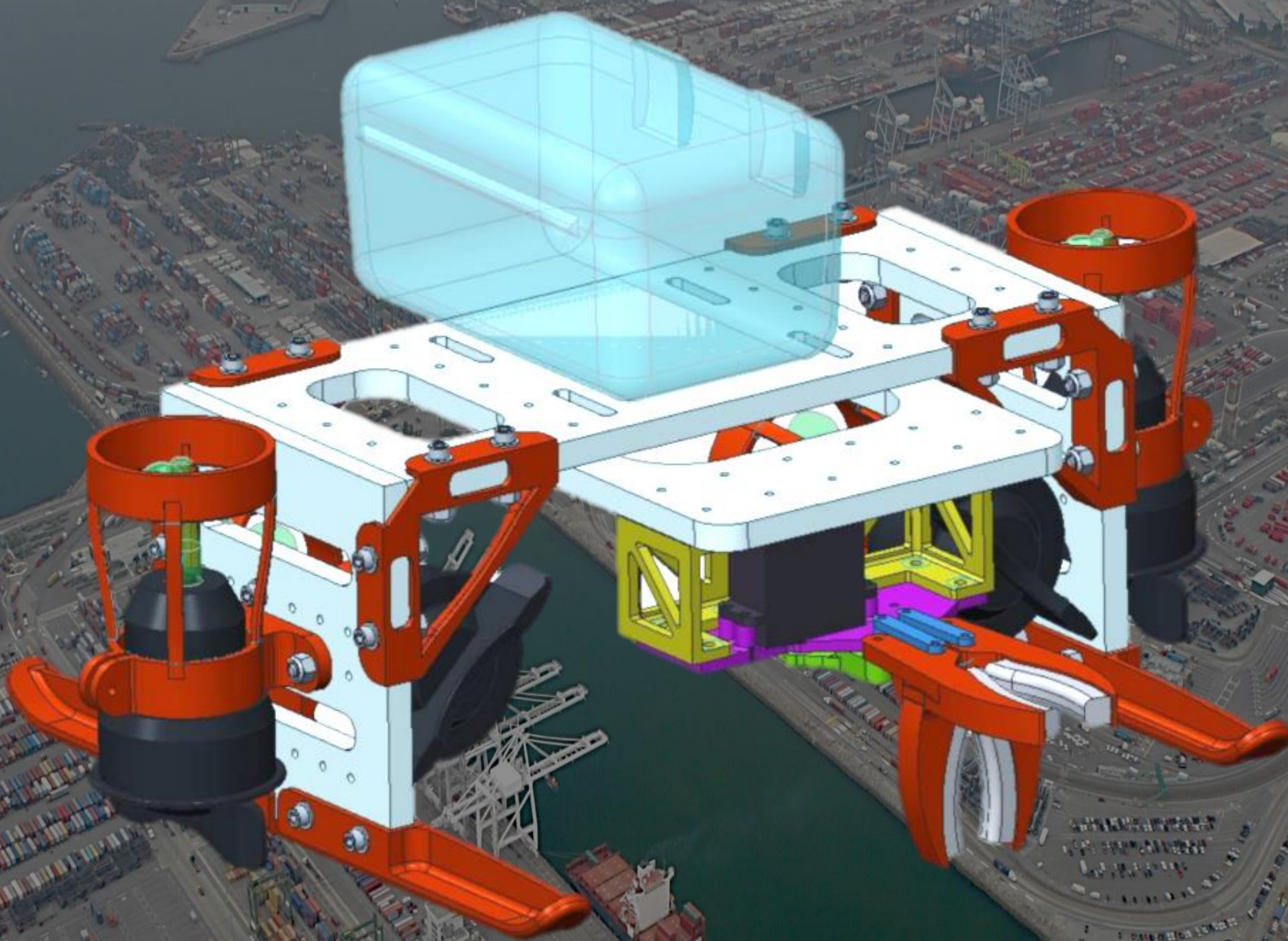
JUNIOR HUSKIES

Seattle, Washington, USA



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***Junior Huskies is not affiliated with any school or organization**

(background image: a photograph of the Port of Long Beach, credit Port of Long Beach, California)

ABSTRACT:

Our new, improved, and compact underwater Remotely Operated Vehicle, or ROV, is equipped with strategic tools and materials designed to mitigate and resolve pressing issues faced along the port and waters of Long Beach. Our ROV is constructed out of Starboard (a marine-grade version of high density polyethylene, or HDPE) and is powered by four bilge pump motors oriented up, down, left, and right. The maneuvering abilities of the motors coupled with the durability of the Starboard will allow our ROV to function efficiently during tasks related to issues of contamination, maintenance, and Hyperloop installation. Our ROV consists of a microcontroller-based control system to operate our motors and servo, a camera to project a real-time video feed of the mission tasks, and an RFID sensor to identify the contents of potentially hazardous cargo containers. Our control system is connected to onboard electronics by way of a 25.3 meter tether sheathed by a flexible braided sleeving. To accomplish the tasks specified by Long Beach's Request for Proposals, our dual-pronged claw offers versatility and simplicity necessary to get the job done. Overall, our vehicle is well-designed to deal with contemporary marine challenges faced along the Port of Long Beach.

