Practical Work Report

Sealegs International Limited
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Employer: Sealegs International Limited
Address: 2 Parkhead Place, Rosedale, Auckland 0632
Supervisor: Maurice Bryham

Work Period Start: 13 November 2022
Work Period End: 1 March 2023

Date of Report: 7 August 2024

1 Executive Summary

Sealegs is the designer and manufacturer of a unique amphibious capability mechanism for marine craft. At the time of writing, they have produced over 1500 amphibious vehicles which are used worldwide with superyachts to coast guard flood rescue.

Over the summer between my second and third year of Engineering, I was employed at Sealegs International Ltd. Sealegs International Ltd specialises in the manufacturing of amphibious marine craft, ranging from luxury to industrial use. I had the opportunity to spend some time at the company previously, but not officially as an engineering intern.

During the summer following Part II, I returned for proper employment as a Summer Mechatronics Engineer. After some time reacquainting myself with the workplace by assisting in design projects and field testing, I began work on an independent drone related project in a temporary division consisting of me and my supervisor. My time in the company has been highly varied, unorthodox, and rewarding whilst working closely with my supervisor and co-founder of Sealegs, Maurice Bryham. I learnt many skills related to the process of prototyping, marine engineering, drone creation, and worked with a wide range of softwares, all of which has prepared me for a future in engineering.

2 Acknowledgements

I would like to thank my supervisor, Maurice Byrham, for providing me with the incredible opportunity to work at Sealegs. Thanks to his guidance, I have not only improved my technical skills but have also gained a deeper understanding of what it means to be a successful and thoughtful engineer.

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4 Introduction

Beginning in 2001 as a simple idea sketched on a napkin, which rapidly evolved into a working prototype, Sealegs has become a leader in designing, manufacturing, and distributing amphibious boats. These boats are equipped with a unique, patented mechanism that allows seamless traversal between land and sea, revolutionising marine transportation.

During the summer of 2022 to 2023, I had the privilege of working as an employee at Sealegs International Ltd. This experience was my introduction to the world of professional engineering, where I gained firsthand knowledge of the intricate manufacturing processes behind each component in marine craft. My role evolved as the summer progressed, allowing me to shadow various skilled employees and gain insights into their expertise. As I became more familiar with the work, I gradually took on greater responsibilities, eventually leading a significant self-directed project in drone technology. This project not only challenged me but also sparked a lasting interest in the field, one that I would revisit and expand upon during my time at university.

5 Workplace

5.1 Workplace Location

Sealegs primary offices and factory is located in the industrial region of Rosedale and Albany, on the North Shore at the corner of Unity Drive and Parkhead Place. It is a highly industrial area, surrounded by numerous industrially oriented companies, which became of use when purchasing materials and components. Being in the North Shore, far from my own place of residence, reaching the workplace each day was a challenge during peak traffic hours. However, a second section of the internship involved a decent amount of work from home.

Figure 1: Location of Offices.

5.2 Workplace Layout

Initially there was one main building acting as the combined engineering and sales offices with an adjoined factory and manufacturing floor, but due to recent expansion an additional building across the road was acquired which came to act as the primary reception and sales offices, and additional space for the assembly line.

This new main reception and sales office section is listed as the location of the workplace, 2 Parkhead Place. This contained a public seating area, reception, offices dedicated to salespeople, and a boardroom for larger meetings. Through the back was additional floor space for manufacturing, focused on fitting rigid inflatable hulls, and finishing the production of boats with the paint jobs and seating fixtures.

The other building, 5-7 Unity Drive, hosted the bulk of the employees. This contained the main factory line and engineering section. The factory section was located on the ground floor, and hosted facilities such as welding stations and sheet metal cutting and bending machines, and was where the main hull of the boats was built. The engineering department was found upstairs. Included was a kitchen, office area, meeting room, and a handful of offices dedicated to the higher staff.

5.3 Workplace Facilities and Amenities

The first section of my time with Sealegs was spent in 5-7 Unity Drive. Here, I had access to some spare desk space amongst the engineers in the central engineering department area. During this I also spent some time in the factory area during my introductory periods and depending on what job I was working on or assisting with.

In the engineering department, each engineer had access to their own desk and desktop personal computer. Much of the work performed by the main team was CAD orientated, designing new marine components for use with the sealegs. Although there were spare desktops available for use, I opted to use my own laptop as at the time it contained numerous softwares that were only accessible to me through my own computer.

Most of the engineering team would bring their own lunches, making use of the kitchen/break room area, as I sometimes would. However, often I would join my supervisor going out for lunch, frequenting a particular sushi place a 10 minute walk from the office.

Although there was a meeting room used for weekly meetings, much of the topics discussed were not relevant to the projects I found myself involved in. Despite this, they served as a welcome introduction to the general workflow of a professional engineer.

For parts of the second section, I worked from the garage of my own home. My garage is fitted with a range of general workshop equipment, including drills, saws, common components such as screws and glue, and a drop saw. When required, I would head to the main facility to use additional equipment that was unavailable to me at home.

5.4 Staff Organization

The main staff organisation structure I interacted with was my supervisor, who was the Chief Design Officer, and on occasion my colleagues. As my work was disconnected from the other departments and work sections, I remained largely unaware of the greater staff organisation. My supervisor was also responsible for overseeing the other engineers with the department.

6 Work Completed

The following sections will detail the work I underwent during my time at sealegs from 13th November 2022 to 1st March 2023. This work period is split into two primary sections. The first section details my introduction to the company and some of the more minor roles and projects I worked on. The second section will detail a larger project I undertook, which took up the majority of my time and focus during this summer internship.

6.1 Settling In

Upon my arrival at Sealegs, my first few days were spent acquainting myself with the factory supply line, the engineering department, and setting up my own personal laptop and desk space. There was no initial software I was required to be familiar with at the time, instead being provided with the ability to bring my own software and skillset to approach the requirements with. Digital projects and updates were shared between myself and my supervisor directly, often through email or just directly in the office. The department had access to SolidWorks, and offered temporary access, but as per my needs, use of SolidWorks ended up being unnecessary.

The manufacturing line was, although not directly worked on or altered by myself, was fascinating to learn about, and gave strong context to the process of how the engineering department moved designs and concepts into full blown production.

6.2 Mini Projects

6.2.1 Boat Display

The first few projects I worked on were graphical in nature. A prototype boat required a specialised on-board display for the early stages of testing, and I was instructed to create it.

I received a list of the processes that a prototypical sealegs would need to display. This included factors such as engine and pump status, amphibious leg orientation and on-off indicators for specific components.

The boat's internal computers were capable of using .MoTeC type files. Traditionally MoTeC is a format used to analyse racing data, but it additionally functions as a way to display this internal data. The marinecrafts onboard computers had been configured to display and work with this data in such a way that a MoTeC file configured correctly will display all this data.

Most of this project involved simple graphic creation, before learning how to utilise MoTeC specific software to create a full graphic showcasing everything. The graphics were created using Adobe Illustrator, a software which I had personal access to outside of the organisation. Although simple, this project got me acquainted with my supervisor, his work flow, and the process of rapid iteration. Repeatedly the designs I provided had required changes and areas of improvement, and learning to quickly update designs, communicate effectively with my supervisor, and receive an insight into a larger project was an engaging and important experience.

6.2.2 Employee Shadowing

Another important aspect of my job early on was shadowing employees, assisting them with their job wherever I could. The main way this was accomplished was by joining in field tests projects engineers were working on. I joined in numerous trips to local rivers and beaches to perform a wide variety of testing. I was also introduced to the wider local industrial area as I witnessed the process of acquiring specialised materials and components from local production companies.

This acted as an introduction to a select few members of the engineering department, and a further look into the general working environment and workflow of a professional engineer. This also acted as further opportunities to improve my networking and communication skills.

6.2.3 Further Jobs

Additional smaller things I worked on whilst at the in my introductory period included photoshopping together concept pictures of some internal sealegs prototypes, rebuilding and updating some broken desktop PCs, and attempting to fix a broken CNC machine. Although more in-substantial in nature, these jobs provided similar learning opportunities to the other aspects which I’ve mentioned above.

6.3 USV Project

After acquainting myself with the company, coworkers, and supervisor, and learning some initial useful skills, I was assigned a larger, primary project to work on. The aim of this project was to use the PixHawk autonomous control system alongside the ArduPilot software, with Mission Planner, to to autonomously pilot an Unmanned Surface Vehicle (USV) over a long range waypoint mission in the sea around Auckland. Weather conditions were not part of the brief, however being resistant to rain was a minimum. The boat needed to be able to complete a mission with zero human input (except for initial launch and landing), be able to start the mission once sufficiently out of sea by switching from manual to auto mode, travel along the way points, correcting for wind and drifting, pass all waypoints, and reach the final destination, to then be manually piloted in.

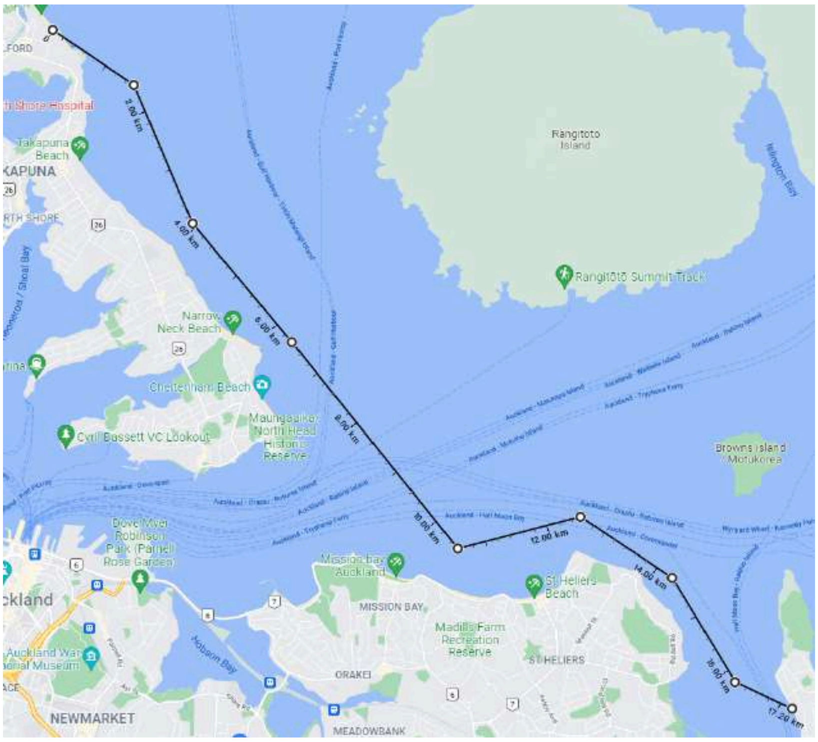

Figure 2: Example of waypoint mission.

6.4 Hardware

6.4.1 Hull

The hull used for the project was a tow-behind kayak storage called the Packhorse Float Boat. Aside from being available at the time, it provided a decent working size for the internal electronics with dimensions of 1180 mm LOA with a width of 630 mm and a depth of 260 mm, and an internal hatch dimension of 425 x 325 mm. According to specifications, the hull was capable of carrying a 50 kg payload.

6.4.2 PixHawk and ArduPilot

This served as my introduction to PixHawk, and flight controllers as a whole. PixWHawk is an autopilot system, suitable for a project like this due to its inexpensive and open-source nature. Its high customizability made it suitable for reconfiguration to allow reconfiguration for a boat setup.

The PixHawk acts as the interface between the ground station (computer running an autonomous control software) and the electric speed controllers (ESCs), data collection devices, GPS, compass, RC receiver, and battery. It allows for the control of the ESCs from the computer, which is the key to autonomous operation.

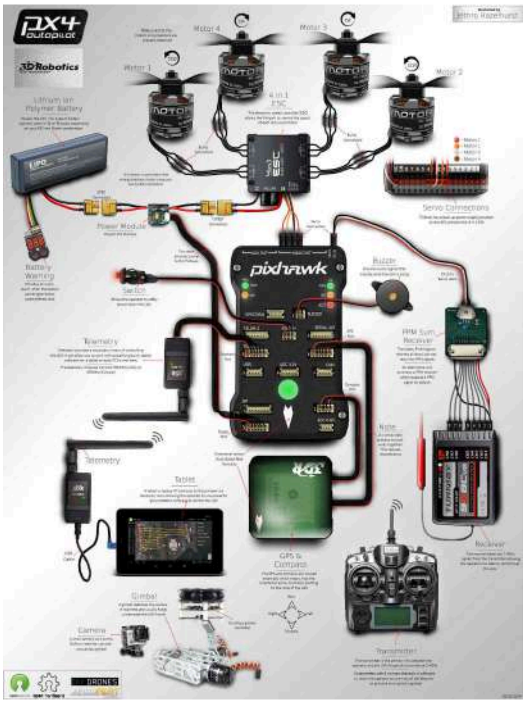

Figure 3: Standard flight controller setup.

The ArduPilot is also capable of supporting numerous sensors such as navigation and sonar, hence providing future potential for retrofitting. Waypoint missions are capable of being loaded in and saved to file.

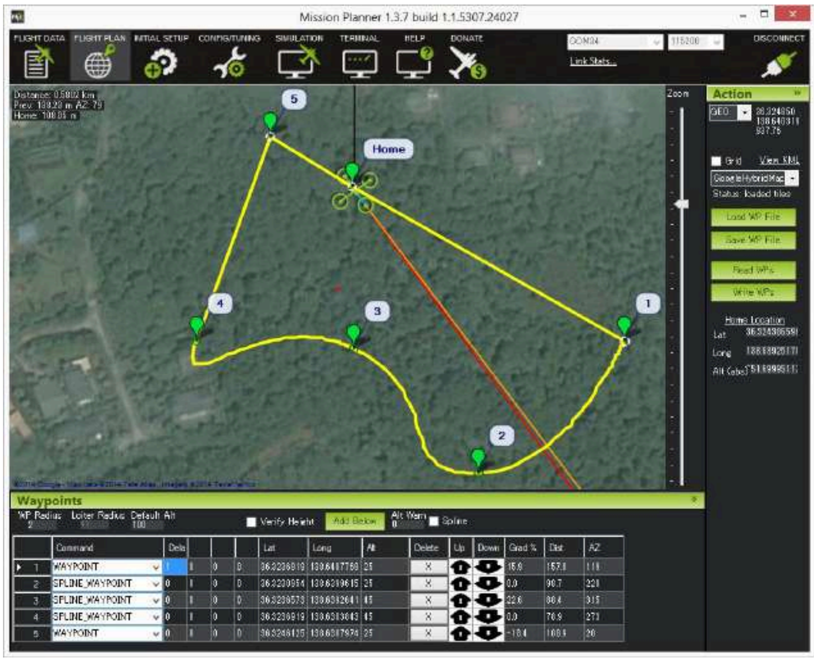

Figure 4: Mission planner showcase.

6.4.3 Motors

12V T60 Underwater Thruster Waterproof Brushless Motor CW CCW 60mm Propeller with 30A ESCs were used. The motors required around 15-23A of current draw. With 2 motors and a 60Ah battery, I calculated that the boat would have a minimum running time of 1.3 hours. However, testing with usual loads showed that the battery would draw approximately 7.5A each, allowing for a run time of 4 hours.

6.4.4 Solar

As a check for a future potential add on, a set of solar panel equipment was provided. A BlueSolar charge controller MPPT 75/15, with a 170W DF flexible solar panel was acquired. An analysis of the electrical components showed that the 12.8V battery with a current draw of 15A would require 192 Watts to stay fully powered. Driving with the solar panel plugged in, assuming maximum wattage output on a sunny day from full charge, the solar panel could negate 88% of the power draw, theoretically meaning the battery would only be drained of 22 Watts per hour, which would allow the boat to travel for 35 hours. I wired up the solar panel system as an experiment and confirmed the numbers, but ultimately for prototyping purposes I did not build an additional boat rig to tow the solar panel.

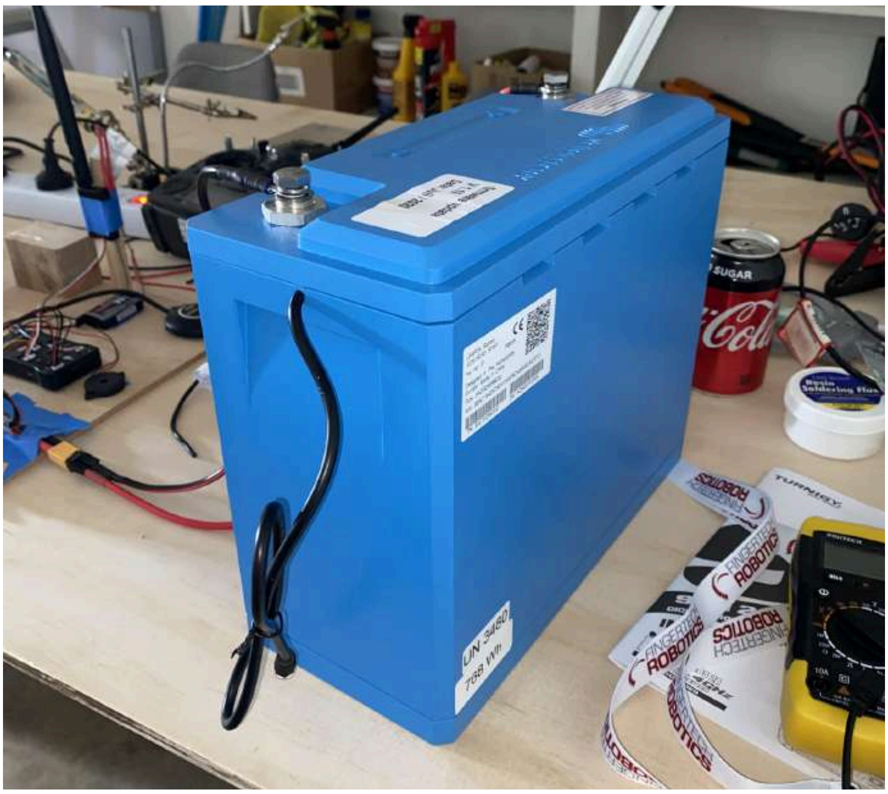

Figure 5: Battery used in USV.

6.5 Initial Testing

6.5.1 Resistance

A test for drag force against the speed was recommended by my supervisor in order to better gauge the performance of the hull. To do this we towed the hull behind a boat with a hanging scale. I placed two different sets of weights in the boat in order to better emulate the final mass of the boat. Initially we used 8 kg of stones, bringing the total weight of the boat and payload to 14 kg. Next I used 20 kg of stones in a bag to simulate a much larger weight (this would be assuming the boat had solar panels + a large quantity of batteries). When I was measuring the drag force of the heavier load, I noticed the boat's stern was sitting deep in the water. So I moved the weight further forward to shift the centre of gravity towards the bow. These are the results:

Speed (Knots)	14 KG	24.5 KG (Weight central)	24.5 KG (Weight Far Back)
2	0.5	1	1.25
3	1.75	3	4
4	3	6.5	8
5	3.5	7.5	10

Figure 6: Field data from drag test.

As the underwater thrusters produce 1.65 kg of thrust for a 3 cell battery configuration and 2.1 kg of thrust for a 4 cell configuration, you can see that at 14 kg we could be expecting upwards of 4 knots. At 24.5 kg we will only expect to see 3 knots and under. A major consideration for the performance of the autonomous boat though will be motor efficiency and longevity. Running the motors at max power is not the most efficient. From the following graph you can see the max efficiency is at around 90% RPM at low torque.

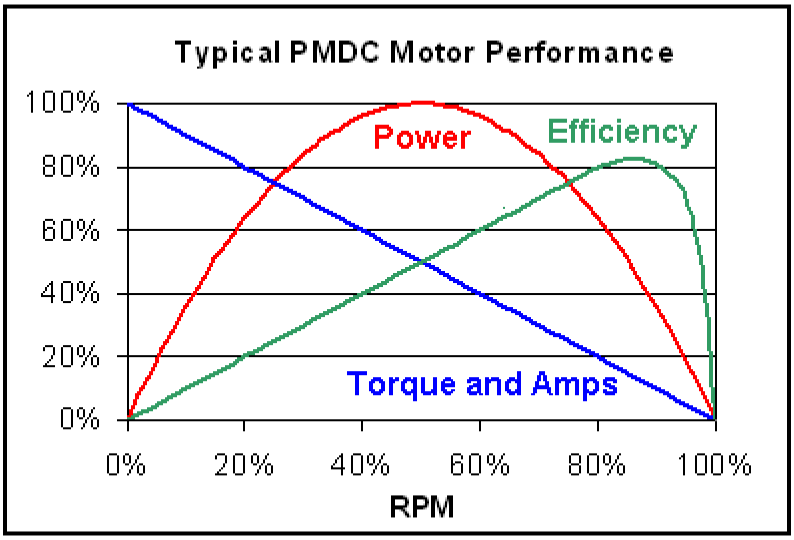

Figure 7: Typical PMDC Motor Performance graph.

This meant that I should only run the boat at sub 3 knots (5.6 km/h) to improve battery life and ensure motors are running at max efficiency.

6.5.2 Calibration

I decided to use Mission Planner as a ground control station after some online research, as it was the most popular choice for autonomous sailboats developed via ArduRover. ArduRover is the firmware most commonly used for drones with dual motor setups. The system was set up with ArduRover 4,3 firmware and the FRAME_CLASS set to the parameter value of 2 to make it compatible with boats. Accel Calibration was the process of ensuring the gyroscope within the PixHawk was calibrated with level, upside down, left, and right by rotating the flight module to those different orientations. Compass calibration required some tweaking as the external compass appeared to encounter large amounts of electronic interference and was not giving accurate readings. Radio Calibration initially did not work as I did not have a PixHawk compatible receiver. A SBUS or PPM connection was required, so as I waited for a suitable Transmitter and Receiver to arrive a spare PS3 Controller was used by installing an ScpServer app onto the laptop. Learning how to set up channels for the controller via Mission Planner gave insight into how to use the Turnigy 9X transmitter when it finally arrived. The Turnigy 9X receiver supported a SBUS and C/PPM Protocol by simply plugging in a small 3 pin cable from the PPM slot of the receiver to the RCIN of the PixHawk with a baud-rate of 57600.

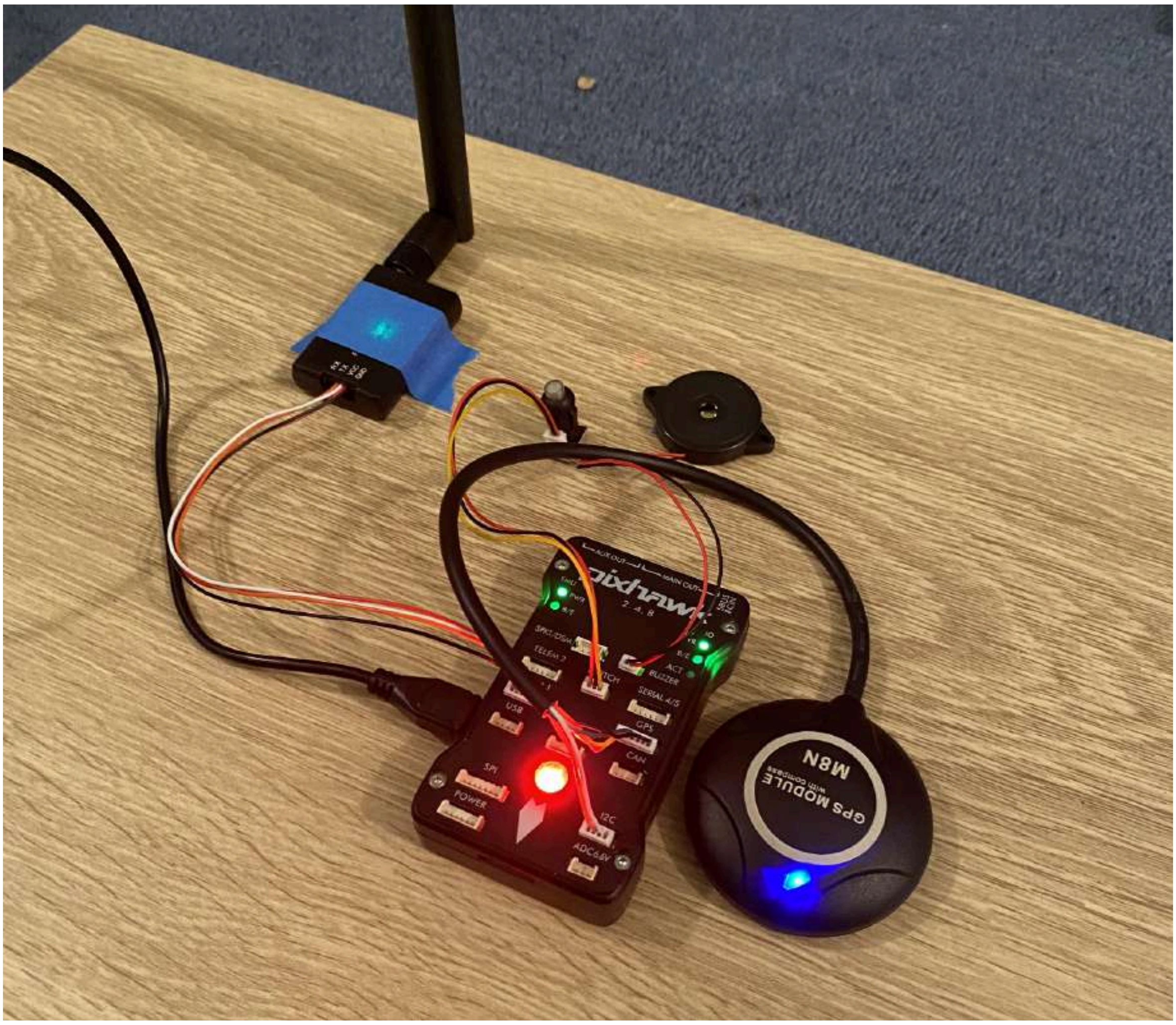

Figure 8: Bench setup of flight controller gear.

6.5.3 Motor Wiring

Researching how to wire our motors led to using the Skid Steering setup. I regarded the shaft end as the front of the motor, hence defining the direction of rotation as what it would be if the motor was moving forwards, and if you were viewing it from the direction it was moving towards. I had the clockwise motor on the starboard (right) side and attached to channel 3, with the counter-clockwise motor on the port (left) side and attached to channel 1.

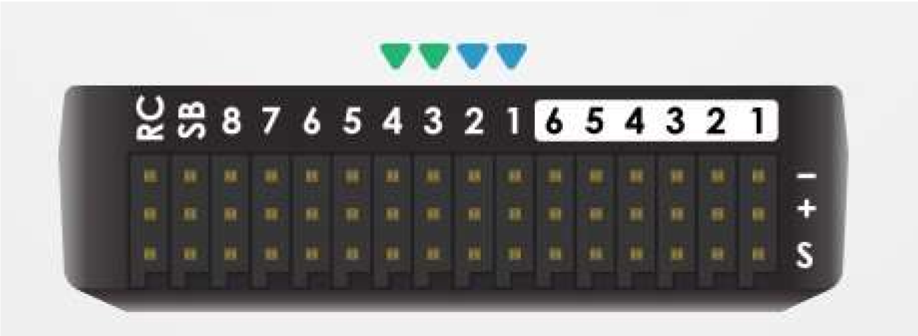

Figure 9: ESC Wiring reference.

6.5.4 ESC Calibration

The calibration of the Electric Speed Controllers required me to use a manual ESC-by-ESC calibration method. I attached a single ESC at a time to channel 3 of the receiver (the throttle channel by default), prime the controller and the PixHawk for calibration mode by placing the throttle stick at the max, listen for 2 beeps, then move the throttle stick to the middle position, and repeat for each ESC. Initial attempts at this process were unsuccessful when I only had a JoyStick, and when I followed incorrect generic instructions only suitable to the ESCs commonly used by QuadCopters. By following the instruction manual provided by our ESCs, and combining this with the ESC calibration arming mode on the PixHawk I was finally able to correctly successfully calibrate it.

6.6 Boat Manufacturing

Several steps needed to be undergone to prepare the Packhorse for the water. The largest concern was ensuring full internal waterproofing after modifications.

6.6.1 Stand, Battery Mount, and Hatch

To work on and move the Packhorse around, I put together a simple wooden stand in the image of a boat trailer, with 3 padded points of contact for stability and scratch prevention. At 150mm off the floor, it ensures the bottom mounted motors weren't prone to damage on dry land.

The mount for the internal battery was made from two 25 by 25 by 2 mm aluminium L channels which were bent and cut into shape with 4 flags to provide an increased surface area for adhesive sticking. 12 by 9 mm foam strips were added onto the mount to cushion the motor from forces induced during movement. An adjustable strap was added to ensure the battery remained in place.

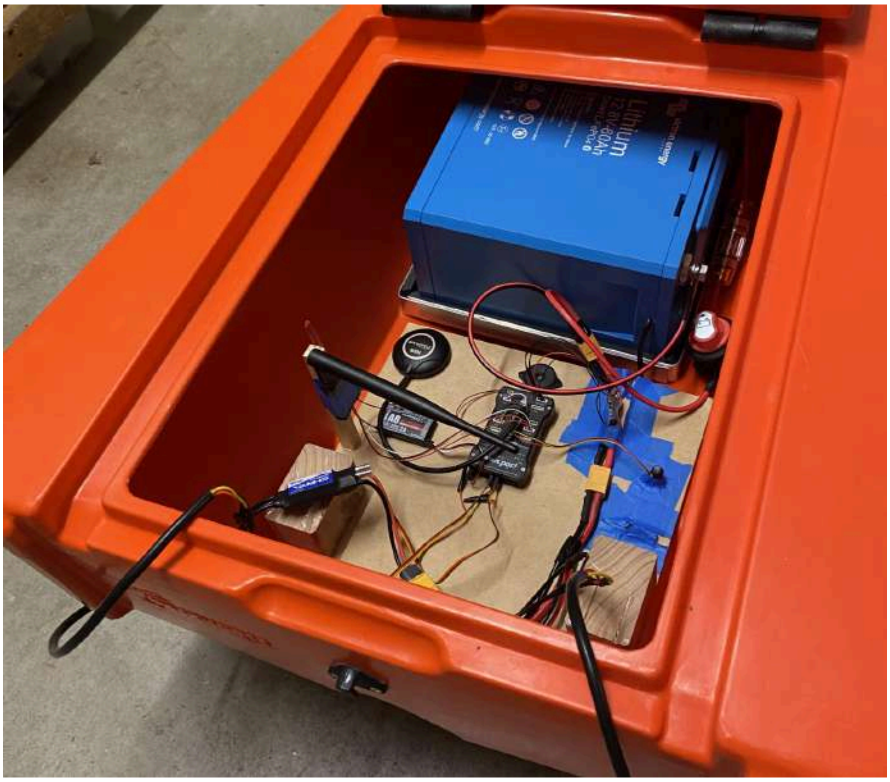

Figure 10: Prototype flight controller setup for bench testing of motors.

I used a 306mm x 546mm removable grey lid from Absolute Marines. To attach the hatch to the boat an acrylic sheet with a thickness of 2.5mm was utilised. I cut the sheet to an appropriate shape to mount the hatch to the acrylic and the acrylic to the boat. I used 3M Marine Adhesive to seal the hatch and acrylic, this ensured a water tight seal. Marine sealant was applied to the screw tops to stop water leaking through the mounting holes. This hatch is just large enough to fit the battery through, and acts as a watertight access hatch for us to work on the inside of the USV

Figure 11: Removable grey lid.

To mount the motors at the base of the boat I used a 50 by 4 by 550 mm sheet of aluminium, with 8 holes cut on the inside and 8 on the outside of the back fins. The motors were mounted on the outer section, on the bottom of the sheet.

Figure 1: Bottom mounted motors.

6.6.2 Testing

The first test was completed at the Onepoto Domain. I tested the integrity of the hull to ensure there were no leaks. I also made sure the remote control feature as well as the autonomous Pixhawk functions worked.

6.6.3 Tuning

For tuning I returned to Lake Onepoto several times. The bulk of tuning was done by changing the following variables: Proportional, Integral, Derivative, Feed Forward, Turning Rate, Turning Radius, Way Point Overshoot and finally cruise speed. The first item that requires tuning is the turning rate. To do this I entered the tuning screen on the mission planner and viewed the Z axis measurement graph, which showed the rotation of the PixHawk. The largest number seen whilst manually rotating the boat at its maximum speed was the maximum rotation in degrees per second which I entered into the configuration list. The next item which required tuning was the Feed Foward (FF). FF involves measurement, prediction and action. I altered the tuning screen to show us PID Achieved, and the PID Desired which both outputted the current turn rate of the boat in degrees per second. I changed the flight mode to Acro, a flight mode designed for drones but necessary for tuning. I drove the boat around in this flight mode and compared the acquired turning rate to the desired turning rate.

After hours of tuning, I was able to achieve fairly decent straight line performance, with acceptable corner turning. Due to the low accuracy of positioning required to be achieved whilst at sea, it was deemed as acceptable.

6.6.4 Watercooling, Sea test, Motor Repair

To prevent future overheating, I attached some water inlets which passed through the ESCs, which contained water inlets. The tubes passed through the back of the boat through small outlets.

Figure 1: Watercooling outlets as seen from the inside.

The final test I was able to perform before my term at Sealegs came to an end was an ocean test. The USV was taken to Milford beach on a clear, low-wind day, where I set up a mission to run along the beach and into a river running to a wharf. The speed was set low, and I was fully prepared to enter the water to retrieve the boat in case of an emergency. Thankfully, the boat performed the same in the ocean as it did in the lake.

Both motors needed repairing and maintenance after the initial sea test. The left motor was unable to turn by itself, potentially due to sediment build up. Once disassembled it was clear there was sediment and salt build up as well as some corrosion occurring on the magnets mounted to the interior of the motor. This was the same as the right motor, which also had some seaweed stuck to the magnets. After cleaning the magnets and ensuring the casing turned as smoothly as possible I remounted everything and applied marine lubricant where appropriate. The motors both performed better than before the maintenance. The USV was returned to the company, along with the unused resources and borrowed tools.

7 Reflective Appraisal

7.1 Impressions of the Company

Sealegs is an innovative, fascinating company with deep ties to the core of New Zealand's engineering spirit. To be afforded an opportunity to work with them has truly been a pleasure. Acting as my first foray into the professional world of engineering, this internship has been instrumental in shaping the kind of engineer I wish to be upon graduation.

Acting as a cross section between a large engineering corporation, yet focused on developing such a unique, unorthodox product, Sealegs has always stood out to me as a place to strive to be. A focal point of discussion for graduate students is the sort of role we may end up in. Many end up with roles at large companies such as Fisher & Paykel, or Beca, which boast large departments and swathes of employees, with strong corporate culture. Despite the well structured nature of such a job, and the high job stability often offered, the type of work on offer has not inspired me in the same way many innovative startups do. Working at Sealegs has given me a glimpse into both worlds.

My supervisor opened my eyes to what a professional engineer could be. The quality and consistency of work, the ideas formed, and the focused yet highly enjoyable way he approached each project make me strive to better myself as an engineer. The rest of the engineering department were also incredibly friendly, eager to anticipate me during field trips and field tests, or answer questions regarding the company. Despite large age differences, it helped me to see that they truly were not too different from me.

7.2 Reflection on My Own Work

I found the work I performed, especially the USV, to be highly engaging and rewarding. I developed a large array of skills not provided to me by my time at university. The opportunity to truly focus on a large task without the hassle of distributing my work load across a range of subjects provided an insight into my own work process, and taught me how to better optimise my time.

Working with my supervisor as he has led his team, solved complex problems, and developed his own projects and companies outside of Sealegs has encouraged me to learn to innovate and develop my engineering skills outside of the classroom. I wish to pursue my interests in ways that are purely beneficial to me, without the thought of grades, arbitrary deadlines, and artificial stress.

Finally, joining a workforce with older engineers, and engaging with a wider range of professionals that I had ever been exposed to before has made me more aware of the industry than I had ever been before. It also provided me with a way to work on my general networking and communication skills.

8 Conclusion

My time at Sealegs has been an excellent experience. I had a chance to try what I had learnt whilst at university, but I came back having learnt far more than I was anticipating. As a summer engineering intern, I began with more general tasks before progressing to a fun but challenging project developing an unmanned surface vehicle. I am grateful for the help from my supervisor. I developed a wide range of both hard and soft skills which I have carried into my time at university, going as far as choosing a Part 4 project working with the Drone Technology Group in-part due to the passion instilled in me during this internship.