Technical Report 2025-26

Team Members

Fynn Chapman - CEO/Electrical
Euan Stables - CEO/CAD
Kate Forrest - Admin
Seth Malcolm - Graphics
Katie Leith - Graphics
Ethan Milne - CAD
Phoebe George - Graphics
Calum Stables - Electrical
Callum Duncan - Electrical
George Hourston - CAD

Mentor

Mr Steven Tubbs
Ms Ruth Jenkins

Keith Grammar School

Address:

impROVise, Keith,
Moray, Scotland



Photographed by S.Tubbs



ASTRID

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1.0 Teamwork

Our members:



Fynn Chapman
CEO/Electrical Dept. Head
S6 (Grade 12)



Euan Stables
CEO/CAD
S5 (Grade 11)



Kate Forrest
CFO/Admin Dept. Head
S4 (Grade 10)



Seth Malcolm
Graphics Dept. Head
S4 (Grade 10)



Katie Leith
Graphics
S4 (Grade 10)



Ethan Milne
CAD
S4 (Grade 10)



Phoebe George
Graphics
S4 (Grade 10)



Calum Stables
Electrical
S4 (Grade 10)



Callum Duncan
Electrical
S3 (Grade 9)



George Hourston
CAD
S2 (Grade 8)

Our mentors:

Mr Steven Tubbs
Mrs Ruth Jenkins

1.0 Teamwork

1.1 Abstract

We are impROVise, an engineering team from Keith Grammar School in Moray, Scotland and we are known within our community for working well under pressure. We have spent the last year improving upon our ROV, Astrid, and working on a new float, Morag. Astrid makes use of six vectored motors for highly stable movement, a claw manipulator for task completion, three cameras, and a slightly positively buoyant frame. Our tooling has been specifically designed to complete multiple tasks without the need for adjustment. The manipulator is made out of PLA. Much like in industry, many tasks must be completed within a specific time frame. The cameras we are using provide the pilot with all the viewing angles they will need to complete the tasks. We have one camera pointing downwards to allow the pilot to view their depth within the pool, and one pointing towards our tooling at an angle to provide a better perception of depth. We also have one front-facing camera that is able to pivot up and down, which is controlled by a Raspberry Pi, to allow for our pilot to gain a better range of perspective suited to their needs. Morag consists of an acrylic tube, with three syringes that are opened and closed automatically using a bilge pump controlled by an Arduino. This allows water to be taken into the syringes and alter the buoyancy of the float to allow it to ascend and descend within the water.

1.2 Project Management

At impROVise, we run our team in a professional structure akin to that in industry, with various subdivisions and company hierarchy. impROVise splits itself into four major departments - CAD, Electrical, Admin and Graphics - each tackling a different aspect of our progress, however these are not rigid and we actively encourage each member to engage with the entire team operation, broadening each member's understanding of the project as a whole.

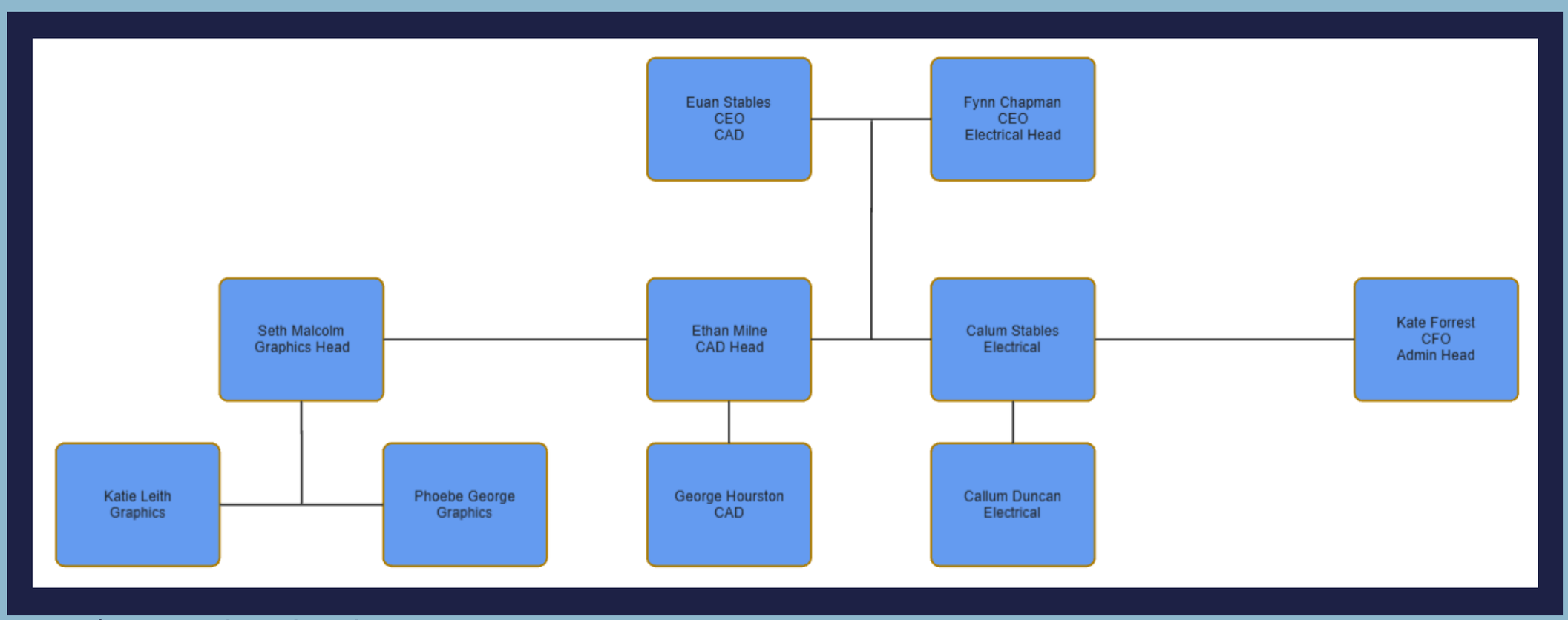


Diagram by Phoebe George

1.0 Teamwork

1.2 Project Management

- CAD, as the name suggests, is concerned with the physical construction of the ROV, working on the design, planning and eventual creation of key components. This team works with 3D modelling software, laser cutters, CNC machines and 3D printers.

- Our electrical team works with electrical design, electronic design and programming, designing the electrical aspects of the ROV including power distribution, cameras, control and tooling mechanisms.

- The administration team works on all of our outreach, financial accounting and public facing aspects of the team. This team works with the graphics department to produce promotional material thanking sponsors, raising awareness of upcoming events in our local community and “thank you” letters to businesses and individuals who have supported our project. This team also includes our CFO, who specifically oversees the finances and the team’s spending on parts, transportation to events and fundraising income.

- Graphics team members work with CVMG software such as Canva and Adobe Photoshop to create the promotional material and documentation such as the team poster, team logos and branding that takes our company visuals to the next level.

- Overseeing all teams are our two co-CEOs, each making sure all of our team members are carrying out their team duties to the best of their abilities and maintaining a positive team environment, while pushing the team’s capabilities to the peak of what we can achieve.



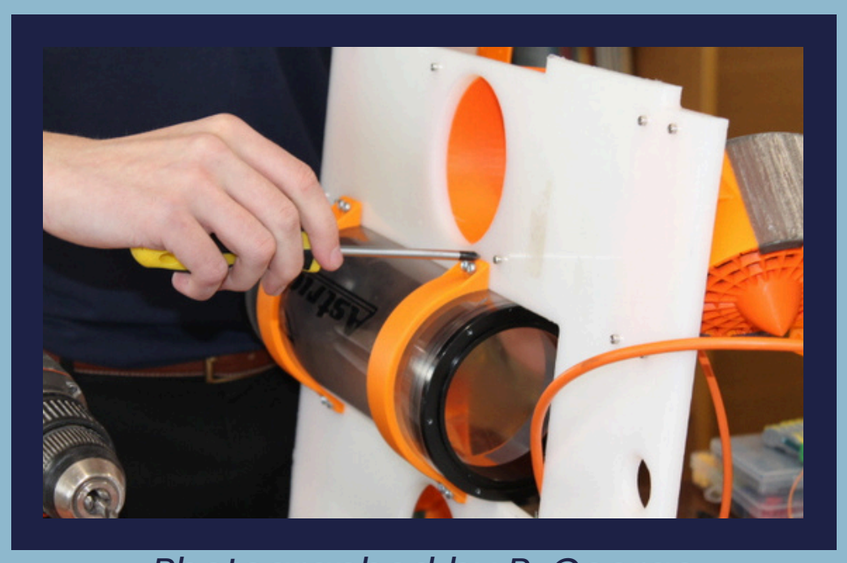
Photographed by S. Malcolm

Our team meets regularly in our school’s technical department on Fridays from 1310 until 1600 to work on our ROV, documentation, and all other aspects of our project. We set aside this time to work on the project as a scheduled event instead of always meeting ad hoc, so that we can regularly have as much of the team as possible at every meeting. During these meetings, we usually hold a discussion about what work we wish to focus on and carry out that afternoon. This consistency creates more efficient work, as each member of the team can be aware of the meeting and prepare everything they need to carry out their work throughout the week. We also occasionally meet outside of our regular hours, working on the project between classes at school or outside of school entirely, and of course during community outreach events in which we aim to include as much of the team as possible.