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MISSION THEME:

The Port of Long Beach, credit container-news.com

ROVs are helpful to the safety, health, commerce, and entertainment of port cities. Among the numerous capabilities of ROVs, one is that they are able to inspect hazardous materials, e.g. explosives, toxic, radioactive, and corrosive substances.[1] By harnessing the camera-viewing abilities of ROVs, it is possible to visually inspect contamination sites to determine the level of risk and hazardousness of the sites.[1] The detection and riddance of the risky materials protects citizen health, ensuring both safety and cleanliness.[4] Mapping out contamination sites with modern 3D sonar technology and other techniques allows ROVs to assist in preventing contaminants from wreaking havoc on port cities.[2] Mapping can help to identify areas occupied with hazardous materials in unknown environments, helping to develop a complex layout of the underwater environment.[3] ROVs can also perform maintenance on tools, such as Long Beach's light and water show structure, to protect entertainment industries.[2] Lastly, ROVs can improve commerce by way of innovations like the Hyperloop system that expedite the delivery of cargo to ports.[2] Overall, ROVs can effectively promote citizen safety, health, and entertainment as a result of their vast technological capabilities.

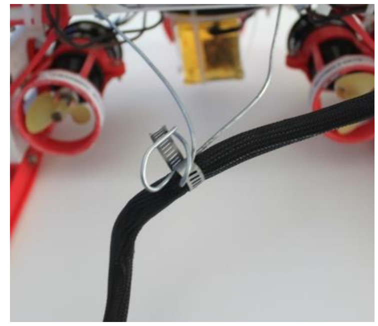
SAFETY:

Company Safety Philosophy: Our company strongly agrees with MATE's belief that "Safety is paramount!"[5]. In order to prevent our vehicle from becoming permanently damaged, we make it a priority to follow safety protocols and incorporate safety features into our ROV. Developing and adhering to safety procedures ensures that our ROV is up to par for company and consumer use. Accordingly, we complied with the MATE Center's safety feature requirements:

- Our motors are shrouded with 3D-printed motor shrouds, which partially encapsulate the propeller on our thrusters to provide maximum protection from debris while still allowing efficient flow of water through the system.

- We installed a 25-amp fuse within 30 centimeters of our Anderson Powerpole Connectors on the positive line, providing all of our electronics with the necessary overcurrent protection while still allowing them to fully function. Our fuse value was calculated by totaling the amperages of all systems then applying a 150% safety factor (calculations shown on Systems Integration Diagram in Appendix 1).

3D-printed motor mounts w/ warning labels



Galvanized steel wire strain relief

- We added strain relief, which allows us to take strain off of the tether without jeopardizing the seal of our waterproof electronics box. Our strain relief consists of a 16-gauge galvanized steel wire crimped into a ring terminal, sealed with marine epoxy, and then bolted onto our frame. It was clamped to our tether using a ½-inch pipe clamp.

- We included visible warning labels on all moving parts.

Additionally, we developed a comprehensive Job Safety Analysis (JSA) form for company members to review before performing high-risk operations, intended to prevent personal injury (Appendix 3).

Protocols: Over the course of the year we developed numerous protocols to increase the efficiency and safety of our team. One of our most comprehensive and important protocols is our safety protocol/checklist. As we went through the list, we would add checkmarks as a way of verifying that we adhered to each step of the checklist.

- ☐ Closed-Toed Shoes
- ☐ Safety Glasses
- ☐ Ensure that Battery is Charged
- ☐ Joysticks in Off Position
- ☐ Check Fuse
- ☐ Clean Gasket w/ Microfiber Cloth
- ☐ Control Box Closed
- ☐ Clamp Down Topside Control Box
- ☐ Clamp Down Tether
- ☐ Setup Battery (Anderson Powerpoles)
- ☐ Above Water Test of Servo, Motors, Camera
- ☐ Tether/Control Case Clamped to Table
- ☐ Check Strain Relief

Another one of our important protocols is our tether management protocol. This allows any member of our team to manage the tether. Our protocol, as seen below, includes important details such as how much slack to let out:

- Do not pull on tether
- Make sure that tether is untangled before use
- During use: maintain proper balance between slackness and tautness of tether
  - Let it out as ROV enters, reel it in when ROV returns
- Coil tether neatly
- Make sure that strain relief is secure

Tether manager, Owen Tiffany, letting out slack on the tether

DESIGN PROCESS:

Interpersonal Problem Solving:

The company evaluating pros and cons of a servo vs. a linear actuator

As we designed and drafted ideas for the ROV, we had to arrive at well-thought-out decisions for the design of our vehicle. To deal with interpersonal problem solving, we developed a highly effective system throughout the year for making decisions about what to use on our ROV. This system revolved around a white board, where each team member would contribute a solution to a given problem, followed by a rationale. As a team, we would closely examine each of the ideas and then vote democratically on which idea we thought best suited our ROV. Whichever idea received the majority vote is what we then attempted to engineer and implement on our vehicle. In the case that the vote was evenly split two-to-two, we would develop a thorough pros and cons list on each of the two ideas and then re-evaluate which solution we thought best-suited our ROV. Using these two systems, we were able to make many excellent choices that pleased our team members and worked out well on our ROV.

DESIGN RATIONALE:

The Starboard frame of our ROV

Frame: We designed our frame out of Starboard (a marine grade version of high density polyethylene, or HDPE) because it is durable, dimensionally stable, lightweight, and cost-effective. Our frame design allows us to change the location of different components by attaching them to different pre-drilled bolt holes. Our frame is also designed to minimize materials and be hydrodynamic. We managed to reduce the weight by removing any excess Starboard during the laser-cutting process, which allowed us to meet the new weight requirement introduced by MATE this year. In addition to Starboard, we used ABS (Acrylonitrile Butadiene Styrene) for 3D-printing certain parts of our vehicle: motor mounts, landing gears, and brackets. We incorporated 3D-printing into our design process through the use of CAD technology. We used ABS instead of other printing materials, such as biodegradable plastics like PLA (polylactic acid), because ABS is more durable and absorbs less water, so it will not affect our buoyancy over time.

