AIS-R EAGLE RAYS TECHNICAL DOCUMENTATION

2022-2023

A Robotics team based in Riyadh, Saudi Arabia

Team Members

CEO:	Amira Nasief
CTO:	Woosung So
CFO:	Elizabeth Phillips
Safety Officer:	Oliver Clarke
Pilot/Mechanical Lead:	Aaron Chaudhury
Co-Pilot/Electrical Lead:	Aniketh Takkallapalli

Mentors

Scott Cressey	Jessi Fisk

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Abstract

The Eagle Rays are a company based out of the American International School in Riyadh, Saudi Arabia. The company consists of 6 students, who range from 9th to 12th grade who are all first-time Rangers and competitors at the MATE ROV competition. Over the course of the past year, we have built our first underwater ROV which is designed to complete a variety of tasks pertaining to marine renewable energy and coral health. In order to achieve our goal of being the first robotics team in our school to travel internationally to compete, we worked countless hours, overcame seemingly insurmountable obstacles, and grew together as a team to become a well-rounded communicative unit.

Our bot, the Kraken Slayer combines multiple features which allow us to best navigate the competition tasks. Two notable features include our single-joint manipulator arm and our sample collection pump. Our manipulator arm extends from the front of our bot so that it's just in view of the camera, and features a Lego claw that opens and closes, allowing our pilots to interact with the underwater environment. Our sample collection pump is a simple contraption with an important use. Using the attached balloon, switching on the pump allows our pilots to fill the balloon with a diseased coral sample which can be brought up to the surface for testing. The following technical documentation showcases all of our teamwork, design process, safety procedures, and critical analysis involved in the creation of the Kraken Slayer.

Teamwork: Project Management

a. Company Overview

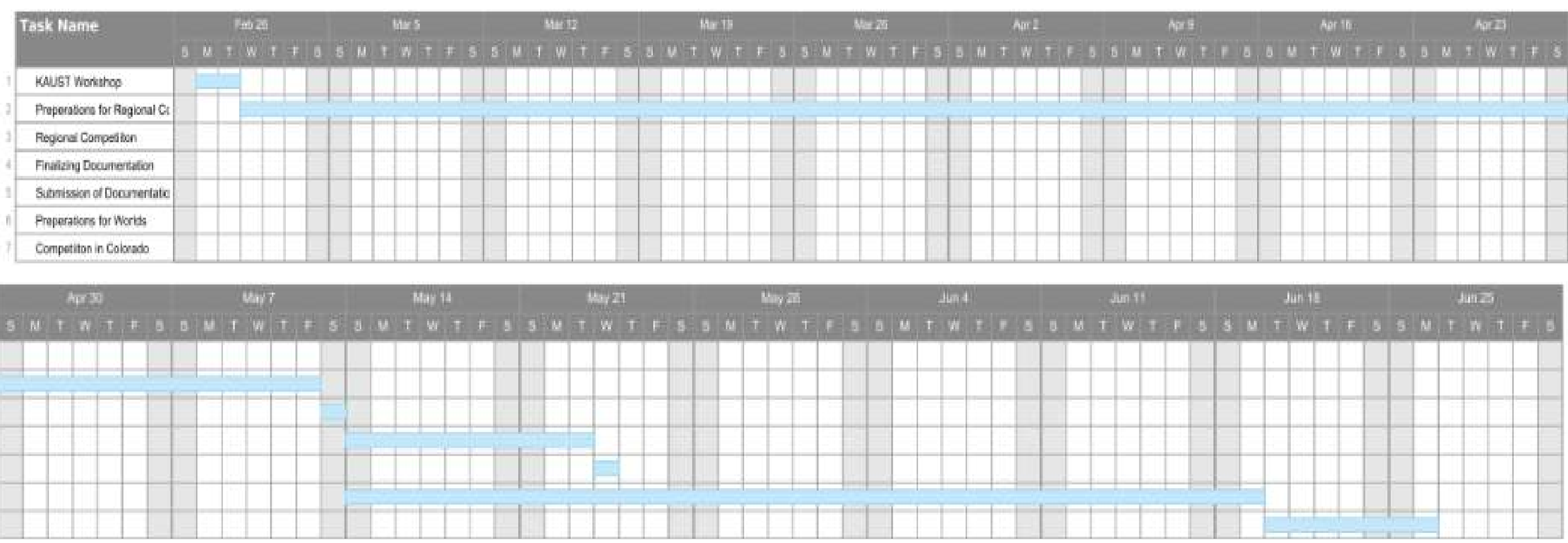
Being such a small team, we often overlapped jobs and helped each other out whenever we could, but we did have our own jobs with more specific responsibilities than just 'build the bot'. Here are our official titles and responsibilities:

Chief Executive Officer (CEO) (Amira Nasief)	**Chief Technology Officer** (CTO) (Woosung So)	**Chief Financial Officer** (CFO) (Elizabeth Phillips
• Assigned specific tasks and was a point of communication for all team members • Coordinated entire team meetings • Created the marketing display	• Created and managed the SID(s) of the Kraken Slayer • Managed the design of the bot and its attachments • Designed custom 3D printed components for the bot	• Handled budgets and accounting of the team • Managed and organized due dates. • Created technical documentation • Updated documents as information changed

Safety Officer (SO) (Oliver Clarke)	Electrical and Mechanical Lead (Aaron Chaudhury and Aniketh Takkallapalli)	Pilot & Co- Pilot (Aaron Chaudhury and Aniketh Takkallapalli)
• Created the Specifications Sheet • Created the Safety Review • Managed the printing of any 3D printed components	• Manual labor tasks including but not limited to: soldering wires, waterproofing pieces, putting together frame pieces, cutting PVC, and testing	• Predetermined flight path for the competition • Studied tasks and kept team informed of their plan • Practiced tasks with self-made obstacles prior to competition

b. Time Management/Schedule

The building of the Kraken Slayer took place over many months, so to keep on track with the dates of everything, we made this Gantt chart which we shared in the our Google Space. It has the most important dates including the date of the regional and worlds, along with the date for the document submission. This chart helped us to visualize how close dates were becoming. Next year we are considering printing something like this chart out so that we can cross of the dates, so we can really get a good sense of how much time we have.



c. Organization Methods

To keep our team organized we implemented the following methods to stay as productive as possible:

- ➢ Our CEO Amira was in charge of delegating tasks to each member of the team, to make sure everyone was doing something relevant to our mission, as well as organizing meetings when she thought necessary
- ➢ We have a Google Space which we use for quick updates and questions
- ➢ We use Google Emails for sharing important documents and/or critical information
- ➢ Used the large whiteboards in our workshop to keep track of to-do lists and plan our flight path

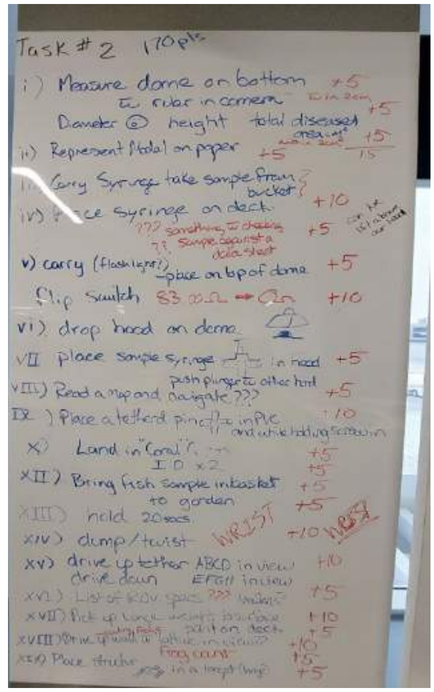


Figure 1: Whiteboard showcasing planning for task #2
Photo Credits: J. Fisk

One problem we had is that we were always working on many things at once, which means we had multiple discussions happening in our Google Space, which oftentimes became confusing. Next year we plan to find a better way to communicate where we can organize our discussions into separate chats. Some of our team members have experience with Discord, which is a social media platform that would provide us with the organization we are looking for, so we are looking into creating a Discord server for the team starting next year.

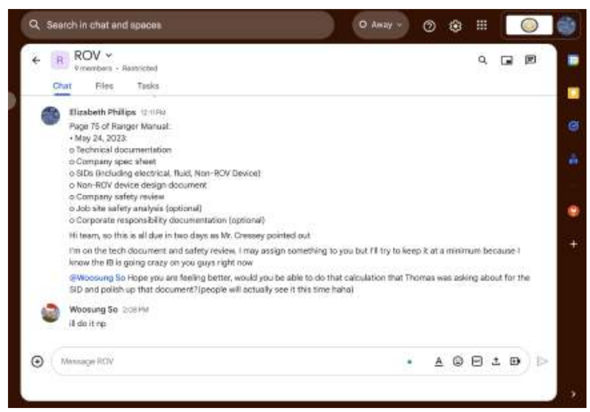


Figure 2: Our Google Space
Screenshot Credits: E. Phillips

Figure 2.1: Google Logo
Image Credits: Google

Figure 2.2: Discord Logo
Image Credits: Discord

Design Rationale

a. Build v.s. Buy, New v.s. Used

With the Kraken Slayer being our first MATE ROV bot, we had to buy a lot of our supplies, however, we tried to build what we could. We are lucky to have our school's entire robotics lab at our disposal, so there were a lot of spare pieces and already-used parts that we were able to repurpose, but we did have to use some new pieces. Here's a rundown of what we built vs. what we bought. Below is the table we made to track what on our bot was built, reused, or brand new:

Build	Reuse	Buy
• Custom 3D printed motor shrouds • Lego Claw • Custom 3D printed Camera Mount • Custom 3D printed Arm Mounts	• Control Box from SeaPerch • Pre-Cut PVC from SeaPerch • Lego Medium Motor • Springs for cable strain relief	• The control box/motors • Camera kit • Waterproofing Materials (Silicone, Epoxy, and Epoxy Clay) • A small amount of PVC • Cable extensions

b. Propulsion System

We decided to use the brushed motors that came with our Triggerfish ROV as our propulsion system. We have four motors that we have strategically placed on the frame in order to give the bot as much agility as we could with only four motors. Motors 1 and 2 (see diagram on right) are placed outside of the frame, angled slightly inwards, controlling the left, right, forward, and backward functions of our bot. We specifically designed the bot so that the PVC where these two motors are attached is left so that we can change the angle to find the best positioning. Motors 3 and 4 are placed on a crossbar in our bot which allows it to go up and down. Having two motors on the up and down function provides our bot with the power to lift heavier items.

Figure 3: Labelled Motor Placement on the Kraken Slayer
Photo Credits: A. Nasief

c. ROV Frame & Structure

We built our ROV out of PVC for three main reasons: it's lightweight, we already had a lot of it, and it is easy to interchange pieces. Our frame structure is two cubes connected by an H-shaped PVC support. The Kraken Slayer's structure was actually inspired by the fly-through video of this year's tasks. As first-time competitors, we were very lost when we started to design the structure, so we decided to base ours off of the video because it seemed to work there. The frame allows plenty of room to attach pool noodles for controlling buoyancy, along with the middle crossbar for attaching the camera. This frame also has a lot of empty space, so we were able to make a large wooden platform to give our claw stability and fit it into the structure of the frame. Overall, we do like this frame design, especially the square shape, however, we plan to downsize for next year's competition.

d. Buoyancy

Being our first competition, our main goal was to use the Triggerfish kit to make a working bot, along with the addition of an arm. Due to this, we decided to bypass more complicated alternatives, such as a buoyancy ballast tank and instead used polyethylene foam. It was extremely easy to add and cut away small pieces of the foam to make our bot neutrally buoyant. In order to make something neutrally buoyant you must make sure that the downward force caused by the weight of the bot is offset by the upward force of the polyethylene foam. This causes the forces to balance creating a neutrally buoyant bot. However, after using polyethylene foam we did research into its environmental impact and discovered that it is incredibly hard to recycle, and we are looking into new, more environmentally conscious methods to create neutral buoyancy next year.

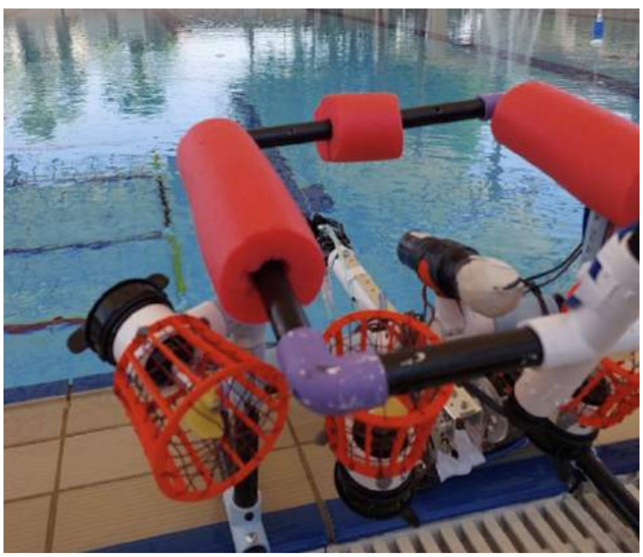


Figure 4: Polyethylene Buoyancy
Photo Credits: J. Fisk

e. Payload and Tools

By keeping our vehicle's payload light we were able to gain extra points by keeping our bot under 15kg. Here are the tools we had on our bot:

Camera	Claw
• Our vehicle has one camera which is angled downwards so that the pilots can see a portion of the ground, and what is ahead of them so they are able to orient themselves. • We used the camera sold by Sea Mate, however, we do not like it, because it is difficult to waterproof, and it has a strange shape once waterproofed. • Because of the strange shape of the camera we custom-printed our own camera mount to make sure it would stay in place.	• Our claw is made using legos reinforced with superglue and is operated by a Lego EV3 motor. • We used some old Lego tires to add traction to the claw so it would be able to grip better underwater. • One interesting feature of our claw is that if the two pieces become unaligned, the pilot simply has to open it all the way and it rights itself. • Our school recently discontinued using Lego EV3 in the classroom, so we had lots of extra pieces.
 Figure 5: The Camera Photo Credits: A. Nasief	 Figure 6: The Claw Photo Credits: A. Nasief

f. Mission-Specific Tools

Our bot showcases one mission-specific tool. When watching the videos about the tasks, our team was very interested in the one where you must use a syringe to pull a sample of water from a bucket. After learning that it doesn't have to be a syringe, but just a sample-collecting device we got to work. We decided to use a pump that attaches to a balloon to get a sample of the water. On the end of the tube which enters the bucket, we cut the tube at a sharp angle and used an empty pen cartridge to poke through the plastic wrap. After the sample is collected, the pilots bring it up to the surface for collection.

Figure 7 (left): The Pump
Photo Credits: A. Nasief

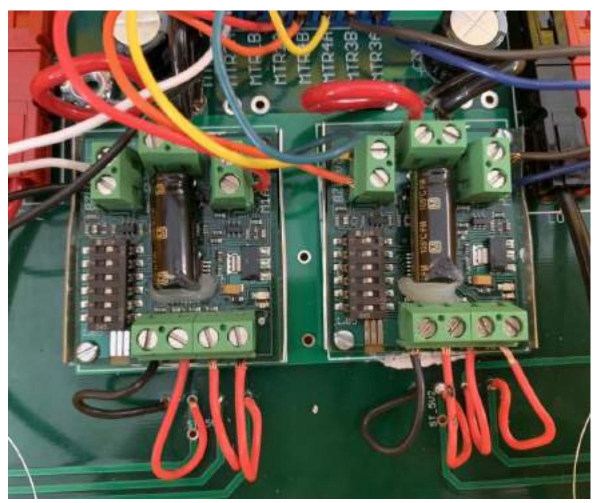
Figure 8 (right): Sample Collection Probe
Photo Credits: A. Nasief

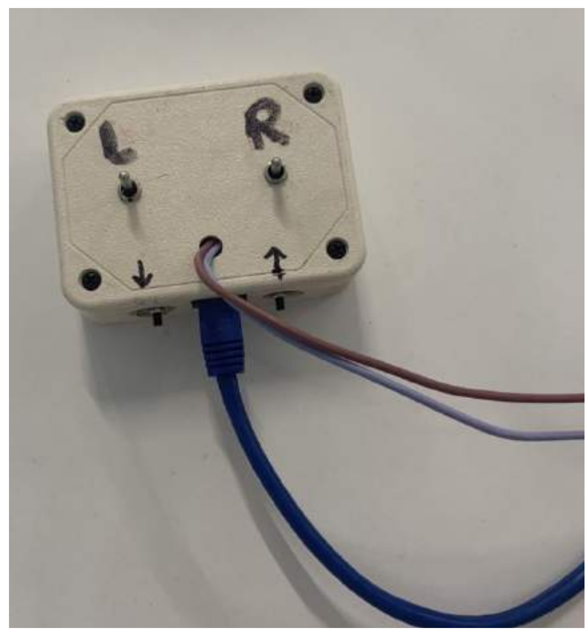
g. Custom 3D Printed Components

Camera Mount	Arm Platform Mounts	Motor Shrouds
To attach our camera to our PVC frame we decided to print a custom camera mount. The design of the camera mount is inspired by the PVC casings on our motors. Our 3D printer never prints things to the right size, so it printed too small. To save plastic, we cut open the mount and taped the camera into it for security.	Our CTO designed mounts in order to attach the piece of wood that our arm rests on to the frame. We were going to use one mount to attach the arm to the frame, but with the risk of cracking the plastic, if we tightened our screws too much, or ran into something, we decided to use two mounts.	Our motor shrouds went through nearly 8 rounds of changes before we settled on our final design. Our main problem was decreasing the water flow to our motors. To remedy this, we printed a large open shroud and used copper wire to weave through to make sure it was up to IP-20 standards.
 Figure 9: Camera Mount Photo Credits: A. Nasief	 Figure 10: Platform Mounts Photo Credits: A. Nasief	 Figure 11: Motor Shroud Photo Credits: A. Nasief

h. Control/Electrical System

The electrical and control system on the Kraken Slayer consists of 5 main components including the monitor, the sabertooth motor controllers, the control box, the seaperch controller, and a switch for our mission-specific pump. These components handle most of the control of our robot.

The Monitor	Our monitor is the one which came with the Triggerfish camera kit. We liked that the monitor fit inside of our control box for easy traveling, and thought that the image it displayed had a nice contrast. It allows our pilots to view the image from our one camera, but if we got a second camera, we could also use this monitor to switch between the two cameras' views. Figure 12: Happy mentor and working monitor Photo Credits: A. Nasief	
Sabertooth Motor Controllers	The sabertooth motor controllers are a crucial element of our electrical system. Motor controllers, like the sabertooth one, are used to protect our motor from receiving too much electricity and also send the motor electrical currents which tell it in which direction, and how fast to spin. The Triggerfish kit came with potentiometer joysticks to direct the sabertooth motor controllers. Figure 13: Sabertooth Motor Controllers Photo Credits: A. Nasief	

The Control Box	Our control box is the yellow plastic box that came with the Triggerfish kit. It safely stores our main PCB and our backplane board. The backplane board in our control box is actually not in use, because in order to extend our camera's wire, we bypassed connecting the camera to the control box at all. However it is a required piece to transfer power to our main board, so we kept it inside of the box. Figure 14: The Control Box Photo Credits: A. Nasief	
The Seaperch Controller	We repurposed a Seaperch controller to control our claw. We had to do a seaperch project in class, so we were very familiar with it, so it was easy to just connect the claw that way, and it works very well. The claw only takes up the two buttons on the top of the controller, and there are two switches that we have left open, giving us the potential to add another claw or more joints to our original arm. Figure 15: The Seaperch Controller Photo Credits: A. Nasief	

The Pump Switch	Our pump came with a long wire already attached, so we just joined it into the tether bundle. We used a simple switch to be able to turn the pump on and off when we needed to get the sample. In the future, it may be beneficial for us to connect the switch for the pump straight into the seaperch controller so that we don't have so many controllers. However our pilots have practiced with our current set-up, so they have no problems with the controls. Figure 16: The Pump Switch Photo Credits: A. Nasief	

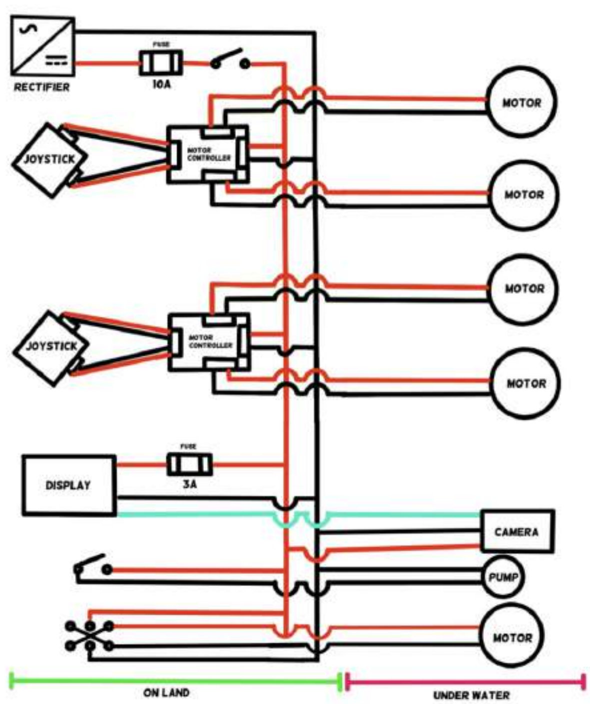
System Interconnections Diagram (SIDS)

2.5A x 12V
= 30W max draw

30w x 5 = 150w

150w / 12v = 12.5A fuse

12.5A ≃ 10A



Safety

a. Safety Philosophy

Our safety philosophy is that the safekeeping of both our bodies and our minds is put above the construction of the Kraken Slayer. Building something using lots of tools always leaves room for injuries, so we made sure to follow the procedures made for us by our safety officer Oliver. His policies were just simple, common-sense, rules that kept us from getting injured. We constructed the entire Kraken Slayer without needing anything more than just a few bandaids, which we also kept in our workstation in a first aid kit. Similarly, although we all love working with robots, building bots is extremely taxing on the brain. We tended to notice that when we worked on the bot for more than 5-6 hours we became mentally exhausted and began to make more mistakes. Due to this made sure not to work on the bot for more than 5 hours, and took frequent breaks for food and water. Our school also requires that we have a teacher in the room with us when we work, so we always had one of our mentors, either Mr. Cressey or Mrs. Fisk, present in the lab.

b. Safety Procedures (Construction)

Safety Checklist (Construction)
• Teacher in the lab
• Manage any cords that are across the floor
• Safety Glasses are used when working with any tool
• Wash hands immediately after handling chemicals including but not limited to epoxy, silicon, and soldering tin.
• You must have a lesson on a tool that you've never used before by Mr. Cressey
• Unplug soldering irons, and other tools when not in use
• Wear proper attire (closed-toe shoes, long pants, tie back hair)

c. Safety Procedures (Operation)

Safety Checklist (Operation)
• Teacher is present
• Make sure all electrical components (control box, power cable, etc.) are secured and will not come into contact with water
• Tether is laid out and detangled so the tether management worker can feed it in and out of the water
• Ensure there are no sharp edges on the bot to avoid injuries
• Plug bot into power, but do not turn on the battery until instructed by the pilots
• Turn on the power while the bot is out of the water, to check everything works
• Slowly place the bot into the water, with the power on
• Keep the area quiet so communication between pilots and tether manager can be heard
• In case of the emergency, first shut off power, then remove the bot from water
• After the bot is finished, remove from water and allow it to dry before making any repairs

d. Safety Features

Waterproofing	Cable Management and Strain Relief
• Waterproofing was taken into high regard since having loose circuits underwater could threaten the safety of our staff, and possibly ocean life in a real-life setting, and ruin our expensive pieces. We used a mix of wax, epoxy, silicone, butyl putty tape, epoxy tape, and heat shrink to secure every possible water entry point. We made sure to wash our hands after using these chemicals.	• Cable management and strain relief are very important safety features. All of the cables on the bot side are secured to our PVC frame using a combination of zip ties and electrical tape. On the land side, we made sure to tape our 4 different cords that make up the tether into one to avoid tripping and tangles. Strain relief keeps our cables safe from being broken by repeated stress, which would allow water to enter.

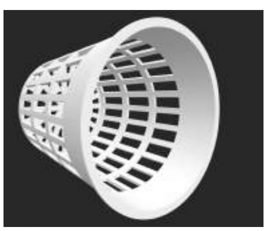
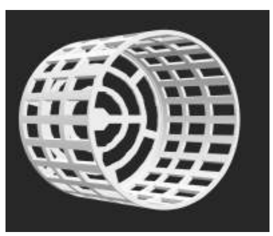
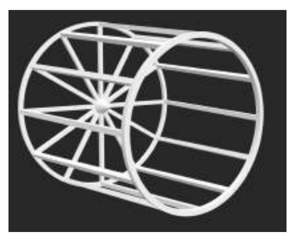
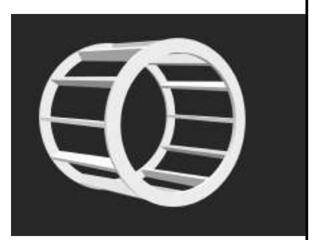
 Figure 17: Claw Waterproofing Photo Credits: A. Nasief	 Figure 18: Tether Strain Relief Photo Credits: A. Nasief

Motor Shrouding	Inline Fuses and Kill Switch
• Exposed motors are a danger to any and all entities within the water, including our staff, as they pose a risk of causing infliction to items within its vicinity. More specifically seen with the potential to injure wildlife, and potentially exposed motors could cut their own wires with repeated impact. To solve this issue we cover our motors with protectors/shrouds to avoid easy contact with the propeller blades.	• Utilization of fuses can protect our ROV circuit from high currents preventing damage to the circuit and avoiding fire caused by overheating. We use Fuses from our power source to our bot and in the control box. Considering that the fuses were a part of the triggerfish's pre-built design, we ensured that the fuses remained at the optimal voltage to protect the circuit's integrity.
 Figure 19: Shrouded Motor Photo Credits: A. Nasief	 Figure 20: Power Cable Fuse Photo Credits: A. Nasief

Critical Analysis

a. Prototyping

There were many instances in the building of the Kraken Slayer where we had to keep re-prototyping certain components over and over again but of the most notable pieces was the motor shrouds. We had at least 8 different renditions of our shroud design, below are four of them:

Version 1	Version 3	Version 5	Version 7
Version 1 was actually an STL for a trash can that we found online. The bars were too close together to let enough water through, but they met the IP-20 standards. The taper was too steep for the propeller, and it hit the edges.	Version 3 was a new design, which had more spaces between the bars while still meeting standards, and a new design for the cap. It still blocked too much water, and the lack of taper made it difficult for us to attach it to the motor.	Version 5 was getting closer when in use our motors were able to push water and move. However the plastic was too thin, and we couldn't handle the shrouds without breaking them into pieces. It also was not up to IP-20 standards.	Version 7 is a thicker rendition of version 5 with the top removed, which still didn't meet standards. To remedy this, we used a thin copper wire and wove it like a basket. This way it both met standards and didn't block too much water flow.
 Figure 21: Shroud Version 1 Screenshot Credits: E. Phillips	 Figure 22: Shroud Version 3 Screenshot Credits: E. Phillips	 Figure 23: Shroud Version 5 Screenshot Credits: E. Phillips	 Figure 24: Shroud Version 7 Screenshot Credits: E. Phillips

b. Testing

Testing is one of the most important parts of the engineering process, and at the regional competition, we had not nearly tested our bot enough. For example, our camera which has been in the water multiple times, but never for more than 5-10 minutes, flooded with water after being in the water for 20 minutes when we were practicing at the regional. Luckily for us, we had another camera, however, we also didn't get much time to test this one, so on the day of the competition the lens fogged over and our pilots couldn't see a thing. From these experiences, we have developed a new policy for testing if things are waterproofed.

Waterproofing Test Checklist
• Check for any visible water entrances
• Slowly dunk into the pool checking for any air bubbles
• If bubbles are detected, remove from the water, let dry, and re-waterproof
• If there are no bubbles, allow the item to sit in the water for 5-10 minutes with supervision
• If the item is still holding up after 10 minutes, secure it in the pool and allow it to stay underwater overnight
• If the item is still waterproof in the morning, the waterproofing was successful

While an overnight waterproofing test seems a bit extreme, our bot should be waterproofed well enough to withstand that amount of time, and if it is not then the work is not up to our company standard anyways and needs to be redone.

c. Troubleshooting

Introducing our arch nemesis: the potentiometer joystick. As robotics students, we collectively have never had to troubleshoot a component as much as we did with these joysticks. We have already decided that we will not be using them in future competitions, but here was our troubleshooting process. Upon the completion of the Kraken Slayer's control box, we noticed that if the box was bumped, our motors would spin uncontrollably. We originally did not know what was causing this so we tried many different solutions. First, we reconnected all of the wires to the sabertooth motor controller, then we resoldered the wires onto the joystick, and added heat shrink to prevent short-circuiting, after that we checked endlessly for loose wires, bad connections, or bad solders. Upon finding nothing wrong we began to search for more answers until we found a troubleshooting guide for our problem. Only after about a month of troubleshooting did we determine that the calibration of the joystick was the root of our problem. So, we calibrated our joysticks and they worked great… for a short amount of time. The problem with potentiometer joysticks that we have learned is that they don't hold calibration well, and every time we calibrated them, they got more and more damaged. This issue finally came to a crescendo at the regional, where we lost control of all of our motors due to our joysticks getting damaged beyond calibration during the transit to the regional.

Figure 25: Bottom of Potentiometer Joystick
Photo Credits: A. Nasief

d. Interpersonal Challenges, Lessons Learned, and Development of Skills

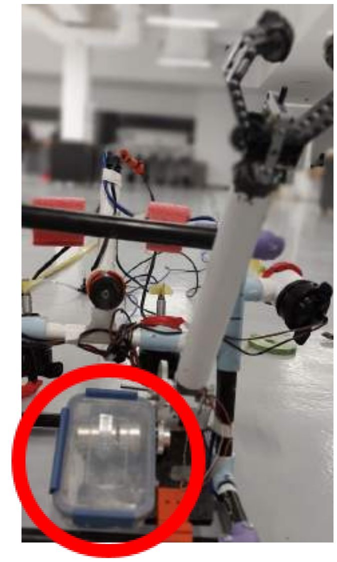


Figure 26: Tupperware Waterproof Fail
Photo Credits: J. Fisk

We were lucky to find that the completion of the Kraken Slayer came without any major interpersonal challenges. However, we learned lots of lessons and developed many new skills. The biggest lesson we learned was about the importance of testing, especially testing if our pieces are waterproofed. The waterproofing of our camera wasn't the only waterproofing disaster we had during our build project, in fact, it was only one of many. One of the other waterproofing disasters we had was that our arm originally had two joints as opposed to the one we ended up with. We worked on the Kraken Slayer until the very last minute, and because of this we didn't get to test one piece of our bot, the motor housing (see figure ?)for the up and down motion of our bot, before we left for KAUST. After arriving we finally got to test it that night, and to our dismay, it filled with water. Because of the time constraint, we had to remove that joint from our arm.

We also learned countless skills throughout the process of building the Kraken Slayer, which includes but is not limited to using table saws, soldering, 3D printing pieces, making SIDS, and how to best waterproof things. Our electrical lead Aniketh was the only person on our team who didn't know how to solder when we went to the workshop in February, and he got so good at it, that he soldered the entire PCB of the control board. Apart from physical skills we also learned interpersonal skills, including communicating as a team, being able to ask each other for help, and how to motivate each other and ourselves.

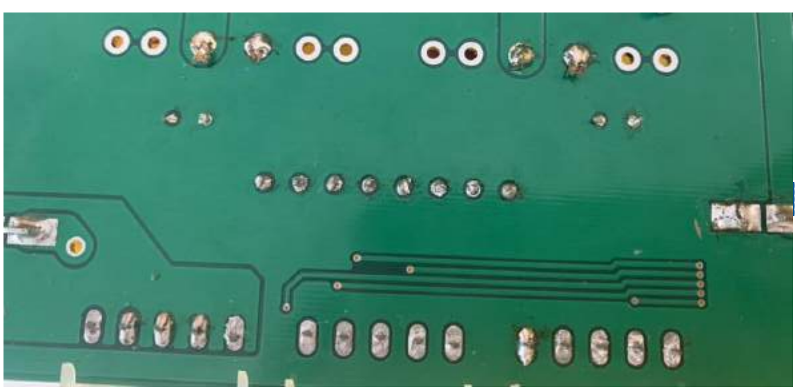


Figure 27 (left): Aniketh's Soldering Job
Photo Credits: A. Nasief

Finances

a. Budget

We were very lucky that our school provided us with a very flexible budget because this was the first time our school was entering a competition, so we didn't know what prices to expect. In the future, we will probably have a budget of around 1,000 USD, which is about how much we spent this year on our bot. We also plan to do some of our own fundraising and seek donations from organizations in our area in the future, to relieve some of the cost.

b. Cost Accounting

Eagle Rays Expenses Tracker				
Item	**Unit Cost**	**Amt.**	**Total Cost**	**Purchased or Owned**
Triggerfish/Barracuda Video System Kit - ONE Camera	$155.00	1	$155.00	Purchased
TriggerFish ROV Kit with Thrusters and Tether (Rev 4)	$850.00	1	$850.00	Purchased
1.5 inch diameter PVC pipe (0.3m)	$1.81	4.5	$18.10	Owned
1.5 inch diameter PVC elbows	$0.01	8	$0.08	Owned
1.5 inch diameter PVC tees	$0.02	10	$0.20	Owned
Lego EV3 Medium Servo Motor	$24.99	1	$24.99	Owned
Toilet Wax Ring	$4.58	1	$4.58	Owned
4 Minute Epoxy	$7.99	6	$47.94	Purchased
Epoxy Putty	$7.99	1	$7.99	Purchased
Silicon Sealant	$9.98	2	$19.96	Purchased
Polyethylene Foam(0.5m)	$0.85	8	$6.80	Purchased
Electrical Tape	$7.68	3	$23.04	Purchased
22 Gauge Copper Wire (8m)	$4.88	1	$4.88	Owned
PLA plastic for the 3D printer	$17.99	1	$17.99	Owned
Total Cost of Everything			$1,181.55	
Cost of Items Purchased			$1,110.73	

Acknowledgements and Sponsors

We would first like to acknowledge our two mentors. Mr. Cressey, thank you for staying after school every day for us to work, and sourcing materials for us all over Riyadh. Mrs. Fisk, thank you for keeping our spirits high with baked goods and encouragement. We want to also give a huge shoutout to Madison Skarda, a 9th-grade artist at our school, who designed and colored our logo. We also thank our school's Eagle Services Team (EST), for building our testing pool and supplying us with any materials we asked for. We finally like to thank our superintendent Mr. Boudreau for taking an interest in our efforts and giving us all the permissions we needed to make it to the competitions.

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