SAGE Engineering Technical Design Report

Abstract

This report describes the unique ROV that Team Tahi from SAGE Engineering has designed and created through the engineering design process. This report will include; a task overview, design approach, experimental results, reflections and next steps, references, acknowledgements, and a budget.

The team had to design their ROV to be able to complete the challenges; the obstacle course, and mission course. Their ROV shape is unique. The team chose to have a sleek rectangular shape at the front with a V shape at the back. The V shape tapers the back of the ROV to a point like a teardrop shape. The teardrop shape is the most efficient shape for streamlining due to its effectiveness at reducing drag, this makes their design hydrodynamic so that it can slice through the water effectively. Therefore, it's faster, more manoeuvrable, stable, and has a good centre of gravity. The team's way to achieve neutral buoyancy and stability is unique. They waterproofed the bottom layer of the ROV making the ROV frame buoyant. The team's attachment is very unique, it is a hydraulic claw to grab the weeds in Prevention of Flooding. It's positioned at the bottom of the back of the ROV and has two fingers to grab with. When they added attachments and motors they balanced them by adding counterweights. For their attachment they have a two-pronged hook that attaches on the front of the ROV.

They didn't follow the engineering design process well leading up to this competition due to only having three weeks to work on their ROV.

Task overview

1. Obstacle course - the obstacle course requires the ROV to be agile in going up, down, and turning sharply to allow it to be able to weave through the hoops (18 inch diameter). The hoops are placed at different angles and directions on the bottom of the pool floor. The ROV needs to drive to the surface and return through the hoops to surface at the wall. The team will need to design their ROV to be fast, manoeuvrable and compact to easily achieve this. They have made their ROV smaller than the standard build (it is 30cm x 17cm x 10cm) so it meets the objectives they outlined above.
2. Mitigation of Flooding - for the mitigation of flooding, the team is required to push the levers down to raise the houses. The team must also create a stop bank by pushing through holes and pushing the lever forward to raise the flag. The ROV must be able to lift the houses off the ground and bring them to the side of the pool. Their ROV's design can successfully complete these tasks due to the ability to change the level of buoyancy on the ROV.. The team have a removable film canister to support buoyancy so they can pick up the houses, as these are quite heavy. When removing the canister they can flip the levers to lift the houses and lift the flags smoothly with the neutral buoyancy.
3. Prevention of Flooding - the team must deliver four t-shaped pvc pipes into holes, there are two different sized holes. For the second part of this task, the team will need to remove and retrieve 4 hoops and 3 ball-shaped weeds. These items are situated on the ground. The ROV's design meets these requirements with the hydraulic claw. The hydraulic claw can bend to wrap around the hoops, ball, and pvc pipe, and can keep control of the item while delivering or retrieving.

Design Approach

The team used the engineering design process (ask - define a problem, imagine, plan, create, test, improve) to make their ROV fit for purpose (Figure 1 - *Welcome to STEM Class!*, n.d.

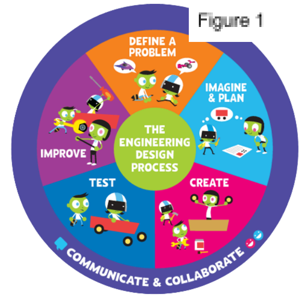

Figure 1

Ask (Define a Problem) - The team identified the challenges their ROV has to face. The ROV must fit through an 18 inch hoop, modifications must cost under $20, the ROV's frame must be built using only PVC, PEX, CPVC pipe and fittings but it does allow 3D printed attachments. It must be fit for purpose for the; obstacle course, mitigation of flooding, and prevention of flooding *(Regional NZAquabots Challenge Rules, 2024)*. For these tasks the ROV needs to be manoeuvrable, fast, balanced, and have efficient attachments.


Figure 2

Imagine - The team wanted to add an attachment that could grab and lift the weeds since their hook claws couldn't hold onto it (figure 2). They decided to use hydraulics to make a claw with fingers that bend. The fingers would be made out of silicone and the team will use a syringe attached to the tubing, when they push water through the fingers will bend and grab onto the object. The team wondered that if they added another attachment would they need to change their current design? (figure 5).

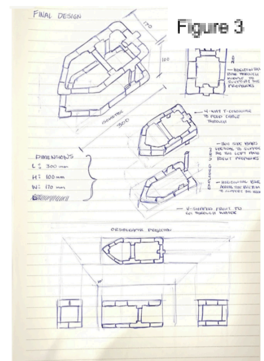
Figure 3

Plan - The team decided to keep the original design because its shape makes it hydrodynamic and size allows it to be more compact (figure 5). Its design left space to add in the hydraulic claws. The red houses would be heavy so the team added additional pool noodles at the front. This meant that the ROV can be more buoyant around the hook and the red houses can be lifted off the ground more easily. To make these hydraulic claws the team used 3D-printed moulds (figure 4).

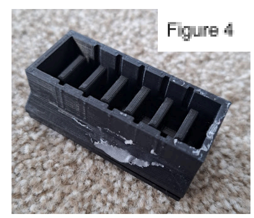
Figure 4

Create Test Improve 1 - For the team's first iteration of their ROV, they tried to use silicone to create hydraulic claws. Because this was their first time learning to create silicone, it proved to be more difficult than expected. Once the silicone had hardened the time found many holes and cracks which would allow water to leak through. If water leaked through the hydraulics wouldn't push through fully and the claws would only slightly bend. The team attempted to cover the holes with super glue, which wouldn't keep it together, and filling it in with silicone didn't work either. They achieved neutral buoyancy by waterproofing the ROV's top layer making the frame buoyant. The team waterproofed the top layer by using hot glue as a sealant between the column pipes attaching the two layers. This was better than the alternative as the air was not compressed the further down the ROV went, meaning that neutral buoyancy was consistent, allowing us to apply Archimedes Principle which states that a "body immersed in a fluid is subjected to an upwards force equal to the weight of the displaced fluid" ("Flotation and Stability," 2008).

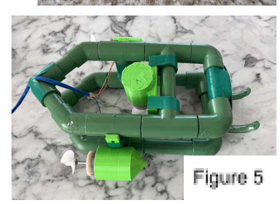
Figure 5

There were some issues with the team's process, like needing to redo the sealant a few times after testing it, however these were resolved. When adding attachments/motors they balanced the ROV by counterbalancing and putting weights on the opposite side. By doing this it increases the ROV's centre of gravity and keeps it balanced when driving (Admin, 2023).

Create Test Improve 2 - For the teams second iteration of their ROV they decided to remove the silicone claws and use hooks instead. This is because the team didn't have enough time to remake the silicone before the competition. They added a double hook on the front of the ROV. The hook can efficiently pick up some of the objects and complete tasks. The team discovered that they couldn't pick up the seaweed at all because of the big gap between the sides of the hook (figure 2). They struggled to hold onto the t-pipes for the prevention of flooding because it would slide off the hooks. The ROV could successfully pick up the hoops and couldn't lift the houses due to buoyancy.

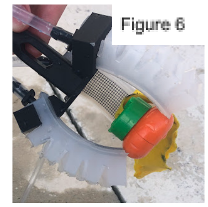
Figure 6

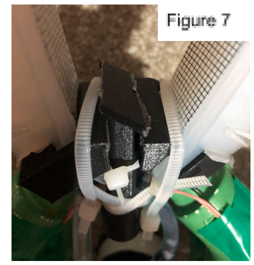
Figure 7

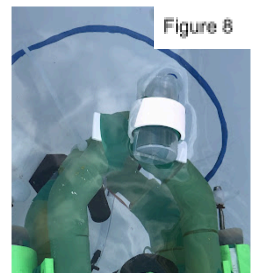
Figure 8

Create Test Improve 3 - The hydraulic claw originally had three fingers but this meant they were more spaced out from each other and the weeds could slip out of the fingers of the claw. The team then reduced the amount of fingers to two which meant the claw had a better grip on the weeds (figure 6). They wanted to improve the grip more by shortening the gap between the two fingers, so they cut the claw into pieces and attached the two sides closer together (figure 7). The fingers wouldn't bend as far and were weak when holding the objects. The team fixed this by changing from the 10ml syringe to a 20ml syringe. This meant it had more power and could push through more water into the fingers. For example, in Pascal's principle the displaced water, the water that's pushed through the syringe, moves the claw. This is because the water spreads out evenly so it makes more space in the fingers for water which bends them. More displaced water means more force creating movement in the claw, which means the fingers bend more. The hydraulic claws added some extra weight to the ROV because of the PLA but the silicone provided some buoyancy to counterweight (Frank, 2023). The team had issues with lifting the houses so they added a film canister for more buoyancy (figure 8). They picked a film canister because they can adjust the amount of buoyancy more precisely by changing the water amounts in the canister. For example, a submarine uses ballast tanks to control it's buoyancy, these tanks have a certain amount of water filled in them to achieve neutral buoyancy. It adjusts this amount of water if it needs to be more buoyant to float to the surface or less buoyant to sink down (*How Does a Submarine Work?*, 2017). The canister the team uses is filled with water to a certain amount to change their buoyancy, if they need to be more buoyant, to pick up the houses for example, then they reduce the amount of water in the canister.

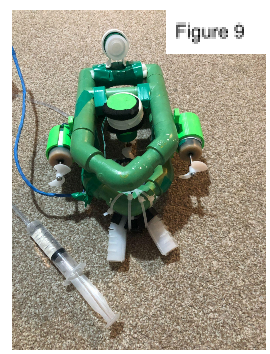
Figure 9

Final Design - Their final design (figure 9) is a refined version of their international design. By using the engineering design process (ask, imagine, plan, create, test, improve). The frame is pvc pipe with a rectangular shaped front and a V-shaped back, making it more hydrodynamic. Therefore, it's faster, more manoeuvrable, and stable. They achieved neutral buoyancy and stability uniquely, by waterproofing the bottom layer of the ROV making it buoyant, and having buoyant motor holders. Their ROV is more efficient in the tasks for 2024 because of the hydraulic claw, it can hold and lift all of the objects in the tasks and is much easier to use than a normal hook.

Experimental Results

While the team was improving their ROV to make it more fit for purpose for the obstacle course, mitigation of flooding, and prevention of flooding, they tested the; hydraulic claw and buoyancy options.

The team designed silicone hydraulic claws which bend and hold onto objects when the water is pushed through them. Our hypothesis was that the silicone claws will be able to grab onto the circular seaweed objects from task 3: Prevention of Flooding. They tested the hydraulic claws with three tests:

1. Grab the seaweed
2. Hold onto the seaweed while moving upwards
3. Hold onto the seaweed while moving around and retrieving

The team conducted these tests with one seaweed laying on the ground with the seaweed pointing upwards in a 1 metre deep pool.

	Grab the seaweed	Move upwards	Move around
Hydraulic Claw Three Fingers Out of Water	Yes, very loosely	No, falls out after small movement	No, falls out after small movement
Hydraulic Claw Two Fingers Out of Water	Yes, loosely	Yes	Yes, but falls out with fast movement
Hydraulic Claw Two Fingers in Water	Yes, more stable in the water	Yes	No, falls out due to drag
Hydraulic Claw Two Fingers Smaller Gap	Yes, very well	Yes	Yes

The team couldn't lift up the seaweed in the water so they conducted more tests on the side of the pool by changing the amount of fingers. As you can see in the results the first test worked loosely. The second and third worked better. The team then kept the hydraulic claws with only two fingers and a smaller gap between the claws (figure 7).

The team had issues with retrieving the square houses because of their weight. Our hypothesis was that if we add more buoyancy to the ROV, we would be able to pick up the square houses and retrieve them. They tested the buoyancy by adding fine neoprene foam:

1. Adding fine neoprene foam to the front where the hook is
2. Adding fine neoprene foam to both sides of the ROV
3. Adding fine neoprene foam to the front and back of the ROV
4. Adjusting amount of fine neoprene foam

Lifted house	Front	Both sides	Front and Back
First Amount	Too buoyant at front, and floats vertically	Too buoyant and can't drive down	Too buoyant and can't drive down
Adjusted Amount	Can't lift the house	Can't lift the house	Can't lift the house

None of the methods above were successful to lift the square houses off of the ground. So they decided to test attaching a film canister.

5. Attaching a film canister

	Full of Air	½ full	Full of Water	¼ full of water
Lifted house	Too buoyant, can't drive down	Too buoyant, can't drive down	Not buoyant enough to lift the house	Can lift the house off the ground but can't retrieve it

The team needed to test the film canister with different water to air ratios to find the best balance of buoyancy. They found that filling the film canister a quarter full with water, allowing the ROV to lift up the house.

Reflection and next steps
This season the team has learnt a lot about the importance of the engineering design process (ask - define a problem, imagine, plan, create, test, and improve). The team have also learnt how to work with silicone, how long it needs to set for, and how fragile it is. Through the silicone hydraulic claws they also learned how to make efficient and simple hydraulics with tubing and a syringe. This experience has assisted the team greatly. The challenges they have gone through have been helpful learning obstacles leading the team to improve in the future. The team has learnt about hydrodynamics, hydraulics, and Archimedes principle as well as other concepts/principles which will help them build a pathway into STEM careers.

They also are really proud of the silicone claws that they have made as they have been quite difficult and time consuming creating them with silicon and using the hydraulics to make them work.

The team would like to experiment with creating disconnecting motors so that if they have any motor issues they can easily remove the motors and isolate the issue. Due to the team already carrying out testing with disconnecting motors, the team will be able to create a better design that is more efficient and water tight for future seasons.

The tether is another aspect the team would like to improve. Whilst the team decreased the weight of the cable by stripping the old wire casing off and replacing it with a lighter heat shrink casing instead, they think it could be worth trying to make the cable slightly buoyant. They think this would further lighten the weight of the cable and would help to prevent the cord from tangling itself and getting caught in the pool courses and ROV.

Acknowledgements
Thanks to Jessica Cathro, for coaching and mentoring the team.
Thank you to the team's families for supporting the team and driving them to practices and events.

References

1. 2024 Regional NZAquabots Challenge Rules - Ministry of Inspiration. https://ministryofinspiration.org/wp-content/uploads/2024/04/Aquabots-Rules-2024.pdf
2. *Welcome to STEM class!* (n.d.). https://www.ashlandcityccs.net/apps/pages/index.jsp?uREC_ID=2149194&type=u&pREC_ID=2403588
3. Flotation and stability. (2008). In *Elsevier eBooks* (pp. 75–115). https://doi.org/10.1016/b978-0-7506-8987-8.00003-2
4. Frank. (2023, April 7). Why some silicone parts float on water - LDGSilicone. lgdsilicone. https://lgdsilicone.com/why-some-silicone-parts-float-on-water/#:~:text=In%20conclusion%2C%20silicone%20does%20not,in%20water%20or%20other%20liquids
5. Admin. (2023, March 22). Centre of Gravity - Detailed explanation, calculation, FAQs. BYJUS. https://byjus.com/physics/centre-of-gravity/
6. How does a submarine work? (2017, May 23). Wonderopolis. https://www.wonderopolis.org/wonder/How-Does-a-Submarine-Work#:~:text=In%20order%20to%20control%20buoyancy,to%20float%20to%20the%20surface.

Appendix A - Budget

Component	Vendor	How was component used?	Cost
3D printed objects	Self-printed	Used to attach their motors to the teams ROV and to make it more hydrodynamic, as the moulds for the silicone grippers, and as the attachments for claws	$4.17
Silicone	Temu	Used to create the grippers which were used in our claw attachment	$3.70
Syringe x2	Trade me		$2.78
3mm 5m Plastic tubing	Bunnings		$5.45
Cable joins - Barded Off take join x 4	Bunnings		$0.96
Barbed Tee x2	Bunning		$1.77
End stopper x1	Bunnings		$0.24
TOTAL COST OF SEAPERCH COMPONENTS			$19.07