CPVC and PVC pipes attached to the ROV's frame by zip ties

Buoyancy & Ballast: Our ROV's buoyancy is constructed with two sealed ½-inch PVC tubes and four ½-inch CPVC pipes sealed with endcaps because PVC and CPVC do not compress under high pressure. On each side of the ROV, there are two CPVC tubes, allowing the vehicle to remain balanced and symmetrical. We determined that our motors made up the majority of the weight on our vehicle so we placed them lower on the frame and the buoyancy on the top of the frame. This allowed our ROV to have a low center of gravity and increased stability underwater which keeps our vehicle in an upright position at all times when piloting. On our tether, we attached pieces of polyethylene (pool noodles) so that the weight of our tether is supported in the water and therefore does not affect the piloting.

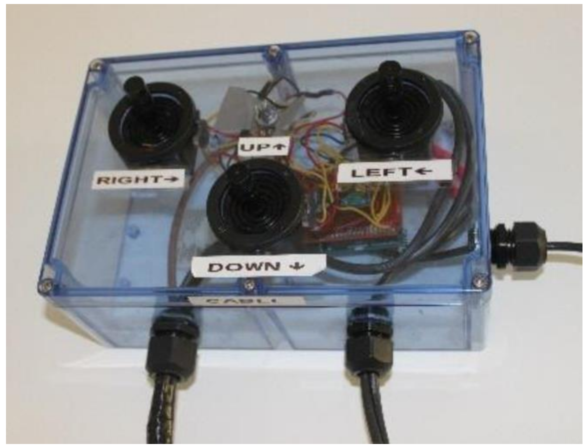
The onboard electronics box with cable glands

Onboard Electronics Box: To facilitate our goal of joystick-based control, we needed to house our control electronics and motor controllers in a secure underwater electronics enclosure. Our onboard electronics box seals with a gasket which interfaces with the lid of our box. We used cable glands because they allow removable wire connections through a bulkhead. Our company installed the cable glands by drilling and tapping holes into our box. We then screwed in our cable glands with adhesive silicone because silicone allows us to have a seal that we know is waterproof and is less likely to leak. Another precautionary measure we took was potting our tether and camera wires. This was to guarantee that our cable glands have a secondary waterproof seal. This allows our company to incorporate onboard electronics in a waterproof and safe way because no electronics will short due to water exposure. We bought a box because we did not have access to the resources necessary to have them machined.

A bilge pump motor attached lower on the frame for ballast

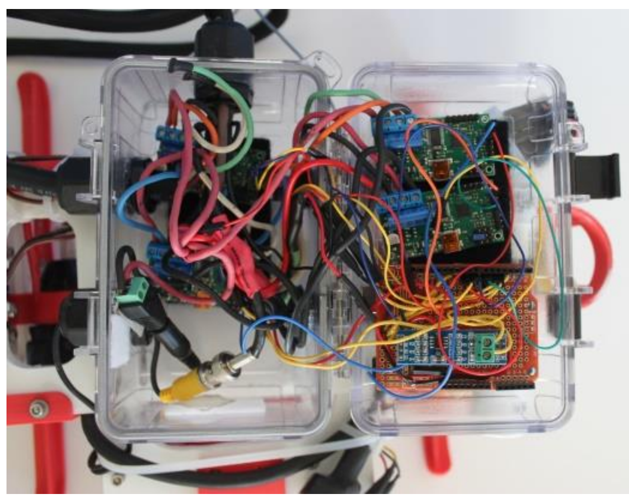
Propulsion: For our propulsion, we used four bilge pump brushed motors. We decided upon four bilge pump motors because they are inexpensive and effective in propelling the ROV. The reason we decided on four motors so we can have two horizontal motors and two vertical motors so we can move in directions as mentioned below. As a result of the 25 Amp requirement, our company limited the number of motors on our vehicle to allow us to add other electronic components. One motor on the right side of the ROV controls horizontal thrust with a right propeller, and one motor on the left side of the ROV controls horizontal thrust with a left propeller. The two horizontal motors allow the ROV to maneuver backwards and forwards, as well as turn left and right. Two motors on each side of the vehicle control the vertical thrust. The reason we have two vertical motors is to balance our ROV while moving up or down. We did not vector our motors, though, because we did not have adequate time to learn and apply complex vectoring to our microcontroller program. The placement of the motors on the robot allows the motors to evenly propel the ROV and make sure the ROV is balanced.

Control Hardware: For our electronic control system, we have an onboard subsystem and a topside subsystem. In this system, we utilize three joysticks to control the speed and direction of the motors and a potentiometer to control our claw. We implemented Arduino Protoshields because they enable us to make multiple solder connections in a space-efficient manner. The Protoshields, therefore, offer the ideal median between adaptability and permanency. As indicated by the Systems Integration Diagram (Appendix 1), the joystick and potentiometer signals are sent to the microcontroller. We purchased microcontrollers because they provided a starting point to learn more about hardware. Another aspect of our system are the RS485 converters, which allow us to transmit the RS485 protocol through the tether.