2.0 Design Rationale

2.1 Innovation

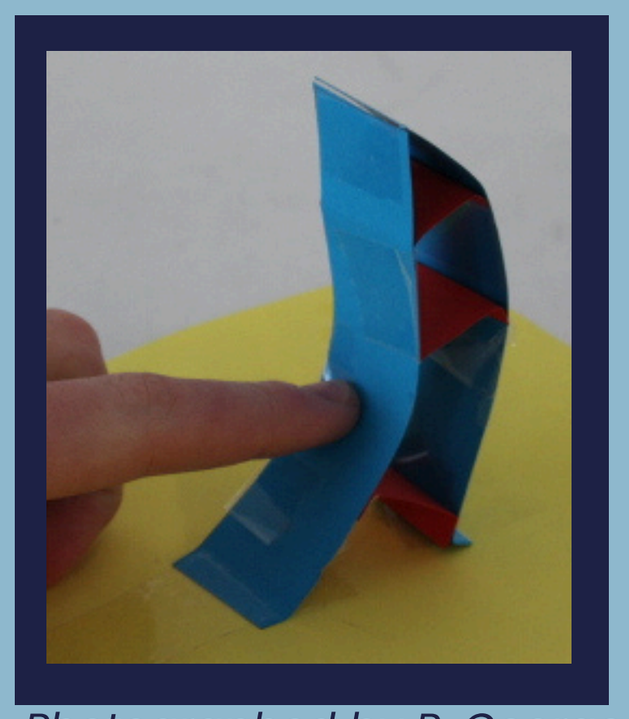
This year we have gone through a significant amount of innovation and reiteration of previous ideas at almost every part of our vehicle. The outcome of a significant amount of this innovation returned as “not yet” – things we want to do, but due to monetary and time restrictions need more time to develop. This includes things like a fully 3D printed chassis, giving us significantly more control over the shape and design of our ROV, as well as aiding modularity, reparability and adaptability to our ROV design. On a design level, we also revised our electronics tube; previously, this was mounted on top of the ROV, raised above the motors. This season, we have chosen to sink this into the frame of the ROV, improving stability and centring what is a massively buoyant part of our ROV. We have also redesigned our motor housings, providing a stronger and more reliable hold.



Photographed by P. George

Inside the electronics tube, we have opted to use a Raspberry Pi 4. This was done to improve our ROV’s computational capability, allowing for fast processing of camera data and fast network response times. We have also opted to use a neutrally buoyant single tether with a shielded 2-pair ethernet cable running parallel to the 12 volt and Ground transmission lines. This reduces the mass of tether that we need to transport, and significantly reduces the amount of effort required to transport everything that we need.

Mechanically, we have improved upon our tooling by adapting to an electronic design. We have previously had issues with hydraulic systems, where leaks would consistently occur. We have opted to use a servo motor to control our claw based tool. Additionally, the claws of the tool make use of the Fin-Ray Effect. The Fin-Ray effect is a structural design choice based on what is used in nature by various sea creatures in which the internal structure and elasticity of a material allows a shape to conform to an object pressed against it. This allows our new tooling to achieve a better grip on any objects it needs to grasp.



Photographed by P. George

Poolside, we have transitioned from using a laptop to using a Raspberry Pi 4 for the topside communications. This centralises our entire control system, reducing dependency on external systems and ensuring everything is stored within the control box. The software written for the control is also brand-new and bespoke for our needs in house. On a software level, we have innovated by improving upon our custom purpose-built software. This gives us complete control over what we want our ROV to be able to do, and allows us to trial new things, such as flight simulation for pilot training.

2.0 Design Rationale

2.2 Problem Solving

Problem solving has been a major part of our journey up to this point. The ability to overcome challenges within the team have helped greatly when we get stuck on something important. This helps us to understand and solve the problem instead of merely hoping luck is on our side. Therefore, the work produced by everyone in the team is a direct result of root cause analysis.

Some examples of problem solving that we have encountered over the past year include placing the electronics tube on top of the vehicle, which resulted in it being too buoyant. To solve this problem, we installed weights underneath the ROV to reduce buoyancy, at the same time ensuring the vehicle's weight didn't increase by too much. Another problem we encountered was during last season, when our hydraulic tooling leaked. We resolved this issue by using electric waterproof servo motors, removing a point of failure and making our tooling more reliable.



Photographed by P. George

Furthermore, we had several problems regarding our propulsion. Being a high KV rating, the brushless motors draw a large amount of current at full power. This has been solved by reducing the KV rating of the motors, resulting in higher torque per volt, but lower speed - as well as by introducing capacitors. We also introduced a software based configurable speed limiter, so that the motors are not pushed beyond their limits. The motors also had a very particular issue with initialisation - our ESCs require a specific series of power signals to "arm" the motor. However, the documented PWM duty cycles did not result in the motor arming. In fact, the correct signals were approximately 100 microseconds out of the usual pulse, which we discovered and solved via iterative design. The exact cause of this problem is still unknown - possibly due to latency in the PWM signal generator - but we continue to investigate the issue in search of a solid answer.



Photographed by P. George



Photographed by P. George

2.0 Design Rationale

2.3 System Approach

We took an open approach to designing our ROV. This involved a large amount of iterative testing of our design, effectively trying various versions of similar ideas to determine which is best. Practically every component of our ROV has undergone a considerable amount of research and development.

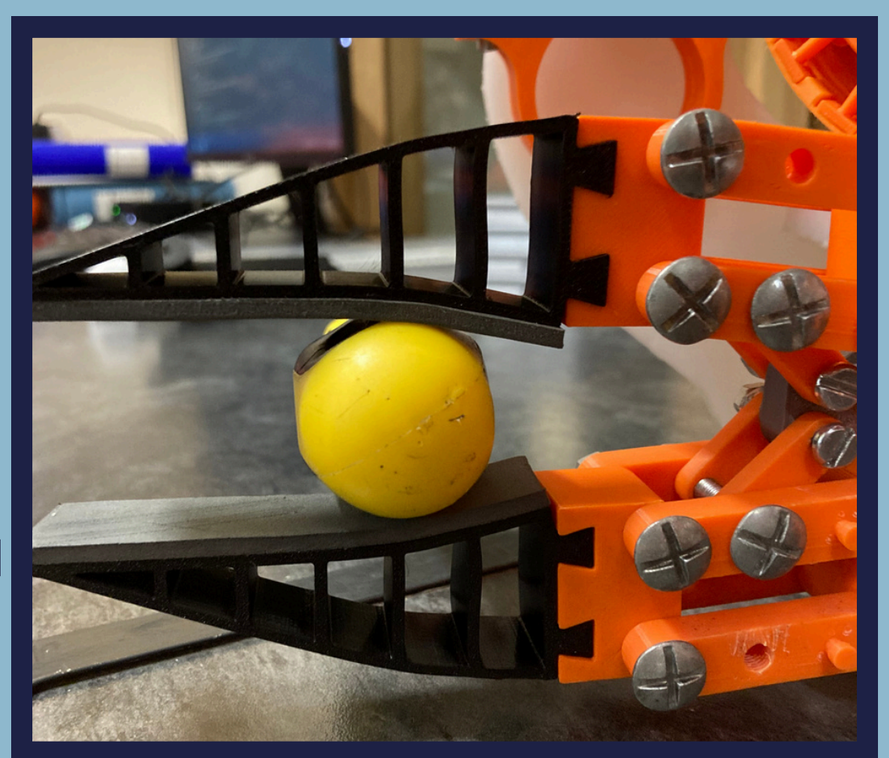
The frame of our vehicle is very important as it holds the ROV together. We have been using the same frame for the past 3 years, and we have chosen not to replace it as it is still remains functional. This saves both time and money, and promotes reuse of components. We 3D printed parts of the ROV in PLA Safety Orange, which is highly visible underwater and user-friendly.

The ROV has three cameras: two external fish-finder cameras that we have reused from last year, as well as an additional USB camera attached to the control system. These are transmitted across the data link adjacent to control signals. The USB camera is also mounted on a servo, allowing the angle to be changed electronically. This was improved from the previous season, where we encountered reliability issues. This led us to ultimately try USB (instead of the Raspberry Pi SPI Camera), which significantly improved dependability and simplified code.



