remains within the adequate range. Because a voltage divider is a linear circuit, as the input voltage increases, the output w ill also increases proportionally. This same principle applies in our specific configuration as all test voltages (0-12V) have a corresponding Arduino measured voltage (0-5V). The linear relationship allows the Arduino to read the voltage at the output of the voltage divider and, through the internal programming, gain an accurate measure of the test voltage.

e. Camera

The ROV HAWKS Engineering has created has the capabilities of functions with four cameras. These are cameras that the company uses in as many possible ways that they can. Of course the pilot must be able to see directly where the ROV is going and due to this the first camera, the main camera, is the Front View of the ROV. However due to changing environment and the different tasks that each demonstration presents, the company has felt that the cameras positions should be altered with the change of missions. For this it was decided that there would need to be a camera focused on the Measuring Device, the Claw, and the Top in addition to the Front View. This allows the company to make use of the payload tools and when needed to get back up through the hole in the ice, the pilot can direct the ROV directly underneath. The change on the ROV from the Science Under the Ice to the Subsea Pipeline Inspection and Repair is moving the Top View Camera to one focusing on the Valve Turning Device. For the final demonstration, HAWKS Engineering finds that the measuring device will be necessary as will the viewing of the Valve Turner. However for this task the claw is not a main priority and instead should be changed to a view of the probes that will be used to test the grounding of anodes. This is how HAWKS Engineering will be able to accomplish all the missions without the Pilot or the payloads operator having to look into the water.



Camera
Photo Credit: Grace Wilkins

The cameras that HAWKS Engineering is using on SeaHAWK are waterproofed rear view back up cameras for cars. These cameras are water resistant however to ensure that they are waterproof the company has coated the cameras in 1-Minute Gasket seal. This protects the electronics housed in the camera from water. The company has been able to test this and it is secure up to a depth of at minimum 4.8768 meters. The cameras are then wired to a longer cable by soldering the tips together and then covering the joints in hot glue before heating up the heat shrink around the joint.

f. Tether

The tether is essentially the lifeline of the ROV as all power and data transfers through it. To transmit electrical power, a CAT 5e, which allows for a high signal to be transmitted through the cable without noise. This means that the interference that the noise could create an issue HAWKS Engineering doe not need to worry about. For communication purposes between the pilot and the four cameras located on the ROV, an addition two CAT 5e cables were utilized. To ensure a longer life for the tether, and that none of the connections on the ROV aren't pulled onto, a mesh like sheathing is used to encase all the cables. The sheathing, provided by Northrop Grumman, works remarkably like a Chinese finger trap; the more the force is applied, the more tightly it grips onto the cables to ensure that individual cables aren't being pulled onto, and the force is distributed onto the rope, rather than cables. Due to the sheathing, the tether acts as one solid wire, with a uniform long body rather than multiple cables held together at intervals. This is extremely helpful when handling the tether, as the team can grip all the cables together, without fear of pulling to harshly on one. To guarantee that the tether won't get in the way of the ROV's movements by constantly dragging it down, it was necessary for the tether to be neutrally buoyant. In order to make the tether neutrally buoyant, flotation devices are secured to the sheathing at 2.5 meter intervals, so that when the entire tether is suspended in water, it is completely neutrally buoyant. This way, when the tether is being lowered into the pool with the ROV, it is not adding any extra weight at the posterior of the ROV, and tilting it, or dragging it down.

4. Troubleshooting

At HAWKS Engineering we are no stranger to problems when it comes to SeaHAWK with the unique and complex systems that are being used. With this knowledge, there is a detailed flowchart that the company refers to in the event of an issue. There are many steps and branches of this troubleshooting plan; however, it can be summarized through these steps: Isolate and Analyze the problem, Determine a solution, Test, and if necessary Repeat the process. This has aided us on more than one occasion when something has gone amiss.

There have been many occasions where there was nothing but human error occurring, causing the ROV to malfunction. To remove this error, HAWKS Engineering makes sure that at least two people check the connections before the ROV is even put in the water. In addition all motors are tested to assure that they work properly and the video signal is up prior to the placing of SeaHAWK in the water. These, though also safety measures, help to determine if there is a problem what is cannot be.

5. Budget

The budget that HAWKS Engineering stuck to was as minimalistic as possible. The company firmly felt that the item that was being purchased was something that only had extreme benefits and something we could not build better. There were items that the company wished could be utilized and this is when there was outreach to other companies and corporations to ask if they would be willing to make SeaHAWK the best it could be. Some of the major products that the company was able to receive are the HDPE (Curbell Plastics) and sheathing (Northrop Grumman and TechFlex) for the tether. HAWKS Engineering is also currently working with other companies so that future improvements can be made to the ROV.