The topside control box with joystick labels

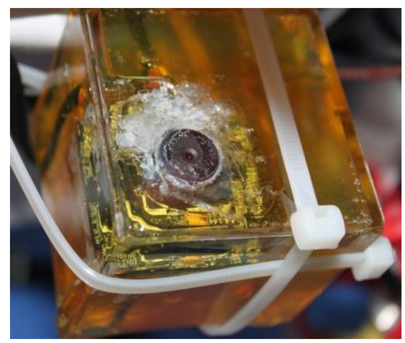
The onboard electronics subsystem consists of a servo, and a box that contains four programmable motor controllers, a microcontroller, and a Protoshield. The commands initiated by the topside subsystem are transmitted via the tether to the RS485 converter, allowing the microcontroller to receive a readable signal. The power from the tether was spliced with 16-gauge wires that power the motors and motor controllers. The motor controller sends power and ground to the motor, and it controls the speed and direction of the motors.


The inside of our onboard electronics box

Control Software: To manage our electronics system, we wrote software in the Arduino IDE (integrated development environment). Since this is our first year writing software, we used Arduino Uno microcontrollers because online resources are readily available. We read our three analog joysticks in a "tank drive" configuration; one joystick controls the right motor, one controls the left motor, and one controls both up and down motors. Our potentiometer controls our servo which subsequently controls our claw. The joysticks and potentiometer values were scaled to travel through an RS485 protocol because the RS485 protocol uses bytes. The joystick values are then rescaled to be sent to motor controllers. This allows us to control speed and direction of the motors. Additionally, the potentiometer values were scaled to be sent to servos. This allowed us to control the position of the claw.

Our tether covered with several pool noodles for buoyancy

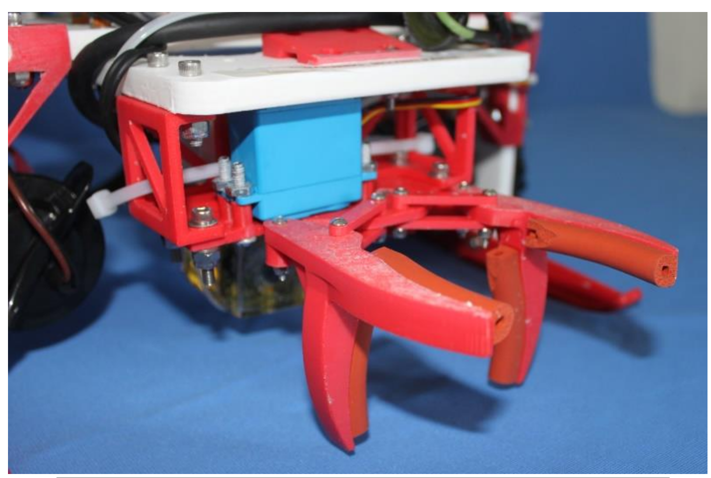
Tether: Due to our limited budget and because we were unable to find any donations that met our requirements, we built our own tether. In our tether, there are two 12-gauge stranded wires, one coaxial cable, and eight 24-gauge stranded wires inside a Cat-5 jacket. These wires are collectively sheathed in a ½-inch braided sleeving. We used the 24-gauge wires for our RS485 communications system to limit the width of our wires, and we used the coaxial cable for our video since it is shielded, offering noise resistance and protection from undesired currents.[6]



The board camera encapsulated in an epoxy mixture

Board Camera: The ROV has one high-definition (700TVL) camera with a 120° wide-angle lens to support pilot navigation. The camera is oriented to display objects in front of our vehicle, our claw, and other nearby surroundings onto our monitor since we connected the coaxial cable through a VGA converter to the monitor. The camera was primarily chosen for its small size, helping to minimize the volume of our vehicle. To ensure that the camera is waterproof, our team carefully potted the camera using a precise one-to-one ratio of epoxy resin and epoxy hardener. While one team member firmly held the camera (which had silicone applied along the rim to prevent epoxy from spreading to the lens) against the inside of a small cubic case, the other team members measured out the resin and hardener, then stirred them together. Subsequently, the two-part mixture was poured into a small cubic case to provide a waterproof enclosure for the camera.

Servo-Operated Claw: For our main tooling feature, we used a dual-pronged claw. Initially, we had planned to use a single claw operated by a linear actuator. We decided to use a servo instead due to servos being more cost and space effective. When brainstorming a concept, we looked through technical reports from previous years and saw a similar concept we imagined would be well-suited for Long Beach, so we adapted it our needs this year. Some tasks our claw is suited for are sampling contaminated clams, installing the rebar reinforcement rods, removing the pin from the



Our dual-pronged claw in an open position

frame after it is lowered onto the baseplate, lowering the frame, and turning the waterflow valve on the light show structure. Our vertical claw allows us to transport clams to the surface. Additionally, our horizontal claw can pick up the rebar reinforcement rods and insert them into sockets on the steel baseplate. Our claw, which is operated by a servo, is controlled via a potentiometer on our topside control box. We decided to use a potentiometer to operate our servo because it allows us to open and close our claw to various positions depending on what prop we need to manipulate in the pool.

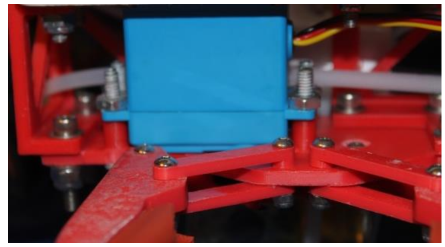
Build vs. Buy: Our company had to consider the perks behind building or buying certain parts of the vehicle during the design process. To analyze and evaluate build vs. buy decisions, the company collectively developed pro and con lists to determine the ideal option. For example, we arrived at the conclusion that designing our own claw and other 3D-printed parts (i.e. brackets, landing gears, motor mounts) was more practical than purchasing pre-made parts because it gave our team more agency and voice toward the design of our vehicle. Also, pre-made parts for brackets and landing gears are nonexistent anyways. On the other hand, it often seemed more pragmatic to purchase components of our vehicle. For instance, we purchased the onboard electronics box due to lack of resources necessary to have a canister machined and manufactured. This, in turn, saved time better spent on programming the electronics themselves.