Photographed by P. George

We chose to use electrically controlled tooling as we previously faced issues regarding this section of the ROV -these issues being due to our old, flawed hydraulic system which frequently leaked. We attempted to mitigate the environmental impact of this by using water as our hydraulic fluid instead of oil, ultimately leaving our tooling dysfunctional. This has been solved with the use of an electronically controlled tether, simplifying the tether, pilot control, centralising more control to the electronics tube, and most importantly, ameliorating the system's reliability.



Photographed by P. George

2.0 Design Rationale

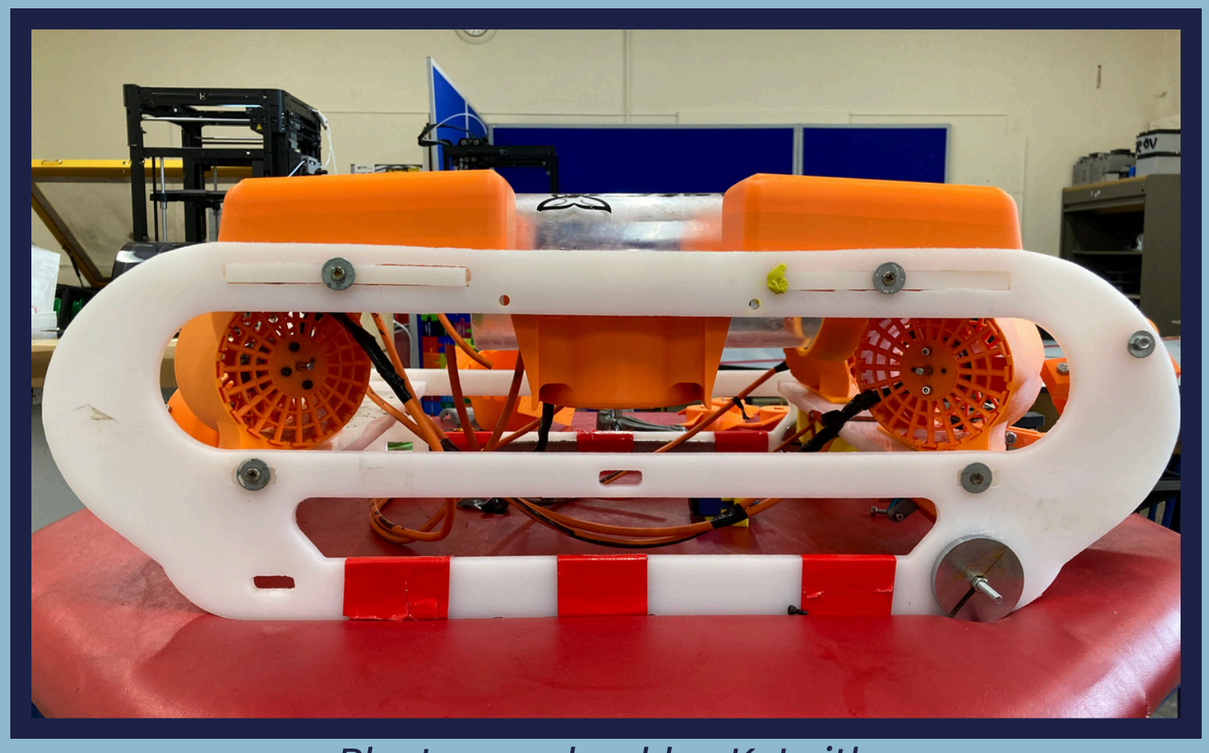
2.4 Vehicle Structure

This season our ROV, Astrid, consists of a HDPE (high density polyethylene) structure, which we have used as a backbone. The safety orange plastic components have been manufactured by 3D printing, with the material being PLA (polylactic acid). We have six thrusters each having a brushless motor. The housings have safety grills covering the propellers which are also 3D printed.

Our ROV is powered by six brushless motors, four of which are positioned at each corner of the ROV and face outward by 43 degrees for maximum efficiency in a vectored position. This placement of our motors allows for our ROV to perform a “crab-walk” motion and increases our range of movement. Each thruster is protected by a 3D-printed safety grill surrounding the propeller. These grills improve safety by preventing accidental contact with the spinning propellers while also protecting the blades from debris and potential damage underwater. We also have the remaining two of six brushless motors in an upward facing position. Additionally, the vertical motors to control ascent and descent are positioned on the left and right of the ROV. As a collective, this allows our ROV to maintain stable depth control and locomotion whilst submerged.



Photographed by K. Leith



Photographed by K. Leith

2.0 Design Rationale

2.5 Control Systems

Astrid is controlled computationally. We created a purpose built program written in-house, run both on poolside and on-board the ROV.

To interface with this program, the pilot has access to a simple User Interface (UI), on a large monitor, and controls the flight of the ROV using a multi-axial “flight” stick and thrust lever. We chose to use this control set up, as this mimics what is used in industry, meaning our pilot has the opportunity to practice flight skills using real simulator software[1]. Our program’s UI features only a small number of necessary elements; primarily a large section displaying a video stream from a USB camera onboard the ROV, a line-graph showing plotted data from our profiling float, and status monitors for the Astrid’s sensors/systems.

Our ROV also features IMU-driven auto stabilization. This toggleable feature allows Astrid to keep itself upright using a small Inertial Measurement Unit (IMU) chip located in the electronics tube of the vehicle. This chip polls gyroscopic changes, which is then reported to the main program, and modulated using Proportional-Integral-Derivative (PID) control. PID control is commonplace in robotics, and uses the following formula[2]:



Photographed by P. George

$$u(t) = P\,e(t) + I\int_0^t e(\tau)\,d\tau + D\frac{d\,e(t)}{dt}$$

PID corrects errors in a system, and accounts for the rate of change, accumulated error and scale of error. The three constants - P, I, and D - can be fine tuned to better the error-handling capability. In this equation, t represents a point in time, and e(t) is some function that returns the value of error in the current system. In Astrid, the PID controller monitors changes in the roll axis, and corrects these by automatically firing the ROV’s motors. e(t) is equivalent to the absolute roll (as in one of the three aircraft principal axes[3], with Ψ as yaw, θ as pitch and ϕ as roll) as reported by the IMU;

$$e(t) = |\Phi|$$

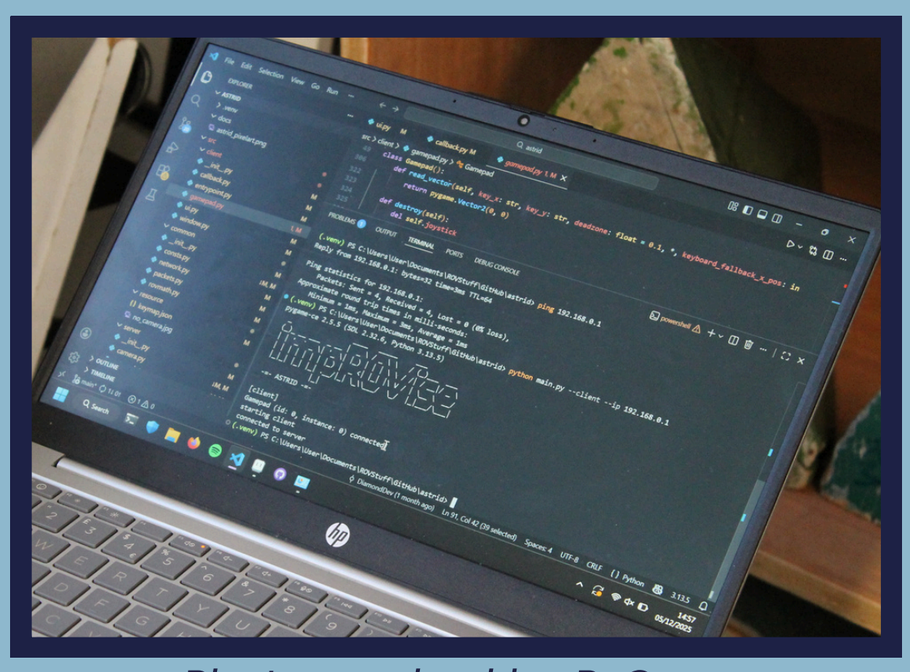
This attempts to aid the pilot, as keeping the ROV level was found to be a challenge. However, the system is designed to be toggleable should the system cause the pilot problems.

2.0 Design Rationale

2.5 Control Systems

The program itself is written in Python 3.13, chosen for its flexibility and simplicity - so that the internal workings of the program can be easily learned by as many members of the team as possible, improving workflow, robustness and maintainability of the program - as well as the large number of libraries available for interfacing with various hardware elements of the ROV. The codebase totals at around 3000 lines of code, with several months of development time behind it. The project structure is split into two halves: the code that runs onboard Astrid and the code that runs at the poolside station; which aids in ensuring the program is efficient and does not unnecessarily drain precious computational resources. The computers powering the control systems are Raspberry Pi 4s, chosen for their small footprint and high power, giving us more flexibility with what our program can do.