Reason	Date	Quantity	Price per	Donation	Purchased	Total
D211 Foundation Grant	9/1/14	1	1000	1000	0	1000
Shedd Aquarium	10/18/14	1	Approx.1000	Supplies	0	1000
Book	11/17/14	1	100	0	100	900
Blue Tooth Module	11/17/14	1	9.99	0	9.99	890.01
Bildge Pump	11/17/14	2	27.54	0	55.08	834.93
Propeller Kit	11/17/14	1	22.99	0	22.99	811.94
Camera	11/17/14	2	19.99	0	39.98	771.96
Positioning Sensor	2/12/15	1	5.5	0	5.5	766.46
Propeller Kit	2/28/15	1	22.99	0	22.99	743.47
Ranger Sign Up	2/10/14	1	100	0	100	643.47
Camera	3/14/15	2	18.99	0	37.98	605.49
Camera	3/21/15	1	18.99	0	18.99	586.5
Hex Nut	3/24/15	1	4.69	0	4.69	581.81
Screw	3/24/15	1	4.25	0	4.25	577.56
Container	3/25/15	1	42	0	42	535.56
Attabox	3/31/15	1	110	85	25	510.56
Easier Cap adapters	3/30/15	4	10	0	40	470.56
Waterproof connectors	4/1/15	4	7.2	0	28.8	441.76
Travel to NorthEastern	4/14/15	2	40	0	80	361.76
Northrop Grumman	4/28/15	1	20	20	0	361.76
TechFlex	4/21/15	1	30	30	0	361.76
Curbell Plastics HDPE	3/31/15	2	50	100	0	361.76
DK Plastics HDPE	4/14/15	2	25	50	0	361.76
Camera	5/1/15	3	26.99	0	80.97	280.79

6. Safety

a. Philosophy

Safety has been a major focus ever since the company was formed. The team's safety policy is one of the classics: Better safe than sorry! To ensure personal safety, all team members are required to wear safety goggles whenever they are using power tools for drilling or cutting any material, and when they are testing the ROV. Around working environment, it is mandatory to wear close-toed shoes to protect feet in case of falling objects. A supervisor always has to be present when the team members want to work, and to prepare for anything, a safety kit is always in reach of the team. Following this safety policy, the team was able to incorporate its safety morals into the design of the ROV as well. The Frame of the ROV is cut with all the corners rounded, and all the edges chamfered, so no sharp edges are present. The shrouding around the propellers is designed such that it would protect the propellers from any incoming objects, while still allowing a swift water flow. All the metal, whether as nuts and bolts used to hold the frame together, or as part of payload tools is replaced by non-corrosive metal to prevent any damage to the environment. Electrically, a current limiting feature is built in to make sure that the video feed always stays clear and eliminated the chances of overloading a system. Not only do the safety features keep the team members safe when they are working with the ROV, but also double to ensure a longer life for the ROV itself. With this safety policy, the team has not encountered any incidents where a team member was harmed.

b. Checklist

Safety Checklist

- Mechanical
  - No sharp objects on ROV
  - Wiring neatly coiled up
  - All electrical wiring is waterproof and sealed
  - Everything on ROV is tightly secured
  - Power is turned off while working
  - Current limiting feature
  - All wires are connected
  - Shielding on motors
- Electrical
  - All motors run
  - Cameras work, and have clear a picture
  - Case is away from water
- By water
  - All members are away from pool edge (other than the tether engineer and the ROV Handler)

7. Challenges

a. Technical

There were many mechanical things that the team learned during the process of making and testing this ROV. A major aspect of this was related to buoyancy. The team realized that it was crucial to the balance of the ROV to have majority of its mass centered, rather than distributed throughout the ROV frame. If the ROV had majority of its mass in the center, it stayed upright and well balanced. However, if the weight was distributed throughout the ROV frame, then even the slightest discrepancy of mass on one side would cause the entire frame of the ROV to tilt. In order to ensure that the ROV did not tilt as easily, the team decided to add a ballast tank in the center of the ROV, which was essentially majority of the mass on the ROV other than the frame itself. Not just that, but the bilge pump motors were set up so they were centered on the frame, and also symmetrical. With this, all of the major masses were either centered, or symmetrical around the center of the frame.

The planer motion propellers were set up on the outside of the ROV, and were extended a little further using brackets. This extra distance gave more mechanical advantage while turning the ROV. Not just that, but they were fixed at a 23 degree angel in relation to the z-axis of the ROV. This arrangement allowed the ROV to sway, and have full planer motion. With this arrangement, the ROV could officially move from left to right, rather than having to turn and then move forward, and turn again, which certain tasks, such as reading the gauge pressure, or examining the pipe required.

b. Nontechnical

As the members of HAWKS Engineering know very well it's easy to slack off when there are other people to do the work for you; however, it's hard to step up when there is a small amount of people to shoulder the load. HAWKS Engineering was originally a company of seven and though it's possible to say that the months of time that we had also made the company slightly lazy, it was the people that were thought to be reliable that kept some urgency out of the project. However as the numbers decreased along with the months the urgency entered and there was the challenge of being able to still accomplish all that HAWKS Engineering had set out to but with less people. This challenge was overcome through an increased meeting schedule, work ethic, and people completely took over certain aspects of the tasks.

8. Lessons Learned

a. Technical

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b. Interpersonal

As the first year of HAWKS Engineering comes to an end, it’s important that we acknowledge all that we have learned as a company. With that being said the company is grateful for the opportunity to learn about company management and teamwork. We all have found out what it means to truly be part of a team. A team where we can be proud of what we each have accomplished both individually and together. With that members of the company have also learned leadership skills that will be with them for years to come. These students are now better equipped to aid a fellow student, assign tasks, and even on occasion not be afraid to ask for help. After all what HAWKS Engineering truly strives for is constant learning.

9. Future Improvements

The product that HAWKS Engineering was capable of creating still has significant room for improvement, improvements that are always being looked for and being made. SeaHAWK is a unique design of our creation however it would be beneficial if the ROV could self-stabilize (keep itself level) with the push of a button. The company also finds that on board electronics would be useful by speeding up the set up time and decreasing the odds of the wires accidentally being pulled out or other aspects of human error. With onboard electrical housing the tether could also be made to be detachable making the process of wrapping it up into a nicely coiled system better for anyone managing the cables and tubes. The company acknowledges our lack of time management and also finds the need to rectify this and make sure that the goals and prioritizes are kept to. This will become a job of one of the members of the company in the future. It is not laziness that drives this lack, nor even that of procrastination, HAWKS Engineering truly just loses track of the time as we spend it doing something we greatly value and simply love. The company's CEO himself could and has spent hours figuring out a malfunctioning electronic device because the desire to understand electronics is so strong. The company however cannot afford to spend these crucial hours when there may be another solution that can be explored and with that acceptance the company also accepts that their must be a designated handler for these type of events.

10. Reflections

As the year comes to a close HAWKS Engineering looks back at all that it has accomplished in it's first year. Wehave gone from seven people to just four and yet there have been many new additions to the original ROV HAWKS Engineering had. The following is what our senior, Laura Turf, and CEO, Dillon Vadgama, had to say on their experience this year.

Overall, the experience when constructing the ROV (remotely operated vehicle) was enlightening and a learning experience. When giving a real life problem (oil spills, science under the ice, etc.) and expected to come up with a solution under constraints using the engineer design process it requires much research and willingness to learn. The experience was valuable from my perspective because it will increase my knowledge on certain areas in which I was unfamiliar with. *–Laura Turf*

Through all of the challenges that HAWKS Engineering faced as the year progressed, from time management to technical obstacles, the building of SeaHAWK certainly proved to be a indispensable learning experience. This process allowed us to gain knowledge of real-life engineering practices and apply skills learned in class while also exercising the ones learned along the way. As CEO, I was able to improve my competence in project management and conflict resolution, something that all leadership career positions require. Overall the experience will aid us all in our future ventures. *-Dillon Vadgama*

11. Hawks Engineering

a. Company Mission

HAWKS Engineering is committed to manufacturing highly advanced marine technology and ways to use such technology through ROVs. Comprised of four engineers, all already engaging in their fields of interest and years of experience amongst them, HAWKS Engineering is capable of constructing unique, efficient, and effective ROVs. SeaHAWK is designed to do just that by the immense work effort put into the creation. The concept of Science and Industry in the Artic of course aided in the detail that is put into the ROV and HAWKS Engineering knows SeaHAWK is the best for the required tasks.

b. Evolution of Company

HAWKS Engineering is the product of high school students who want to know more about mechanics, physics, programming, and design, but ultimately hope to become engineers in the future. It was a question posed to the third year Project Lead the Way (PLTW) students at Hoffman Estates High School because a former student thought this competition was something that the students could participate in. The team was originally seven students consisting of either juniors or seniors. Unfortunately, three members unfortunately were unable to continue due to personal matters. These four are who made up HAWKS Engineering and all found roles that they personally felt they could accomplish. As the workload of the project increased and the number of team members dwindled, HAWKS Engineering was able to hire an engineering student that is a sophomore. Sadly, shortly after winning the Shedd Midwest Regional Competition, one of the members of the company felt that since they were graduating and would no longer be able to dedicate as much time to the company. However, these were challenges the company was able to overcome and we are feverishly preparing for the competition in June.

c. Project Management

Though HAWKS Engineering did not make a Gantt chart until late in the year, the company did make lists that the members could easily refer to if they wanted a project. One of these lists is that of the Ranger Class Requirements, everything underneath being either a *should* or a *shall*. This was a constant reminder of what was accomplished and what needed to be accomplished with the exception of one statement that hoped we would have time to make the ROV do. In addition to this list all the demonstrations as listed on the Shedd Midwest 2015 Challenges Ranger Class page (http://sheddmidwest.marinetech2.org/rangerspecs2015) was written on the chalkboard as a small summary of what the company would have to accomplish. Next to this were the additional points that the team could and would receive for the Technical Report, Sales Presentation, Marketing Display, and Safety. These lists were how HAWKS Engineering was able to accomplish what they set out to do.

12. References and Acknowledgements

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