New vs. Used: Last year, our company competed in the Scout division, where the missions were considerably easier than this year's and our vehicle, constructed out of PVC pipe, was much less sophisticated in comparison to our vehicle this year. And with the new 2017 size and weight requirement implemented by MATE, our team saw no benefit in trying to modify last year's vehicle. This prompted us to start from scratch this year, learning how to program microcontrollers, develop a functional claw, waterproof a series of onboard components, and so forth.

TRADE OFFS:

Over the course of the year we had to make important decisions on what to include in our design. One of our biggest tradeoffs was deciding to use a servo to operate our claw instead of a linear actuator. We decided to do this because it is much more cost- and space-effective with a servo costing approximately $50 compared to a linear actuator costing around $150. Last year we wanted to use a linear actuator but had to give up that goal due to time restraints, so this year with much more time we thought we would use a linear actuator; however, when we analyzed the options in more depth we realized that a servo would be a much better option. Another tradeoff was our decision to build our own tether instead of buying a premade tether; this was mainly due to it being much cheaper than buying a premade tether that met our conditions. Early in the year we began an overall very successful letter writing campaign. One aspect of this campaign that was not successful was our efforts to get a tether. We reached out to numerous companies but none responded to our various messages. As a result of this, we built our own tether by assembling separate wires which only cost us $135, whereas a tether that was pre-made and met our requirements would have cost us upwards of $500 dollars without any discounts.

CHALLENGES:

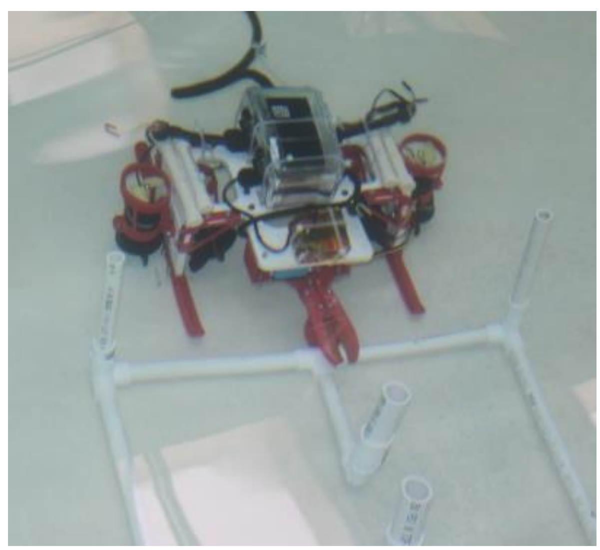


The current and functional servo attached to our vehicle

Technical: One of our biggest challenges was obtaining a fully waterproof and functional servo. Without a functioning servo, we cannot control our claw, and our claw is the only way we can pick up objects for the missions. The first servo claimed to be waterproof in its specifications, but after we tested the servo for over five minutes in the pool, the servo started twitching. When we brought the ROV back to the surface, we opened the servo and found that it was wet and had leaked. We decided to buy the same servo, but this time we chose to waterproof it ourselves. We tested the second servo in the pool, but it still leaked. Next, we decided to buy an already waterproofed servo that we had seen in previous teams' technical reports; however, new challenges arose when we bought it. The servo, unfortunately, did not have enough torque to rotate the claw, so to fix this we loosened the screws to reduce friction, and this allowed our claw to be able to rotate. Once again, another problem arose with our servo; our servo was twitching. We looked at the program, but nothing appeared to be wrong, so we decided to write the values regularly to the servo instead of using the servo library. With the new program, the servo stopped twitching, and so we finally had a fully functional as well as waterproof servo.

Another challenge our company faced was a leak in our onboard electronics box due to the company not fully latching the onboard electronics box. In our box, we originally had a pair of dual-channel motor controllers to operate the four motors of our vehicle, but the leakage fried both of the motor controllers. We were unable to replace the dual-channel motor controllers because they were out of stock at the time. To solve the crisis, we purchased four programmable motor controllers that each operated one motor, which offered a fast and cost-effective solution. From then on, we realized the necessity of a poolside checklist prior to deploying the ROV (see "Lessons Learned") and of having spare parts on hand.

Non-Technical: A nontechnical challenge the company came across was being able to complete the ROV with enough time to test in the pool. Since this is our first year in the Ranger division, we do not have past experience with programming and wiring microcontrollers. A month before the regional competition, we started to meet almost every day for at least three hours and some days for even five hours. Two weeks before the competition, we were able to get our ROV in the pool, but we experienced some setbacks since our electronics box leaked and our servo had many problems when we tested it. We persevered, and we were able to resolve our tooling setbacks in time for the regional competition.



The ROV preparing to transport the rebar reinforcement rods

LESSONS LEARNED:

Technical: This is our first year in Ranger, so we do not have much past experience with hardware and software. Thus, this year we had to learn how to create hardware on top side and bottom side as well as software that could communicate between two microcontrollers. We learned that we required a Protoshield to be able to mount our RS485 converters as well as any extra wire connections that we needed to make. We also learned how to program our motor controllers to be able to run from our Arduino IDE programming. With learning how to program using Arduino IDE, we were able to learn how to use "if" statements, set up variables, include libraries, and to use simple logic to be able to send data from the joystick all the way down to the motor controllers. To be able to learn these things, we had to grapple with them for a while, and persistence paid off. Furthermore, when our ROV was finally ready for pool testing, our company accidentally forgot to fully seal the onboard electronics box, which led to the frying of our dual motor controllers. This experience helped us realize the importance of developing and adhering to a detailed poolside checklist.