We chose to use multithreading in our control code. Concurrent programming adds an increased level of difficulty in both development and debugging of the program, but unlocks a further level of computation power for us to use. Primarily, a second thread is used in our code that handles communication between the poolside and the ROV, allowing the communication to effectively “run in the background”, and can then use an event-/notification- driven system to then communicate to the main thread of the program to perform some action, such as changing motor powers, or turning on or off IMU stabilisation.



Photographed by P. George

Communication was a large part of the consideration for the software requirements. At the physical layer, the system uses two twisted pair ethernet for communication between Astrid and the poolside station. Other options considered are shown in the following table:

Protocol	Used?	Reason for Rejection/Use
Ethernet, 4 twisted pairs	No	Additional cable needed for tether.
Ethernet, Fibre Optic	No	Fibre optic multiplexers require additional power and current, as well as the tether being harder to make removable while staying waterproof.
Ethernet, 2 twisted pairs	Yes	We have a long, neutrally buoyant multi-core wire with 2 twisted pairs of shielded ethernet cable. This makes our tether as concise as possible.
UART	No	Unreliable over long distances[4]. Intended for use between nearby devices.
I2C	No	Unreliable over long distances[5]. Intended for use between nearby components.
One-Wire	No	Too low speed[6].

Table by Fynn Chapman

At the application layer of the software, the system uses custom protocols built on top of UDP sockets using Python’s socket and struct libraries. These libraries are used to communicate data between the two ends of the entire system.

2.0 Design Rationale

2.6 Electrical Systems

Astrid has an acrylic tube housing that contains all of the electronics onboard our ROV. At the back of this tube has a 3D-printed plate with penetrators, passing through all the wires that go out to the motors and tooling outside the electronics tube, and the main tether line into Astrid herself. This main tether line is terminated by a removable waterproof inline connector, meaning that the tether can be completely removed from the ROV. This aids transportability of our ROV, as well as ease of reparability.



Photographed by P. George



Photographed by P. George

The electronics onboard Astrid inside the tube consist of few elements. Primarily is the Raspberry Pi 4, which is the main flight computer and runs our control program. This Raspberry Pi is connected to a camera onboard the vehicle via USB, as well as an I2C PWM Breakout Board (PCA9685) and an I2C Inertial Measurement Unit (IMU) for the auto-stabilisation code. There is also a small step-down transformer onboard to step down the 12V from poolside to 5V, used to power the various components inside the ROV. 12 volts are used to power each of our 6 brushless motors, each driven by an Electronic Speed Controller (ESC), shared between two identical circuit boards and one other quadruple-motor controller. The motors are controlled by PWM, using the PCA9685 board to interface the PWM signals.

At poolside, our control crate has been designed to require as little active maintenance as possible. It is, of course, designed so that should maintenance be required, it is easy and straightforward to carry out. However in order to achieve a clean working environment for the pilot, all electronics are hidden out of sight and physical interface connectors into the components inside the control crate such as USB, coaxial connectors, the Anderson powerpole connectors for power into the system, and tether out to the ROV are exposed by compartments on the side of the control crate. These compartments are made from 2-gang outlet lining boxes and can be sealed by blanking plates.

2.0 Design Rationale

2.7 Propulsion

We use 6 500kv brushless motors inside our ROV as our propulsion system - two on top, two at the front, and two at the back. These are each controlled independently by ESCs (Electronic Speed Controllers) inside our electronics tube, which are connected to the Raspberry Pi 4 computer via a PCA9685 PWM I2C Breakout board, sending the necessary signals to the motors to initialise and provide thrust. Additionally, our thrusters are angled at 43 degrees, giving us vectored thrust - this allows us to “crab-walk” our ROV (sideways linear movement). This vastly improves our manoeuvrability. At 12 volts, each of these motors can spin at approximately 6000 RPM under zero load, however the real speed under load is significantly lower, giving us greater torque.



Photographed by P. George

2.8 Buoyancy and Ballast

Our buoyancy system includes safety orange fenders at the front and rear on the left and right of the vehicle. The fenders have been designed with a hexagon grill on top with the idea of being as hydrodynamic as possible alongside minimising air pockets from any inconsistent buoyancy within our system.

The plastic tube that holds the “brain” of the ROV adds to the up-thrust as it contains a large volume of air. This year, we made the decision to place the brain level with the motors to centralise the buoyancy. Additionally, the curved design we have used contributes to the hydrodynamics, making flight smooth and efficient.

When operating in freshwater, the ROV requires slightly more buoyant material to maintain neutral buoyancy. In saltwater, however, slightly heavier material is required due to the water being more dense, naturally providing more up-thrust. By adjusting the buoyancy setup for each environment, we can ensure that our ROV remains neutral, meaning it neither sinks nor floats excessively. Achieving neutral buoyancy is important because it reduces the workload on the vertical thrusters, improves energy efficiency, and allows for more stable and controlled underwater movement.

Ballast has been implemented at the skid of the ROV this lowers the centre of gravity which ensures the ROV maintains a stable and upright position whilst in operation. The skid allows for an interchangeable mass of ballast which guarantees accurate placement of the ballast.



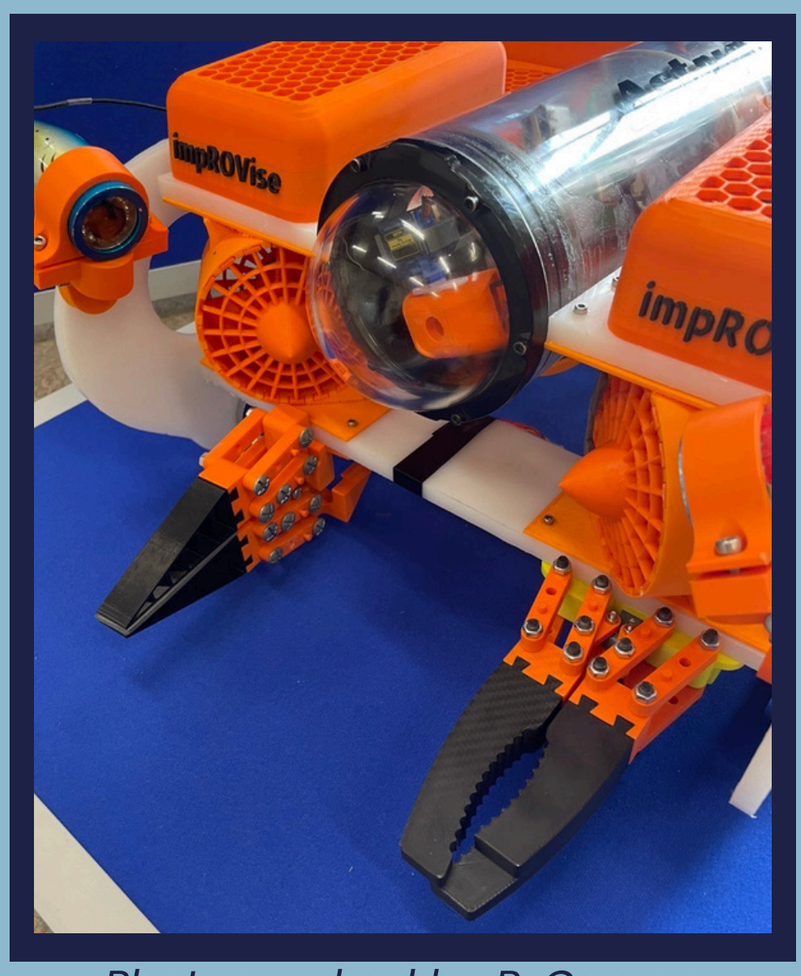
Photographed by Phoebe George

2.0 Design Rationale

2.9 Payload and Tools

In terms of Tooling, we are experimenting this year with an electrical motor. In previous years we have used a hydraulic system to power our tooling, however this has been met with failure on both occasions. This year, each manipulator makes use of a servo motor to supply the mechanism with movement.

We have two clawed manipulators this season, as opposed to our regular approach of using only one. A mechanism within each motor mount converts the rotational input from the servo motor into a linear movement that opens the two jaws of the claw. We have two designs for the jaws of our manipulators, each removable on a pair of dovetail connections: one is static with a serrated inner edge for enhanced grip, and a second made of a flexible material called TPU with similar properties to silicone under 180 degrees celcius. This flexible pair of jaws make use of the “Fin Ray” effect[1], a mechanism based on the biological structures found in many fish. This structure is designed to bend around any applied force, conforming to its surface. We have used this structure for increased grip strength and stability when interacting with tasks underwater.



Photographed by P. George



Photographed by K. Leith

All of our tooling structure, excluding connecting bolts and nuts, is fully designed and 3D printed, in-house, by our team. We have used bright yellow and orange filament to highlight their location on the ROV to the cameras and any submerged personnel. Both manipulators are situated at the very front of our ROV with two cameras aimed towards them to allow for our pilot to see any objects with which the vehicle may be interacting. This gives us an unobstructed view of our tooling from multiple angles for greater precision when piloting.

2.0 Design Rationale

2.10 Build VS Buy

This competition season we have chosen to design and manufacture as many aspects of our ROV as possible in order to save money and allow us creative freedom. The only components we have decided to buy are those which cannot feasibly be created in our school's technical department including our motors, cameras and computer systems. We have bought Raspberry Pis for use, both in our control box and electronics tube; the electronics tube itself and the brushless motors used in our thrusters. Furthermore, we have opted to reuse many components from previous years, our school's departments and the ROV industry. The neutrally buoyant tether came from ROV Scotland, our Thrustmaster control system and weights are reused school equipment, and from previous years we have recycled the ROV's frame and the crates used for transport and our control box.



Photographed by K. Leith

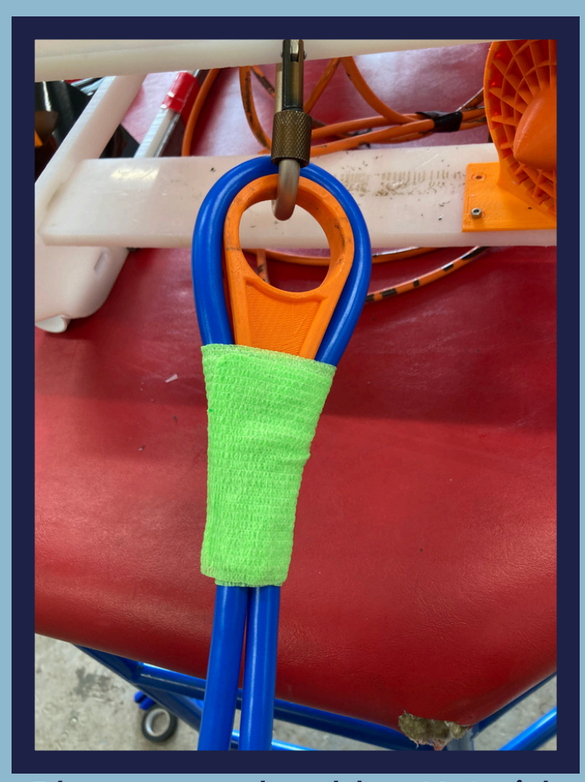


Photographed by P. George

This year we have designed and manufactured many of the key components of our ROV. The thrusters were each modelled and 3D printed in-house by the team, as were the clasps for the electronics tube, both sets of tooling, the buoyancy fenders, strain relief and electronics mounts for inside the waterproof tube. It has been greatly beneficial to design and create these components in-house as it allows us to work outside of the confines of pre-made components, allowing us to quickly prototype and test each design. This has hastened the production of our ROV and saved us a lot of money. The volume of creative work has also allowed us to better train our newer members in CAD software, helping to grow their skills and capacity to contribute to the project.

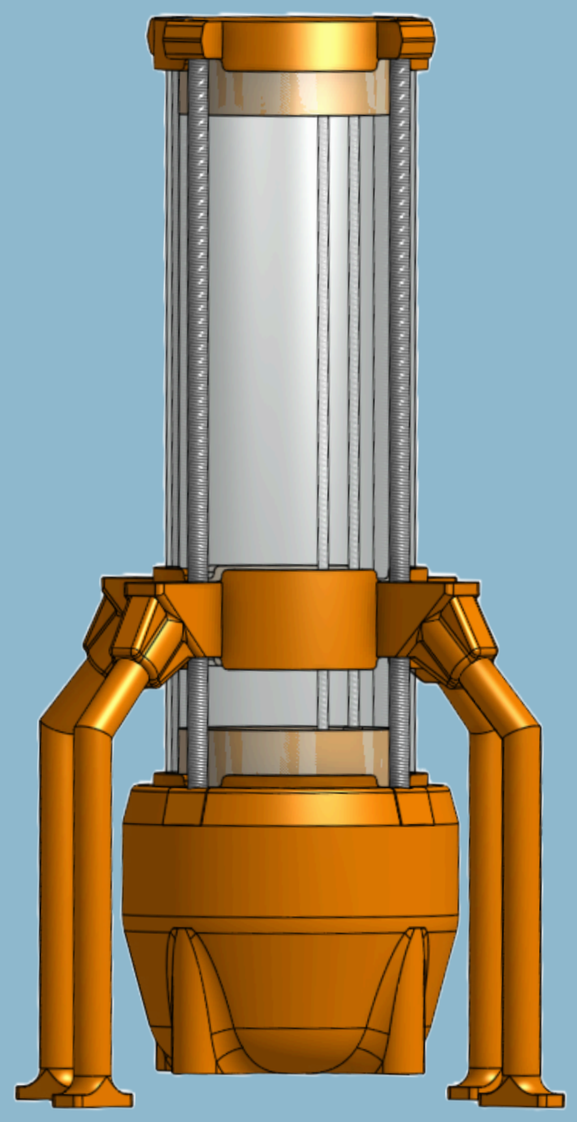


Photographed by P. George



Photographed by K. Leith

3.0 Vertical Profiling Float



Morag, our float, consists of an acrylic tube, 5mm thick and 100 mm in diameter, housing three 60ml syringes to control its movement. The syringes are controlled by a bilge pump acting as a stepper motor by compressing or extending them to displace the water. By adjusting the water in the syringes, Morag changes her mass and sinks or rises depending on what is required. She is equipped with a MS5837 pressure, temperature and depth sensor to collect data during vertical profiles. This data is transmitted from an ESP32 to a poolside computer via Wi-Fi. The computer then displays the data as a depth-versus-time graph for easy monitoring. Once the data is received, the computer sends a signal back to Morag, prompting it to begin another vertical profile.

3.1 Morag SID

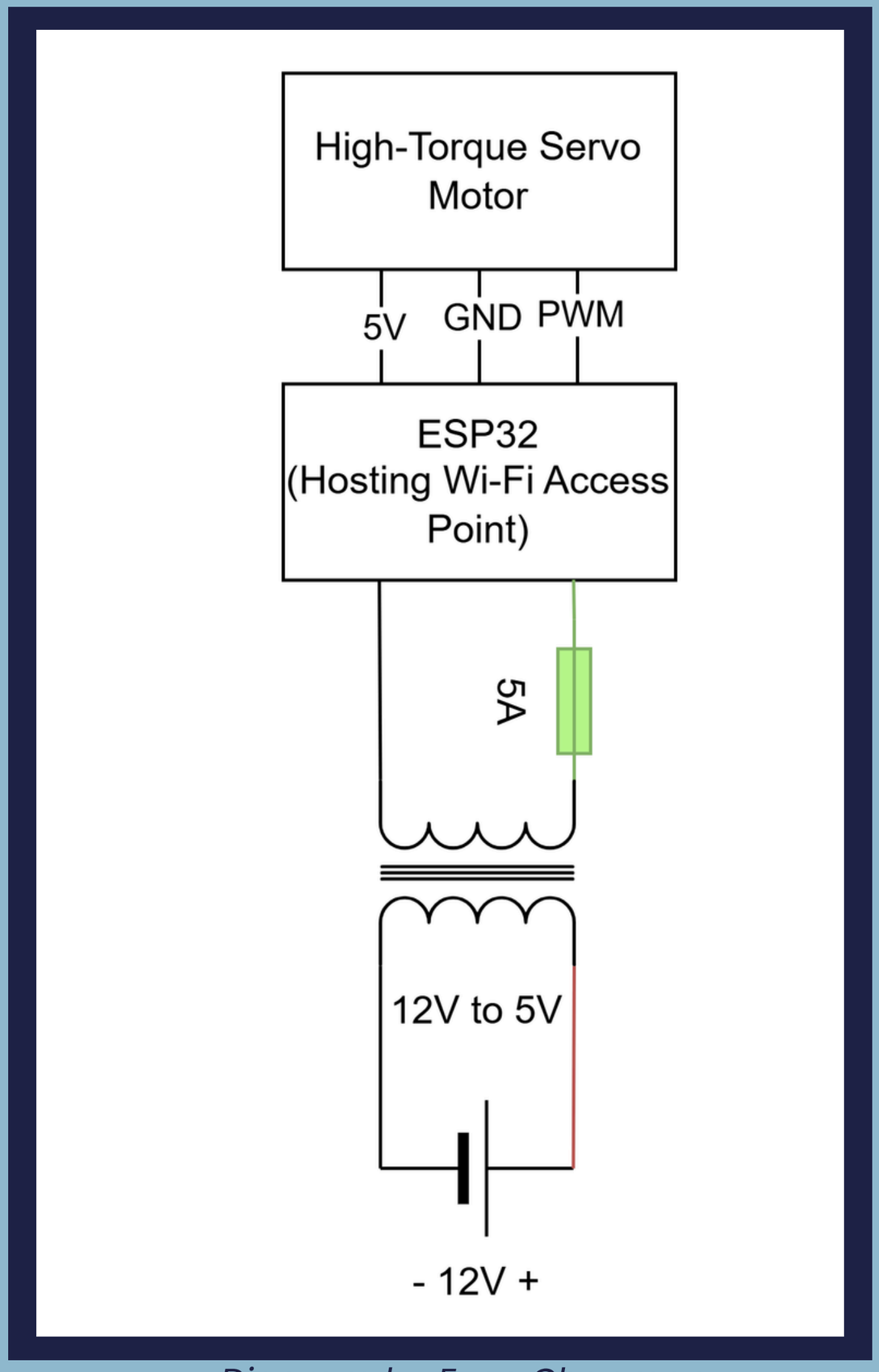


Diagram by Fynn Chapman

4.0 SID (System Integrations Diagram)

4.1 SID

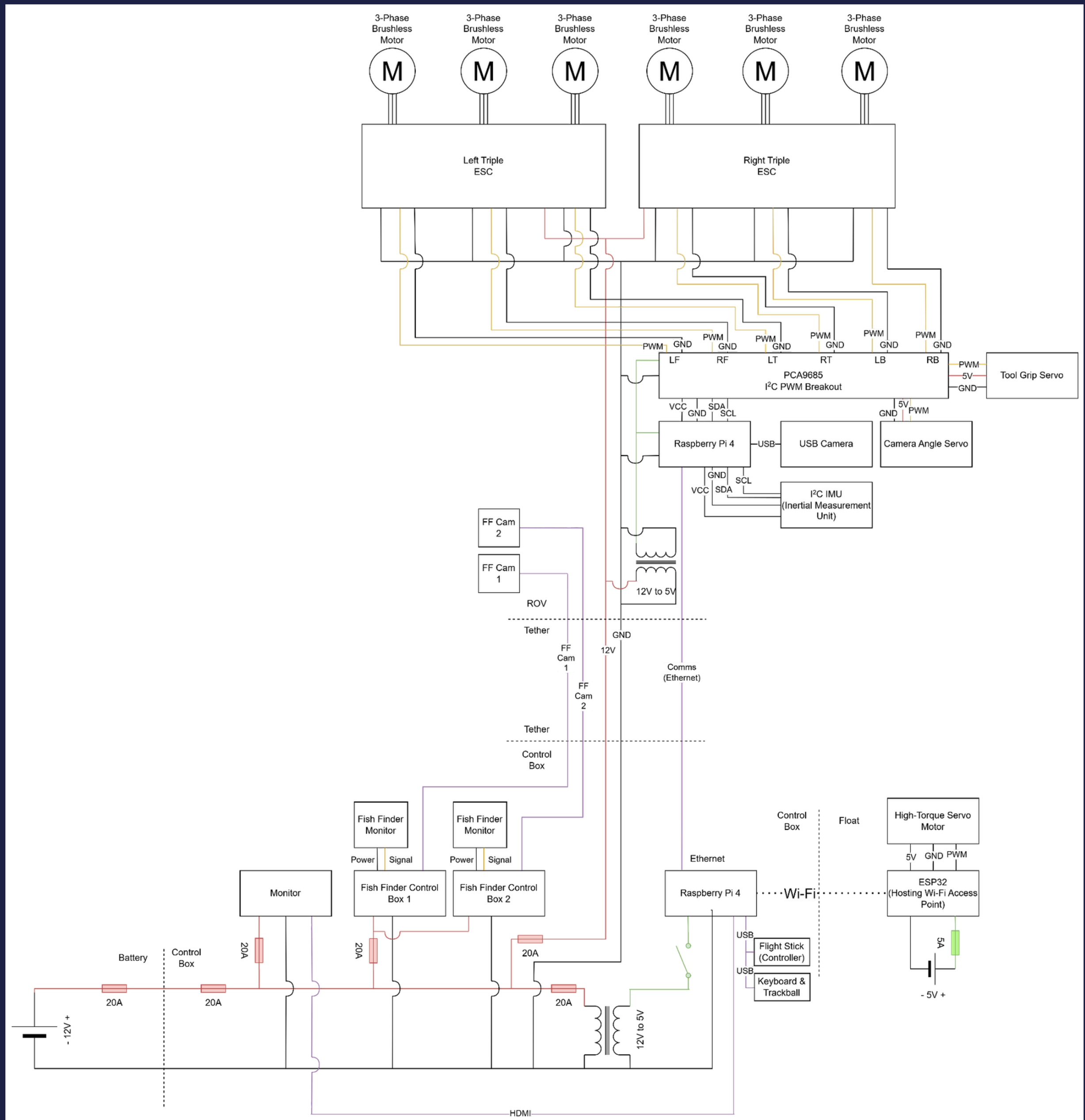


Diagram by Fynn Chapman

5.0 Safety

The safety of our members is very important to our company and we are committed to ensuring that every member remains safe while on poolside, operating the vehicle and during the construction of Astrid.

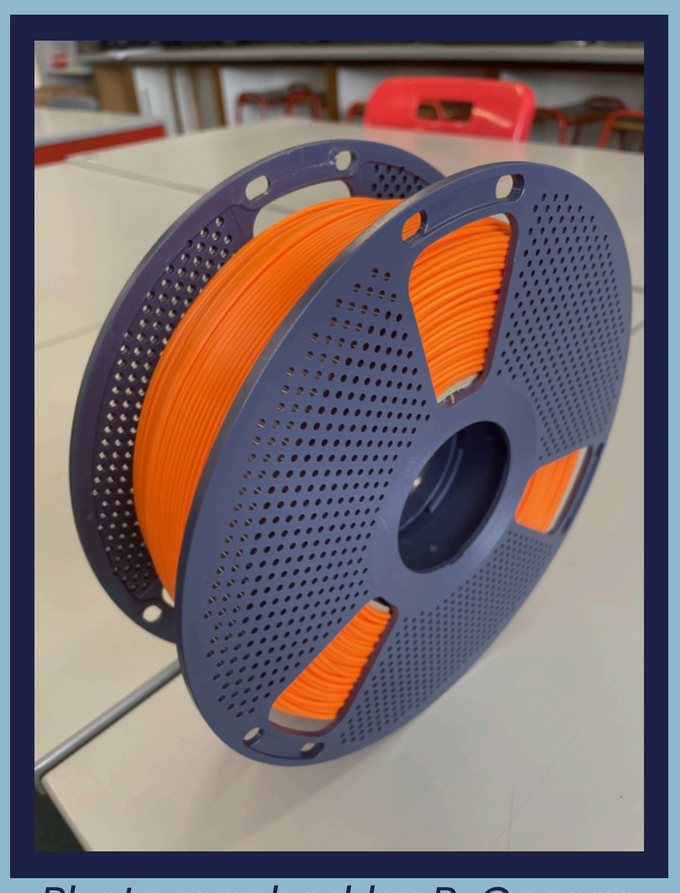
5.1 Safety Rationale

Personnel

- We have many arrangements in place to maintain our personal safety, such as wearing PPE. This consists of every member on poolside wearing a hi-vis vest and safety glasses.
- Suitable clothing and footwear are worn with no loose hair or accessories. This prevents anything loose from getting caught leading to injury or becoming hazardous.
- The ROV retrieval member wears gloves to minimise hand injury.

Vehicle

- Our 3D printed parts of the vehicle have been printed in a bright orange filament named “safety orange”. This ensures Astrid is highly visible underwater to nearby divers and that the areas of danger are highlighted.
- Each and every one of our six thruster motors are encased in a motor housing with IP26 grating on the sides, lowering the risk of any hand injuries. In addition to this, when flying our ROV in the sea, the guards on our motors help to protect aquatic life and leave them unharmed, promoting sustainability.
- As we printed our frame in-house, we were able to file all of our edges to make them rounded and therefore safe.
- Epoxy was used to seal all of our connectors making them watertight. This adds a layer of protection in case of any leaks into the brain, keeping our electrics dry.



Photographed by P. George

Equipment

- When in transportation, our tether is coiled on a spool. This minimises the risk of tripping whilst keeping a clear workspace to allow more room for safe movement around the vehicle.
- Our tether is wrapped in cable wire to keep all loose cables together with fluorescent pink and green cable wrap which highlights its prescence.
- When placing down our heaviest equipment such as Astrid and our control box the members responsible have been shown how to lift and deploy these safely to avoid any strain. This is achieved by bending at the knees as opposed to bending at the hips
- We utilise strain relief on our tether to take the strain off of our electrics, reducing the risk of them losing power due to damage in the wires.

5.0 Safety

Operational

- Our team are well practiced at standing at a safe distance from the water and all have the ability to swim confidently in case of emergency.
- A minimum of three team members poolside are certificated first-aiders and know how to conduct themselves safely if an accident were to occur.
- Every piece of equipment taken onto poolside is placed 2 metres back from the water to ensure of a clean operation space, with towels on hand to dry any parts of the ROV that may be modified during the pool run.
- When retrieving the basket stars and the coral in task 1.1, the retrieval member is required to take the items from the claw of the ROV. To ensure this is executed safely, the communicator will shout “Armed!” when the tooling is active and “Disarmed” when it is safe to obtain the items to the retrieval member on command of the pilot.

5.2 Safety Procedures

As a team, we have many rules that we strictly adhere to, which guarantees that we carry out tasks in a safe manner in accordance to our safety checklist. This is performed at the beginning of every pool run we do in preparation for the competition. This ensures that all members have a good understanding of what is expected and the necessary protocols implemented for any challenges we may face.

Personnel:

- ☐ Correct PPE
- ☐ No loose clothing
- ☐ Correct Footwear
- ☐ Hair tied back
- ☐ Retrieval member wearing gloves
- ☐ All aware of first-aid kit location

Pre-Power:

- ☐ ROV carried by two members
- ☐ Equipment deployed properly
- ☐ Tether connected securely
- ☐ No damage to tether
- ☐ Waterproof seals are checked
- ☐ Vacuum test
- ☐ Monitor voltage rise
- ☐ Cameras tested and positioned
- ☐ All thrusters tested
- ☐ Tooling tested

Deployment:

- ☐ Clear launch zone
- ☐ Members distanced 1m from water
- ☐ Clear line from tether to ROV
- ☐ ROV disarmed when deploying

In flight:

- ☐ No bubbling to surface
- ☐ Control box maintains power
- ☐ Disarmed again before retrieving items in tasks
- ☐ Float deployed within reach of retrieval

ROV Malfunction:

- ☐ ROV flown back to poolside (unless communications gone if so pulled back by tether)
- ☐ ROV disarmed
- ☐ Brain is dried
- ☐ Check all electrics for leaks
- ☐ Check tether connections
- ☐ ROV lifted safely back into water
- ☐ Retrieval member communicates to team its safe to arm

Retrieval:

- ☐ ROV is disarmed
- ☐ Communicator tells retrieval member
- ☐ Power off
- ☐ Tether has been coiled in
- ☐ Side of pool clear
- ☐ Retrieval member lifts ROV effectively
- ☐ ROV brain dried
- ☐ Everything packed neatly
- ☐ Members carry same equipment

Checklist by Katie Leith

6.0 Critical Analysis

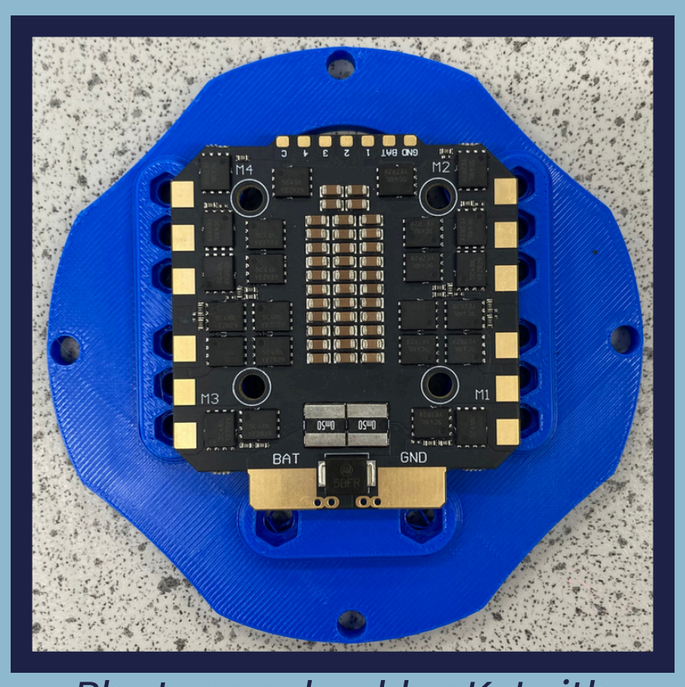
6.1 Testing/ Troubleshooting

Throughout the year we have encountered many problems with our ROV design, both structurally and electrically. Using iterative design practices, we were able to overcome these issues, requiring sometimes a complete redesign of a specific part or circuit, or a couple small changes.

During testing and troubleshooting structural problems we highlighted when the frame was in operation as the material HDPE may experience some flex under pressure due to the lower density in this material compared to materials like steel. We considered continuous loads of equipment can also lead to weaknesses leading to further issues needing to be improvised.

We also suffered many electrical and electronic problems. For example, during early testing of our motors, using BlueRobotics ESCs, we were unable to correctly arm the motors. This was caused by a large number of compounding issues, starting with faulty code, and eventually boiling down to timing issues in our PWM board leading to the microsecond delays being around 100 microseconds out. This was solved by simply changing the pulsewidths required for each part of the sequence.

Other problems in code we encountered were largely due to networking issues. Originally, our program operated under TCP sockets, which gave us a faster connection at the cost of being harder to work with. Unfortunately, this also had the downside of, due to the nature of TCP, causing even small connection issues and glitches to potentially bring the program to a halt. This was solved by rewriting the networking code to use UDP. While this does bring a large amount of its own issues and a slower overall connection, it is both easier to work with (aiding maintainability) as well as being more reliable to work with.



Photographed by K. Leith

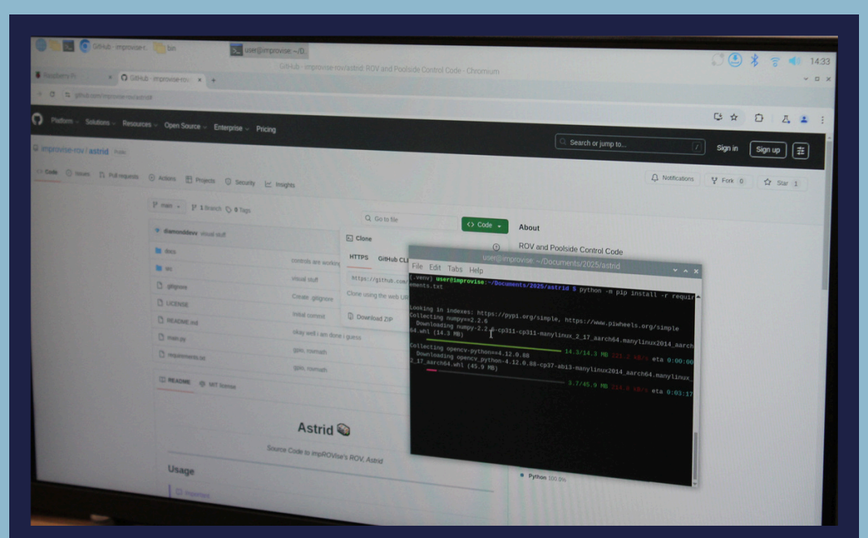
During the initial design phase of our project, we rigorously tested each new component that would be introduced into the system in order to reduce confounding factors in any problems that would arise. An example of this was using an Arduino to test each of our ESCs from our previous year in the competition, which we had feared to have suffered water damage due to failures at our previous regional competition. Thankfully, these were not damaged, and worked perfectly. Testing each component in isolation also allowed us to narrow down other electrical problems such as power distribution, as we were able to guarantee each component was functional outside the larger system.

6.0 Critical Analysis

6.2 Influence of Troubleshooting

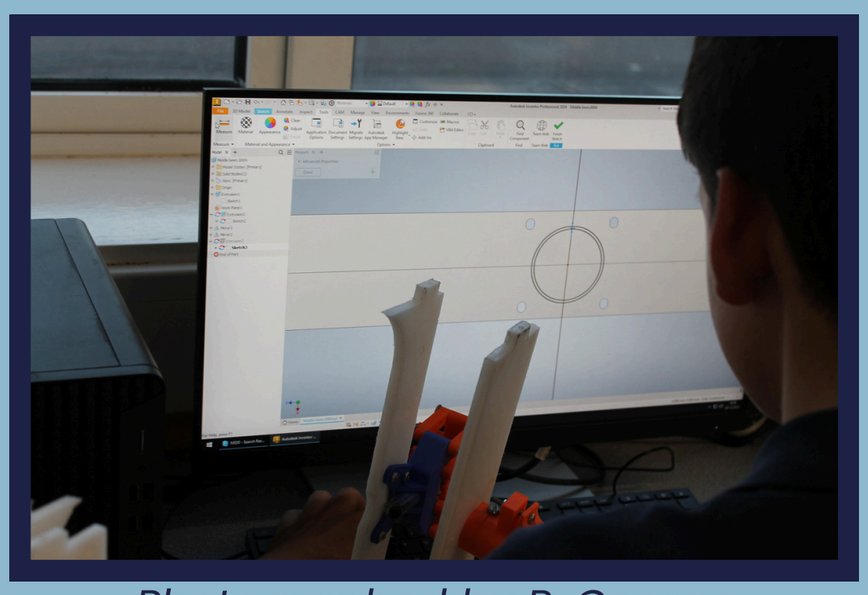
Testing and troubleshooting has saved us a large amount of money. For example, due to our successful testing of the ESCs, we saved around about $268.70 due to not needing to buy in replacements. Testing also led to us being able to solve design problems, as we could put components through conditions that were outside what we actually needed them to perform, such as high acceleration of our motors, pushing power draw to an extreme.

Computationally, troubleshooting the various bugs in our code was a tedious process, due to the complexity of the program. However, this led to the program being slowly rewritten in a far more modular, more object oriented structure that will no doubt benefit the future of the program and our project as a whole, as the program can be easily adapted to whatever changes are needed for the future.



Photographed by P. George

On the structural end there were reinforcements and stronger attachments made at the joints of the frame that increased frame stability and reduced movement caused in the joints. The method that was used to carry this out was by simply drilling a screw in the joint with a washer to cover as much surface area as possible.



Photographed by P. George



Photographed by P. George



Photographed by P. George

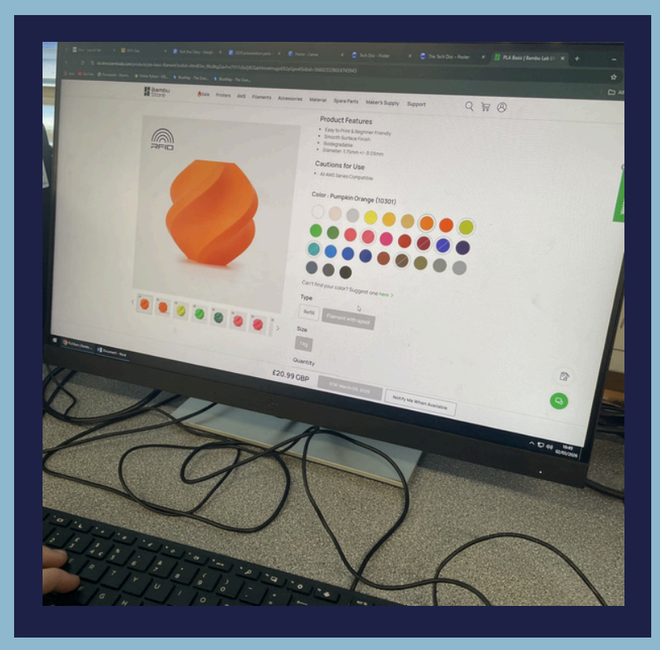
7.0 Accounting

7.1 Budgeting

At impROVise, monitoring cash flow plays a significant role in making sure our company runs like a well oiled machine. Keeping records of what has been donated, bought, reused and recycled helps us to collect and maintain our funds throughout the year and puts us in a good position for attending MATE competitions and setting goals for how much we'd like to fundraise for the project in the future. Being responsible with how we spend and knowing when to manufacture or reuse components increases team security and confidence when handling money, and also promotes one of our most important values, sustainability.

In terms of fundraising, our quiz night held at Keith Golf Club in January raised $692.34 USD. Additionally, in May, we gathered a total of $101.83 USD at an indoor market where we showcased our project to the public, set up lucky squares and hosted a small coffee morning for refreshments. Our main expenditures this year have been purchasing components, accommodation and transportation. In total, our transport costs from Keith to Aberdeen, covering a distance of 97.8 miles for the Regional Competition in April 2026 came out to $122.01 USD. For the World Championships, the total cost equates to approximately $7472.38 to travel from Scotland to Canada (covering approximately 2,181 miles). Lastly, our accommodation in St. Johns' Sheraton equates to approximately $2040.00 USD for our 10 team members across the week (or $340 USD per night).

We have done a great deal of accounting throughout the year, and have made an account list of all expenses for the team and listed what was either donated, bought or reused. This year, we used a spreadsheet to make sure that none of our costs were lost or forgotten.



Photographed by P. George

7.2 Cost Accounting

We have done a great deal of accounting throughout the year, and have made an account list of all expenses for the team and listed what was either donated by our supporters, bought for efficiency or reused for low environmental impact. For example, we have chosen to 3D print components such as our tooling and fenders and reuse our frame from previous builds. In total, our vehicle's cost equates to $886.49 USD.

7.0 Accounting

7.2 Cost Accounting

Our budgeting sheet accounted from 7/11/25 - 4/24/6

Product/ Expense	Departm	Category	Price per unit (USD)	Total Cost (USD)	Additional Info	Total
Brushless Motors	CAD	Purchased	41.12	246.68	600kv / X6	$12,315.01
5 volt regulator	Electrical	Purchased	14.88	14.88		
Orange Filament	CAD	Purchased	20.79	83.15	X4	
Raspberry pi 4	Electrical	Purchased	130.01	260.01	X2	
mpu 6050 5pcs IMU	Electrical	Purchased	8.53	17.06	X2	
Scotland flag	Worlds	Purchased	11.63	11.63	large	
Shock Tags	Travel	Purchased	3.67	44.02	X10	
Tracking tags	Travel	Purchased	17.46	69.82	X4	
Table banner	Graphics	Purchased	77.58	77.58		
Pull up banner	Graphics	Purchased	89.77	89.77		
Poster	Graphics	Purchased	43.86	43.86	rollable	
Uniforms	Team	Purchased	32.49	129.97		
Quiz Night	Funds	Raised		692.34	Keith Golf Club	
Indoor Market	Funds	Raised		101.83		
Bus Hire	Travel	Purchased		122.01	Regionals	
Flights	Travel	Purchased		7472.38	Worlds	
Accomodation	Travel	Purchased		2040	Worlds	
Motor housings	CAD	3D Printed				
Tube Brackets	CAD	3D Printed				
Fenders	CAD	3D Printed				
Electrical Support In tube	CAD	3D Printed				
Strain Relief	CAD	3D Printed				
Tooling	CAD	3D Printed				
Raspberry pi 4	Electrical	Purchased	55.98	55.98		
Waterproof connectors	Electrical	Purchased	32.45	32.45		
Raspberry pi 5	Electrical	Purchased	100.73	100.73		
50F supercapacitor	Electrical	Purchased	11.17	67.02	X6	
Toggle switch	Electrical	Purchased	10.66	10.66		
Metal film resistor	Electrical	Purchased	5.9	35.26	X6	
Raspberry Pi 4	Electrical	Donated				
Servo Driver	Electrical	Donated				
HDPE Sheet	CAD	Donated			X2	
Inline Connectors	Electrical	Donated				
Bus Hire	Travel	Purchased		121.85	Greenwell Base	
Chassis Mount resistor	Electrical	Purchased	05.10.	5.10.		
Tether	CAD	Donated				
T Shirts and Jumpers	Team	Donated				
Raspberry pi 4	Electrical	Purchased	55.98	55.98		
Inline connectors		Purchased	8	24	X3	
HDPE sheet		Purchased	144.54	289.08	X2	
Frame	CAD	Reused				

Budgeting spreadsheet by Kate Forrest

8.0 Outreach

Throughout the season we have been very busy reaching out to the local community to showcase our project and achievements. We take immense pride in the relationship that we hold with our community and are very grateful for all that they do to support us on our journey.



Photographed by P. George

One of our main fundraising events each year is our annual quiz night, held at Keith Golf Club. On the night, we had a table set up which gave us a great opportunity to share our progress with the community. Additionally, we 3D printed some impROVise keyrings for the winners to give a personalised touch. This year we raised $685.18 thanks to the help of our families, friends and past members of the team who donated our raffles and gave the team overall support at the event.

In February we were fortunate enough to be invited along to SubSea7 for a tour of the site and presentation from the base manager. This was a very educational and helpful trip for our team as we were able to see many of SubSea7's working ROVs and compare their similarities and differences with our own ROV, Astrid. The presentation from the base manager also allowed us to learn more about the history and uses of their ROV's.



Photographed by S. Tubbs


Photographed by P. George

We also held an open day on the 6th of March. The main purpose of this event was to invite locals from the industry to learn more about the project and the work that we do. We were overwhelmed with the amount of support that we received and it was great opportunity to engage with our community. We were also lucky enough to showcase our company to a variety of people from the industry who seemed very interested in involving themselves in the work that we do by supporting us in ways which we have found greatly beneficial.

In May, we held another quiz at Keith Golf Club, with aims to raise money for the World Championships alongside giving those who were interested in our company and Astrid, an update by showing off recent modifications. This also gave us an opportunity to catch up with past members of the team, including a few of the members that travelled to the World Championships in California 2017. They gave us valuable insights into what the experience would be like and got to see the many differences within our team and vehicle from the past 9 years. We completely filled out the golf club and got overwhelming support from the local Keith community. Overall it was a very successful night with $1,880.90 being raised and lots of advice being given, as well as a lot of praise for how far we've come and how much of an achievement this is for us.


Photographed by P. George

7.0 Acknowledgements

impROVise would like to thank all of the companies, the community of Keith, parents and most importantly our mentors, Mrs Ruth Jenkins and Mr Steven Tubbs. We are very grateful for all of your support, time and dedication that has helped us on our journey to the 2026 MATE ROV World Championships!

9.1 References

2.5

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Entire Document

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