Task List	
Order Topside Control Box	Finished March 22
Order Extra Motor	Finished March 11
Add 3 joysticks and extra motor controller to Arduino program	Finished March 24
Camera Potting	Finished April 15
Order 1 more Motor Controller	Finished March 15
Order Tether	Finished March 24
Buy epoxy resin and adhesive silicone	Finished March 24
Get screws for control box	Unfinished
Get standoffs for control box	Unfinished
Get nuts for control box	Unfinished
Design Frame/Figure Out Tooling *-What missions are we going to do?*	Finished March 14
Fix RS485 Program	Finished March 11
Order propeller/propeller mounts	Finished March 22
Outreach and Inspiration******	Unfinished
Poster + Oral Presentation	Unfinished
Pool Testing!!! - Bring buoyancy materials	Unfinished
Get HDPE---(@ Tapp Plastics: two 6"x24"x3/8")	Finished March 25
Get Heycos	Alex Got Them!! April 20
Proto-Shield Soldering	Finished April 14
Update SolidWorks	Unfinished
Test to see if propeller works for 5 minutes (doesn't have to be underwater)	Almost Finished
Assemble tether	Finished April 1
Finalize claw design	Unfinished
Waterproof the Servo (power for claw)/Worm Gear	Unfinished
Finish Building Props	Unfinished
Drill holes into control box for Heyco/tether	Finished April 16

An organized task list delineating steps to ready our ROV for pool testing

Non-Technical:

Last year, when our team competed in the Scout division, we had very little time to test our ROV underwater at a local pool. This was a result of our collective underestimation of how much time it would take to wire our topside control box. This year, however, we resolved to follow a detailed task list to organize our time more efficiently. The task list delineated each and every step required at a given point in time to ready our ROV for pool testing. We realized that this, in addition to a Gantt chart, effectively help the team to stay on track with deadlines. While the Gantt chart helped improve our productivity, we were still time-pressed this year.

FUTURE IMPROVEMENTS:

For future years of underwater ROV competitions, our company will improve our time management skills to accommodate the extensive amount of time required to wire and program our control system by meeting more frequently. This will assuredly open up more time for pool testing and fine-tuning of our vehicle's mechanical systems. In retrospect of the regional competition this year, our one piece of tooling– the servo-operated claw–was unable to complete every single Long Beach mission, meaning that in future years we will endeavor to add more tooling (if necessary); whether it simply be a pair of steel rods, hooks, or suction cups. In future years, we will most likely add more board cameras to make driving and observing underwater surroundings much easier. By studying vector math prior to next year's competition, we will also vector our motors to allow us to complete more complicated tasks. Moreover, we will design and manufacture an electronics canister ourselves to entirely eliminate the risk of a leak. Lastly, we will manufacture a custom circuit board to replace our Arduino and programmable motor controllers in a more space-efficient manner.

The company at Seattle's port; L-R: Aidan Grambihler, Colby Smith, Owen Tiffany Graham Hyland

BUDGET:

At the start of the year we decided to set a $2,000 budget. As part of our budget evaluation, we considered whether or not we should design a new ROV or re-use our vehicle from last year. We elected to design a completely new ROV because last year's vehicle does not meet the caliber necessitated for the complex Ranger missions. Furthermore, last year's vehicle would not be a good fit for Long Beach's size and weight requirements. Another strategy to determine the budget was by examining many "project costing" spreadsheets found in technical reports from prior years. We corroborated this estimated cost with our own that we formulated by considering the Long Beach tasks in-depth and the amount of money necessary for constructing a capable ROV. Fortunately, we arrived under our initial budget by attaining $470 in donations through a letter and email writing campaign (see "Project Costing" spreadsheet).

PROJECT COSTING:

CATEGORY	ITEMS	Amount Spent (USD)	Donated (USD)	Market Value (USD)
Frame/Flotation	Laser-cutting	$ -	$ 30.00	$ 30.00
	Starboard	$ 21.00	$ -	$ 21.00
	3D-printing	$ -	$ 173.00	$ 173.00
	PVC/CPVC	$ 11.00	$ -	$ 11.00
	Galvanized Wire for Strain Relief	$ 8.59	$ -	$ 8.59
	Total	**$ 40.59**	**$ 203.00**	**$ 243.59**
WEC	Waterproof Electronics Container	$ 24.93	$ -	$ 24.93
	Cable Glands	$ -	$ 35.00	$ 35.00
	Total	**$ 24.93**	**$ 35.00**	**$ 59.93**
Thrusters	Motor Controllers - Pololu (8)	$ 367.84	$ -	$ 367.84
	Propeller Coupling (4)	$ 19.96	$ -	$ 19.96
	Propeller	$ 20.56	$ -	$ 20.56
	Bilge Pump Motors	$ 79.63	$ 100.00	$ 179.63
	Total	**$ 487.99**	**$ 100.00**	**$ 587.99**
Electronics	Arduino V2.1 RS485 Shield (2)	$ 23.98	$ -	$ 23.98
	Topside Control Box	$ 42.68	$ -	$ 42.68
	VGA Adapter and Cables for Monitor	$ 63.16	$ -	$ 63.16
	Underwater Lights and Switch	$ 24.00	$ -	$ 24.00
	2 Channel DC 5V Relay	$ 19.57	$ -	$ 19.57
	Joysticks	$ -	$ 60.00	$ 60.00
	Total	**$ 173.39**	**$ 60.00**	**$ 233.39**
Camera	Epoxy Resin for Camera	$ 59.40	$ -	$ 59.40
	Cameras	$ -	$ 50.00	$ 50.00
	Total	**$ 59.40**	**$ 50.00**	**$ 109.40**
Tether	Tether Cables/Wires	$ 118.00		$ 118.00
	Tether Sheathing	$ 17.85		$ 17.85
	Total	**$ 135.85**		**$ 135.85**
Tooling	Silicon Rubber for Claw (EqualSeal)		$ 20.00	$ 20.00
	Digital Hitec Servo	$ 60.49	$ -	$ 60.49
	Total	**$ 60.49**	**$ 20.00**	**$ 80.49**
Miscellaneous	Analog Servo	$ 47.46	$ -	$ 47.46
	Spare servo	$ 16.99	$ 16.99	$ 33.98
	cytron motor control boards	$ 52.96	$ -	$ 52.96
	heat shrink and electical tape	$ 126.98	$ -	$ 126.98
	Anderson Powerpoles & tool	$ 65.23	$ -	$ 65.23
	Spare electronics box	$ 24.93	$ -	$ 24.93
	Wire and screws	$ 19.94	$ 10.00	$ 29.94
	Competition registration fee	$ 150.00	$ -	$ 150.00
	Zip Ties	$ 22.00	$ -	$ 22.00
	Total	**$ 526.49**	**$ 26.99**	**$ 553.48**
Presentation	Poster Board	$ 4.50		$ 4.50
	Printing	$ 150.00		$ 150.00
	Total	**$ 154.50**		**$ 154.50**
Income	2017 Award	$ (1,000.00)		$ (1,000.00)
	Total	**$ (1,000.00)**	**0**	**$ (1,000.00)**
Travel	Airfare	$ 65.52		$ 65.52
	Hotel	$ 2,384.00		$ 2,384.00
	Shipping ROV	$ 500.00		$ 500.00
	Total	**$ 2,949.52**		**$ 2,949.52**
	Grand Totals:	**$ 3,613.15**	**$ 494.99**	**$ 4,108.14**

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All photographs used in this document belong to the Junior Huskies, and were taken by the Junior Huskies or their families.

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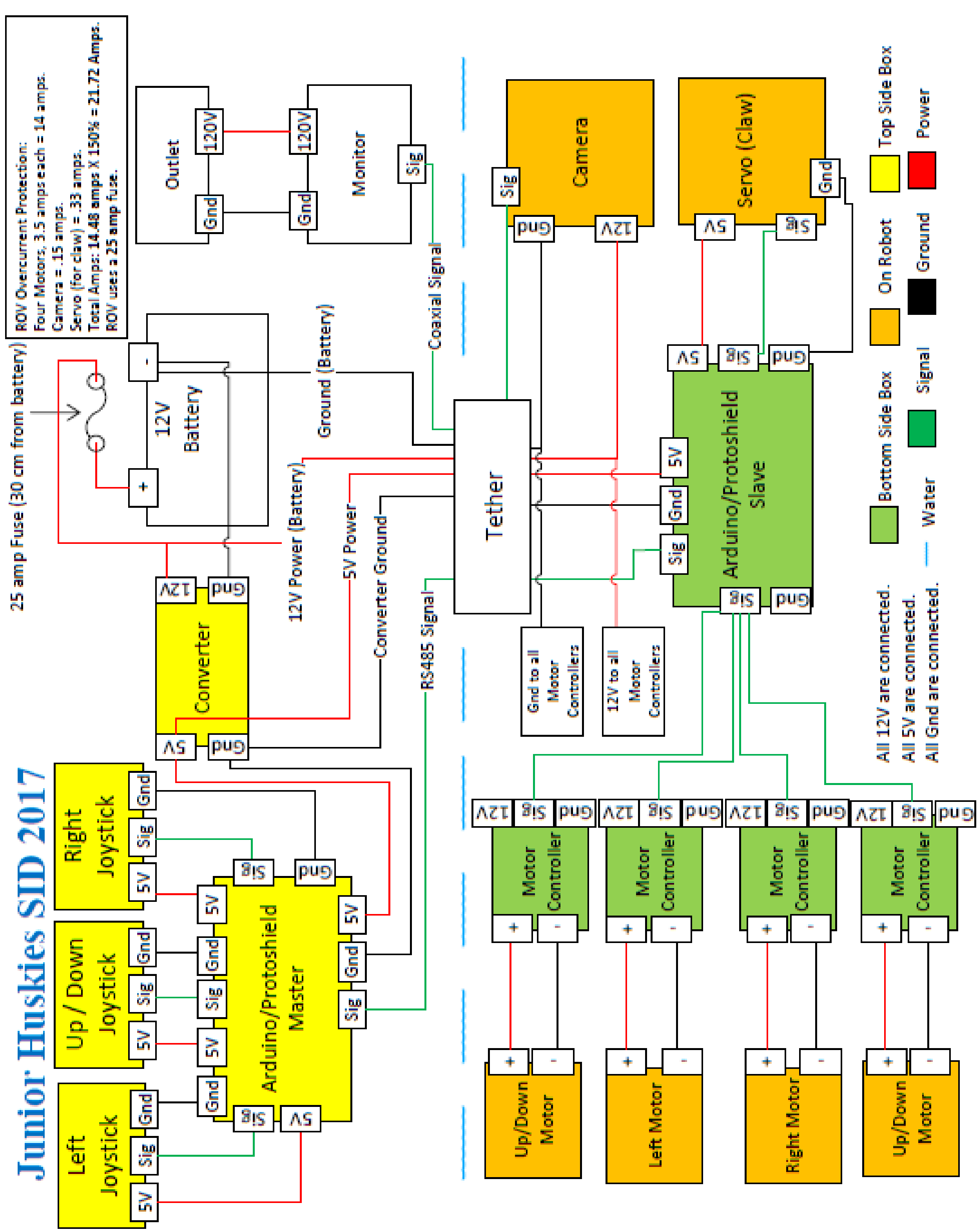
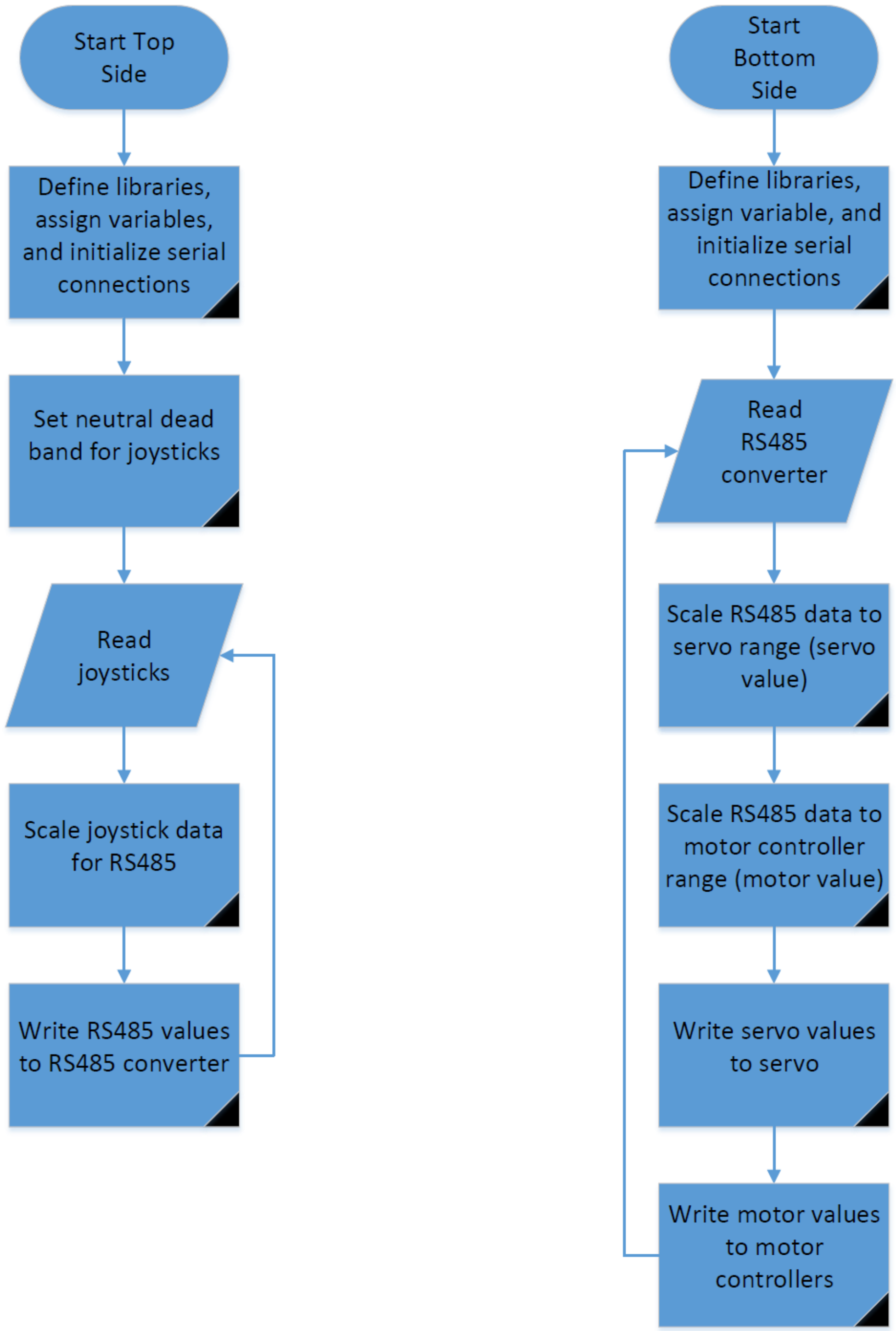
APPENDIX 1: SYSTEMS INTEGRATION DIAGRAM (SID)



APPENDIX 2: SOFTWARE FLOWCHART



APPENDIX 3: JOB SAFETY ANALYSIS

Task:	Hazards:	Controls:	Responsible Members:
1. Pre-Launch	Slips, Trips, and Falls	-All team members must be wearing closed-toed shoes. -Upon entering the poolside environment, examine for any potential trip hazards.	All Initial:
	Electrocution	-Make sure a viable 25-amp fuse is placed securely inside the fuse holder. -Clean electronics container gasket using a microfiber cloth. -Securely close the electronics container.	Graham Hyland, Owen Tiffany Initial:
2. Electrical Safety	Static Discharge	-Always be properly grounded when working with fragile electronics.	All Initial:
3. ROV Operation in Water	Tangles with Tether and Props	-If necessary, tether manager communicates with pilot to prevent damaging tangles.	Owen Tiffany Initial
	Electrocution	-Tether manager keeps an appropriate balance between tautness and slack. -If a leak is detected in the bottom side, immediately cut all power to the ROV.	All Initial: