EGH400-1 Progress Report

Development of a Small-Scale Underwater Remotely Operated Vehicle (ROV)

Faculty of Engineering

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Unit Code:	EGH400 - Research Project 1
Assessment:	#2 - Progress Report
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This report is submitted in partial fulfilment of the requirements for EGH400.

Contents

Acronyms

AUV Autonomous Underwater Vehicle. 1, 34, 35

CAD Computer-Aided Design. 1, 35

CFD Computational Fluid Dynamics. 35

DOF Degrees of Freedom. 1, 2, 33, 35

GUI Graphical User Interface. 1

IMU Inertial Measurement Unit. 34

ML Machine Learning. 1, 2

PID Proportional-Integral-Derivative. 2, 35

QUT Queensland University of Technology. 1

ROS Robot Operating System. 2, 34

ROV Remotely Operated Vehicle. 1–3, 15, 16, 33–35

1 Introduction

This project aims to design, develop, and validate a small-scale underwater Remotely Operated Vehicle (ROV) to address the gap in accessible research-grade platforms. The primary objective is to create a fully operational vehicle for use in Queensland University of Technology (QUT) demonstrations and as a versatile testbed for novel Machine Learning (ML) control pipelines. The research focuses on integrating robust hardware and software solutions within a compact form factor, a challenge not fully addressed by larger commercial systems.

The expected outcomes of this project include a fully assembled ROV, complete Computer-Aided Design (CAD) drawings, control system software with a basic Graphical User Interface (GUI), and a final report detailing the design, methodology, and performance results. This will be done in three phases:

- Phase 1: Research and Design (current phase)
- Phase 2: Validation and Prototyping
- Phase 3: Testing, Evaluation and Reporting

2 Literature Review

2.1 Literature Review Summary

A comprehensive survey of existing literature reveals a distinct gap in the field of underwater robotics for small-scale, low-cost, and modular Remotely Operated Vehicles (ROVs) that are also computationally equipped for modern research. While the domain is populated with large, work-class vehicles for industrial applications and highly specialised Autonomous Underwater Vehicles (Autonomous Underwater Vehicle (AUV)s), these platforms are often financially and logistically prohibitive for academic research and rapid prototyping [25]. This review synthesised key design philosophies and technical trade-offs from a range of academic papers and technical reports, establishing a theoretical foundation to inform the design of a novel research platform.

A primary theme is the fundamental decision in chassis architecture, which presents a trade-off between modularity and hydrodynamic performance. Open-frame designs are consistently favoured for research and educational platforms due to their inherent modularity, which simplifies the process of mounting, testing, and reconfiguring sensors, thrusters, and other payloads, as seen in vehicles like the eROV [5]. This adaptability is paramount for a vehicle intended to serve as a testbed. Conversely, enclosed, torpedo-style hulls are chosen when operational efficiency, speed, and endurance are the primary drivers, as their streamlined form minimises drag [13, 29]. For this project's objectives, the principles of the open-frame design are more closely aligned with the need for a flexible and extensible research platform.

Maneuverability in a compact form factor is another critical consideration, heavily influenced by thruster configuration. While simple 3-thruster systems can provide basic motion [27], the literature indicates that full 6-Degrees of Freedom (DOF) control is a key enabler for complex inspection and intervention tasks. This is typically achieved with six or more thrusters [15, 17]. A common and effective strategy is the use of a vectored thruster arrangement, where horizontal thrusters are angled to provide coupled control of surge, sway, and yaw [11, 25]. This approach allows for high agility and omnidirectional movement without a large physical footprint, a key idea that heavily influenced this project's propulsion system design.

The selection of onboard hardware reflects a clear scalability based on mission complexity and budget. At the lower end, simple microcontrollers like Arduino are sufficient for basic teleoperation and sensor reading [1, 27]. However, to serve as a viable testbed for modern algorithms, particularly in computer vision and ML, a more powerful single-board computer, such as a Raspberry Pi or Nvidia Jetson, is essential. These platforms provide the necessary processing power for real-time video streaming, network communication, and running inference models [11, 12, 16, 28]. This distinction highlights the necessity of selecting a companion computer that not only meets current needs but also provides headroom for future computational expansion.

Finally, the software architecture and control system design are integral to the vehicle's capability. The Robot Operating System (Robot Operating System (ROS)) is frequently cited as the framework of choice for complex, modular robotic systems due to its robust inter-process communication, extensive libraries, and available hardware drivers [15, 16]. While simpler platforms may use custom firmware, open-source solutions like ArduSub offer a powerful, community-supported alternative that can significantly accelerate development [10]. At the control level, the Proportional-Integral-Derivative (Proportional-Integral-Derivative (PID)) controller is a foundational and ubiquitous method for achieving basic stability, such as depth and heading hold [12, 17]. However, its performance can degrade in the presence of external disturbances, leading more advanced projects to explore robust control techniques like Sliding Mode Control or Fuzzy Logic controllers [9, 27]. These established ideas from the literature provide a clear benchmark against which this project's design choices and practical progress can be evaluated. The full literature review is available in Appendix B for further detail.

2.2 Evaluation of Literature Review Findings and New Literature

During the phase one of the project it was found that the insights from the literature review were largely applicable to the design and development of the medium scale ROV but not small scale ROVs. Using 6 thrusters to achieve 6 DOF was found to be impractical for a small scale ROV due to size and power consumption constraints. This was also true for the use of a companion computer such as a raspberry pi or nvidia jetson. These components while useful for ML applications, were found to be too large and power hungry for the size of ROV being designed. This lead to further literature review to find alternatives that would suit the size and power constraints of the small scale ROV. A paper by Sujan et al. (2024) [22] presented a design for a small scale ROV that used 4 thrusters in a vectored configuration to achieve underactuated control of the ROV as seen in figure 1. This design was found to be more suitable for the project as it allowed for a smaller footprint and lower power consumption, however the underactuation resulted in the lack of pitch control.

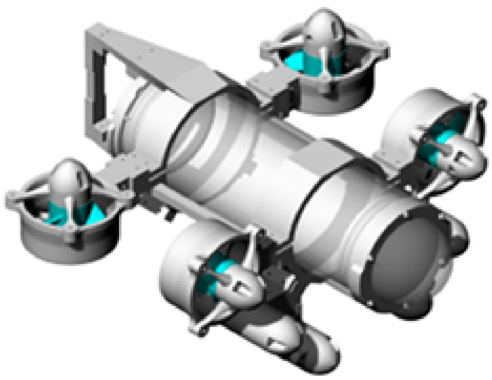


Figure 1: 4 thruster vectored configuration for small scale ROV from Sujan et al. (2024) [22].

This approach was modified into a experimental design using custom 45-45 degree brackets to give each thruster a vectored force. This design will need to be tested to see if it can achieve the desired dof and control. The benefit of this design is that it reduces the number of thrusters from 6 to 4, which reduces the size of the battery and ESC's required. This is a key area for the small scale ROV as it allows for a smaller hull and overall size, as well as cost reductions.

Due to sizing constraints found during initial design phase it was found that lithium-ion batteries were too large and had to be replaced with the smaller, lithium-ion polymer battery. While Lithium-ion Polymer (LiPo) batteries were selected for this project due to their high energy density and discharge rates essential for powering the thrusters, their use introduces significant safety considerations. An issues paper by the Australian Competition & Consumer Commission (ACCC) highlights the primary hazard associated with Li-ion batteries as 'thermal runaway' a rapid, self-sustaining temperature increase [4]. This event can be triggered by manufacturing defects, over-charging, physical impact (a key risk during ROV operations), or water ingress leading to a short circuit. The consequences of thermal runaway are severe, including intense fires that are difficult to extinguish, potential explosions, and the release of toxic and flammable gases [4]. For this project, these risks underscore the criticality of a robust, impact-resistant, and completely watertight enclosure for the battery, as well as strict adherence to balanced charging protocols. A detailed Risk Assessment has been conducted (see Section 4.1) to identify and mitigate these hazards, ensuring the safe operation of the ROV in aquatic environments.

Finally, new literature on the mavlink communication protocol was found as the small size rov was not large enough to hold a companion computer. This lead to the use of a pixhawk flight controller as the main computer, which uses the mavlink protocol to communicate with the surface station. Mavlink is a lightweight, header-only message marshalling library for micro air vehicles. It is designed as a very efficient communication protocol between drones and/or ground control stations [18]. This protocol is widely used in the drone community and has been adapted for use in underwater vehicles. The use of mavlink allows for a reliable and efficient communication link between the rov and the surface station, which is essential for remote operation and data transfer.

3 Project Progress and Achievements

This section details the progress made in the project to date, highlighting key achievements and milestones. These include design work, component procurement, assembly, experimentation, and any technical drawings produced. Below is a summary of the major milestones achieved so far:

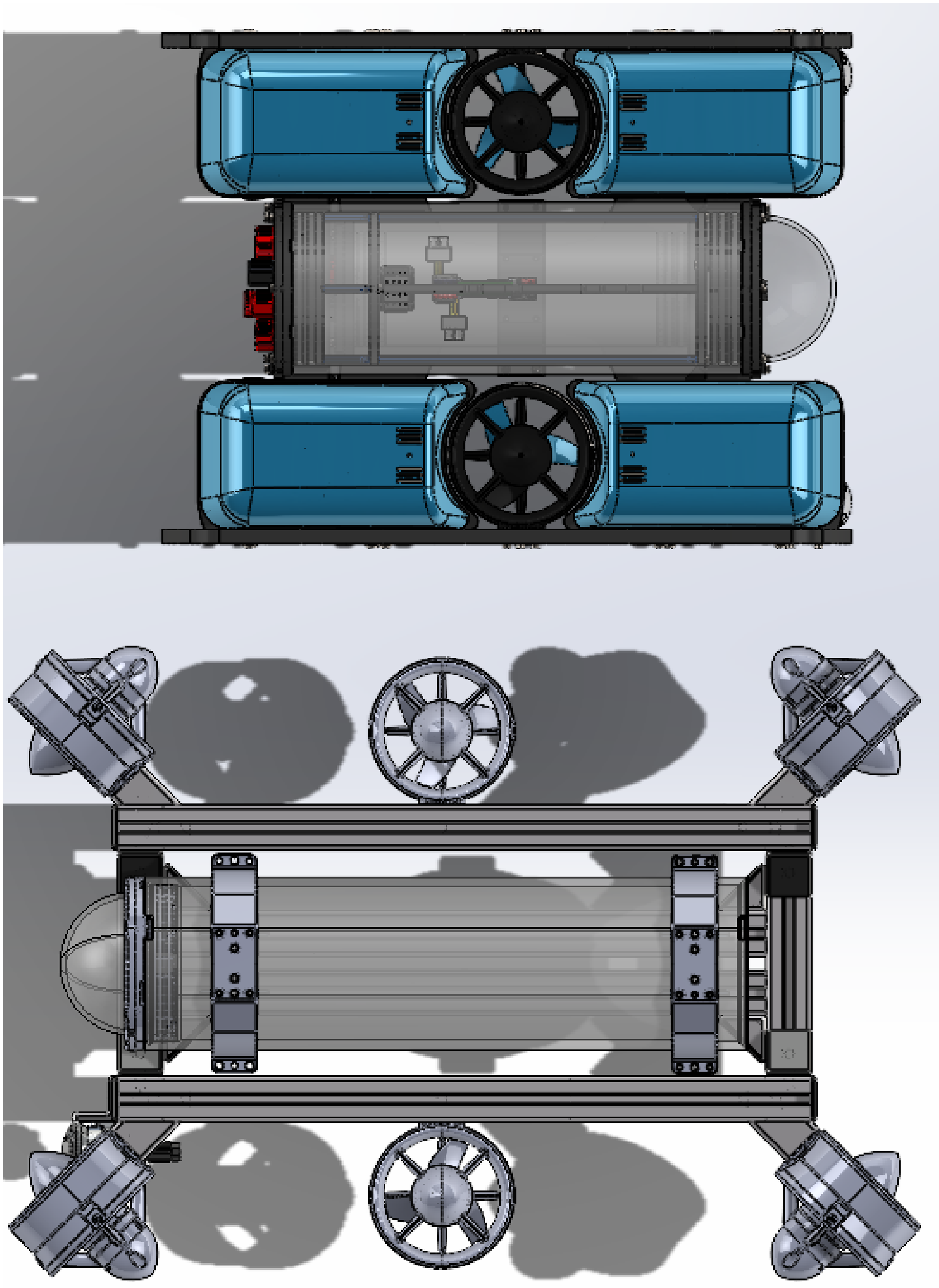
- Design iteration and problem-solving to meet research objectives
- Bom produced and components sourced.
- Final Solution in SolidWorks 2023 produced
- Construction of prototypes started
- Risk assessment completed and submitted for review
- Required hardware sourced and prepared for simulation

These items while not fully completing the first research and design phase (not complete as components are still missing), place the project in a good position to move into phase 2.

3.1 Design Iterations

When starting the design phase, components were picked based of literature review and existing designs. Key components that fall under this were the thrusters, hull, battery, main computer and camera. The initial design also followed this with 6 thrusters in a vectored configuration to allow for 6 degrees of freedom. Below is a rendering of the first design iterations Hull and WTE designs.

3.1.1 Mechanical Design



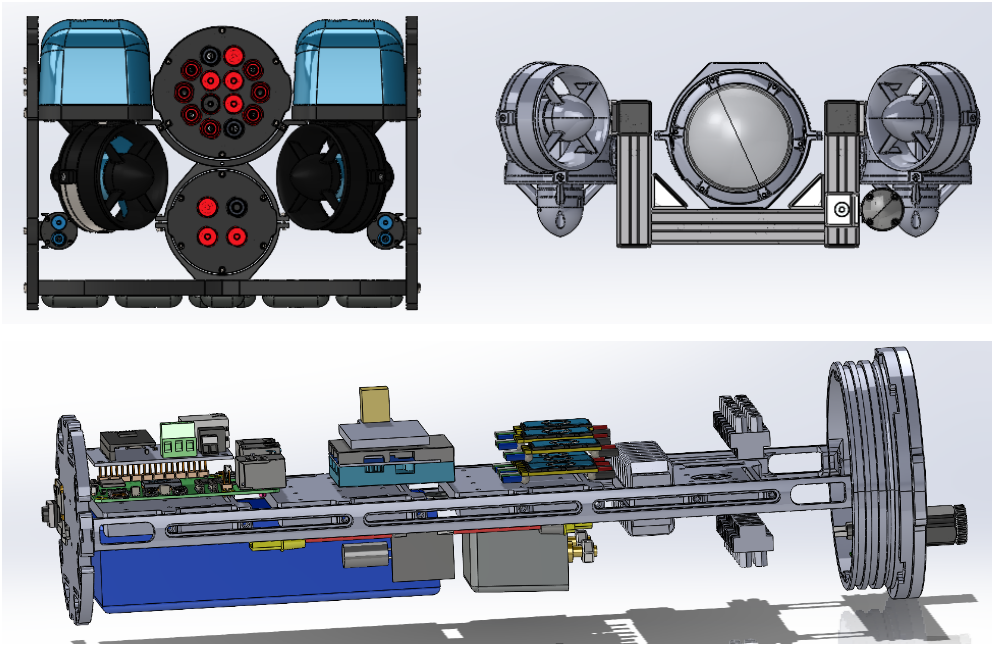
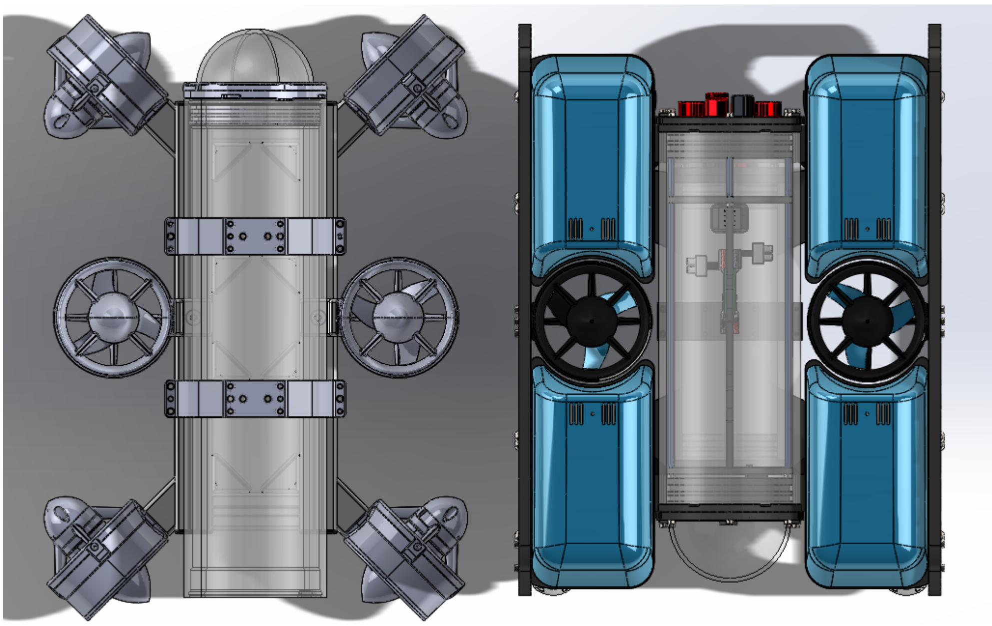


Figure 2: Top: Initial design of the ROV with 6 thrusters in a vectored configuration from a top view.
Middle: Front view of initial design
Bottom: detail view of the WTE assembly for design 1 and 2.

After getting feedback that the design was too large in comparison to the existing BlueRov2, an attempt to reduce its footprint was made. This can be seen below in design 2. It was made clear that sizing and battery life were key areas for this project.



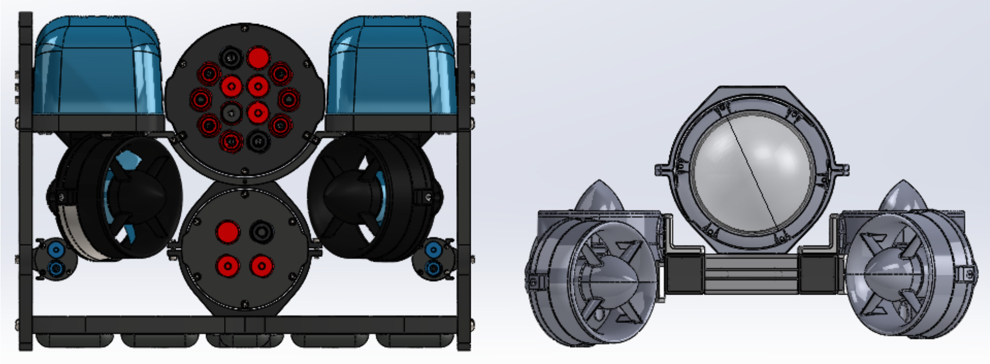
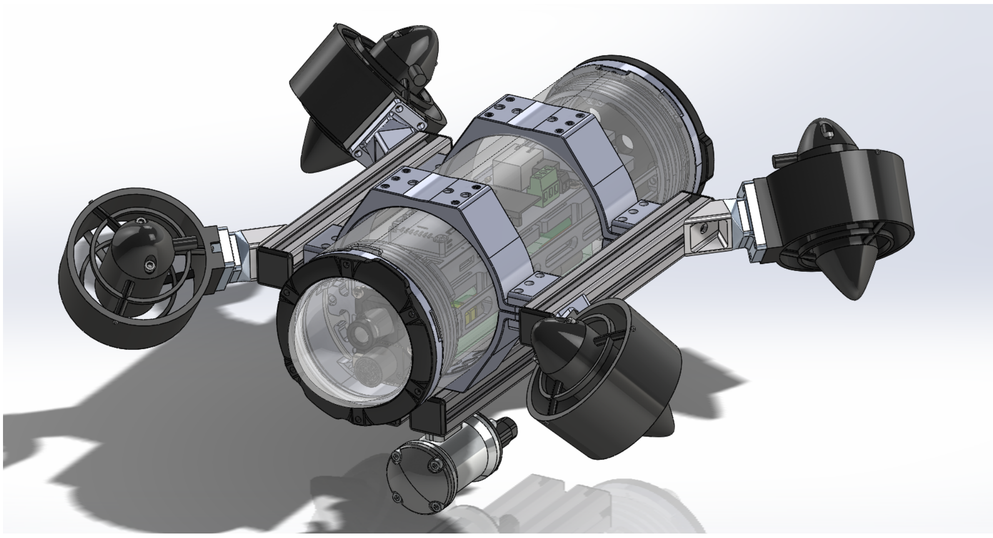


Figure 3: Top: overall second design of the ROV with 6 thrusters in a smaller footprint in comparison to the BlueRov2 from top view.
Bottom: size comparison of design 2 to blue robotics blue rov2 front view.

as seen in figure 3, the second design was still too bulky and had a large footprint relative to the existing BlueRov2. This was due to the large battery required for the selected T200 thrusters, the 6 ESC's required for thrusters and the inclusion of the companion computer the pi 5 in the chassis. This lead to a meeting with the supervisor to address the limitation of size with these components. The outcomes of the meeting where

- Reduce the number of thrusters to reduce size of battery and ESC's
- research different thrusters to get a smaller footprint
- Move the companion computer outside of the main hull to reduce size
- Connect the autopilot to the companion computer via a short tether These changes lead to a new design which had its own set of challenges. these included sourcing new thrusters, a change in camera as the original Pi compatible camera could not interface with the autopilot. Another challenge was maintaining a high dof with only 4 thrusters. A experimental design using a custom 45-45 degree bracket was made to give each thruster a vectored force. A custom control system will need to be implemented, however if successful the power consumption will be lower and the size of the ROV will be smaller. The benefit of removing the companion computer from the main hull allows the hull to have a smaller diameter and shorter in length. This change is what got design 3 to be accepted and allowed for prototyping to start. Below is design 3 that will be prototyped.



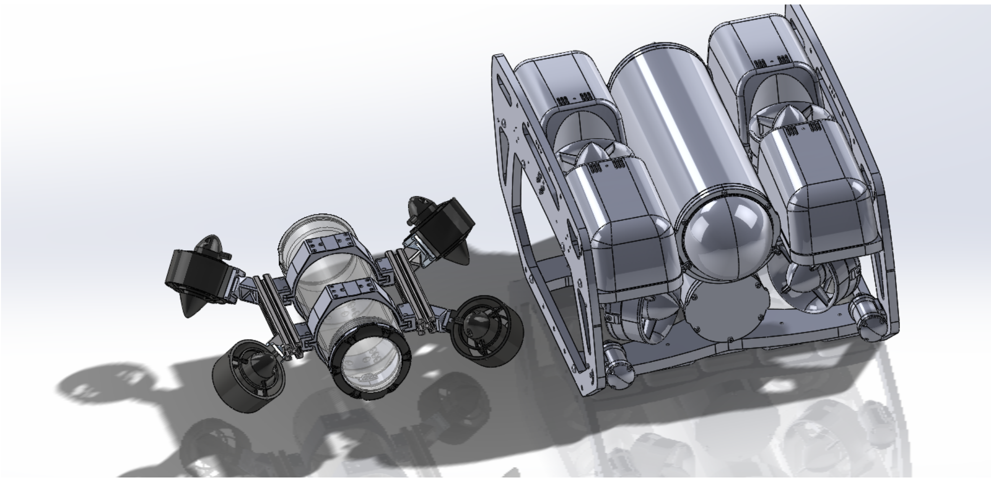


Figure 4: Top: overall third design of the ROV with 4 thrusters in a smaller footprint.
Bottom: size comparison of design 3 to blue robotics blue rov2.

This design used 4x U2 Mini thrusters by apisqueen to reduce size and power consumption. The battery was changed to a 4s 5200mah lipo battery to power the thrusters and electronics.

After it was accepted it was revealed that the camera selected was no longer on the market. This lead to a final design iteration to change the camera to a z-1 mini gimballed camera and the addition of a handle for safer handling. This required a new mount to be designed to fit inside the blue robotics 3" diameter watertight enclosure. This final design can be seen below in figure 6. However there was still some uncertainty with this design. Key areas of uncertainty are

- The 3D printed brackets for the thrusters need to be tested for strength
- The waterproofing of the main hull and WTE's need to be tested
- Will the custom 45 degree brackets work as intended
- Design validation needs to be done to calculate the buoyancy and additional volume required to achieve neutral buoyancy

these are planned to be addressed in the next phase of the project.

3.1.2 Electronics and System Integration

The electronics system is designed for reliability and performance, centred around a Pixhawk 6X flight controller and Z-1 Mini gimballed camera. Communication with the surface is achieved via a pair of Fathom-X Tether Interface Boards, which enable a robust, high-bandwidth Ethernet-over-power connection to a ground station. A lumen Subsea light will act as a inital payload but this can be swapped out for other sensors in the future. A Matek Systems PDB XT60 is used to simplify wiring and power distribution to the four APISQUEEN U2 MINI thrusters, each with there own external ECS and capable of delivering up to 130W of thrust. The entire system is powered by a small onboard LiPo battery, chosen for its high discharge rate and energy density, ensuring sufficient power for extended operation. The electronics are housed within a Blue Robotics 3" diameter watertight enclosure, providing protection against water ingress while allowing easy access for maintenance and upgrades.

3.1.3 Power Budget and Runtime Analysis

A detailed power budget was created to inform battery selection and estimate operational endurance. The power consumption of major components was determined from manufacturer datasheets, as summarised below:

- **APISQUEEN U2 MINI Thrusters (x4):** The most significant power consumers, drawing up to 130W each at maximum throttle. A typical cruising state is estimated at 25-30% throttle, corresponding to approximately 35W per thruster.
- **Pixhawk 6X Mini:** A consistent draw of approximately 3.0W.
- **Fathom-X Boards & Camera:** A combined constant draw of around 1.0W.

Based on this, the total system power draw for different operational scenarios was calculated:

- **Idle:** 8W
- **Cruising:** 144W
- **Maximum Thrust:** 524W

The chosen power source is a Tattu 5200mAh 4S (14.8V) LiPo battery, which has a nominal energy capacity of $5.2\,\text{Ah} \times 14.8\,\text{V} = 76.96\,\text{Wh}$. Using this, the vehicle's runtime can be estimated:

$$\text{Runtime (Cruising)} = \frac{76.96\,\text{Wh}}{144\,\text{W}} \approx 0.53\,\text{hours} \approx 32\,\text{minutes}$$

This runtime is deemed sufficient for the demonstration and testing objectives of the project.

3.2 Bill of Materials (BOM)

Significant progress has been made in sourcing and ordering components. All critical long-lead items, including the flight controller, thrusters, and enclosure are currently received. Mounting hardware is on order and the power sensor is on reorder due to a mistake with shipping. A full BOM can be found in the appendix. The total estimated cost for all components is currently $2900.

3.3 Final Design of Phase 1 in SolidWorks

The final design from phase 1 of the ROV has been completed in SolidWorks, incorporating all necessary modifications and optimizations identified during the design review process. The assembly includes detailed models of all major components, including the thrusters, mounting hardware and electronics enclosure. It is missing buoyancy elements as these will be designed in phase 2. Below are the renderings of the final design, technical drawing with dimensions included can be found in the appendix.

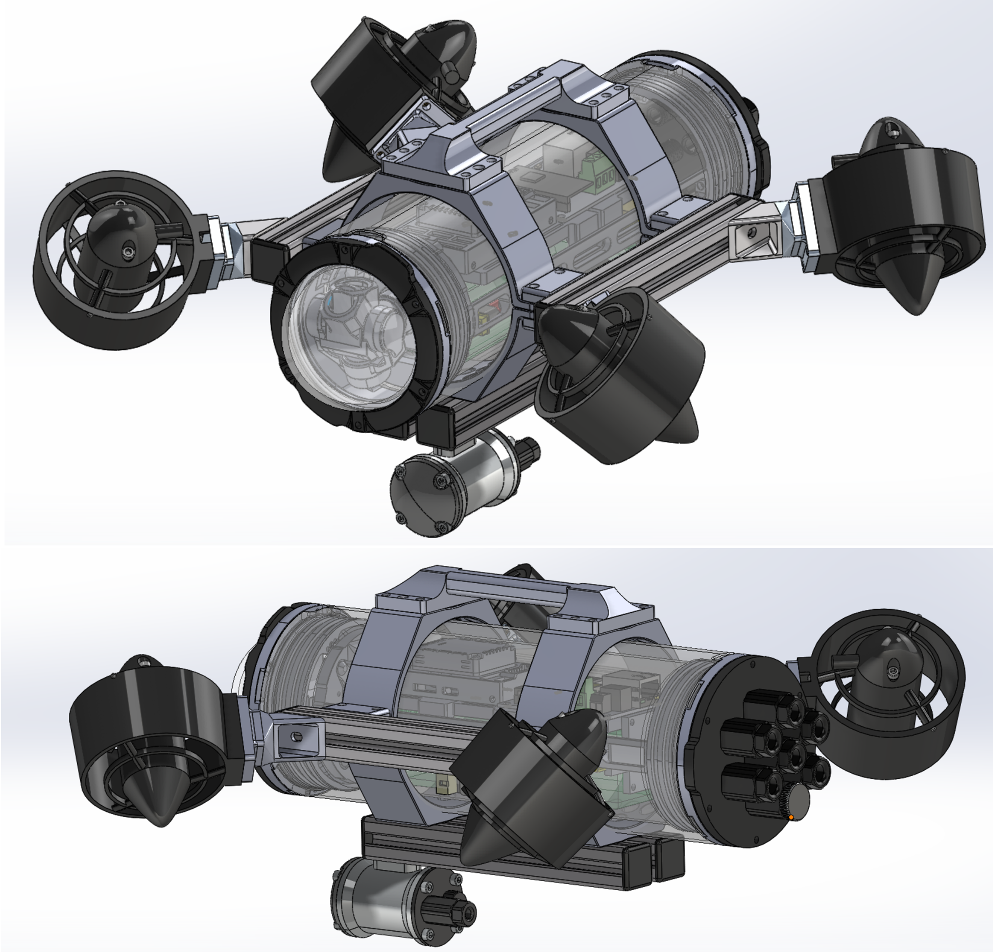
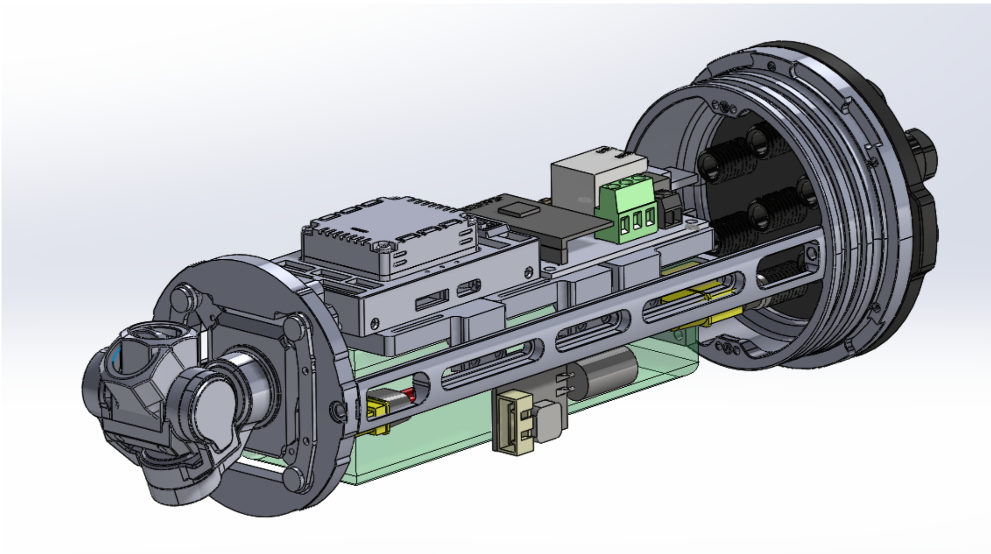


Figure 5: This figure shows 2 views of the final design of the ROV with 4 thrusters in a compact footprint. Technical Drawings with dimensions can be found in the appendix.



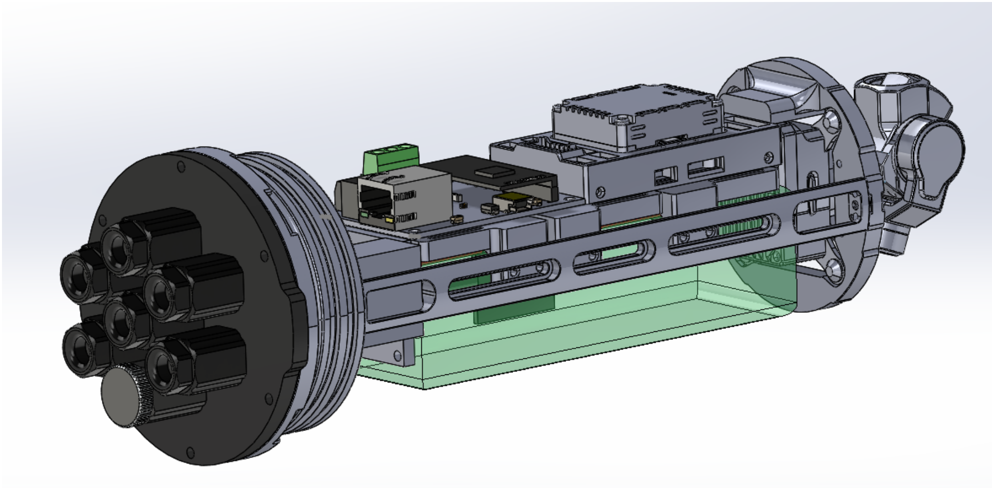
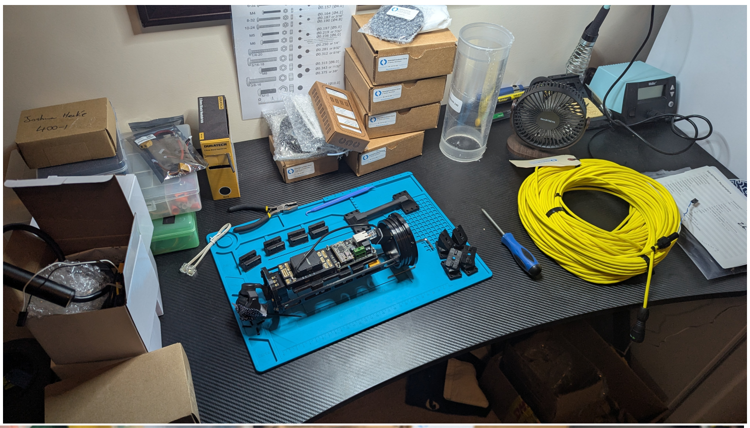


Figure 6: Final design from phase 1 of the the water tight enclosure with the blue robotics 3" diameter product. This includes the new camera mount and handle added from design 3. Technical Drawings with dimensions can be found in the appendix.

3.4 Prototyping and Assembly Testing

To validate the Solidworks design, inital construction of the WTE has started. This includeds the mounting of the interal control and power electronics. It was found through this prototype that some of the mounting holes needed slight modification. However once this was done the Pixhawk 6X, PDB-XT60 and Fathom-X boards fit well inside the enclosure. Below are some photos of the assembly process.



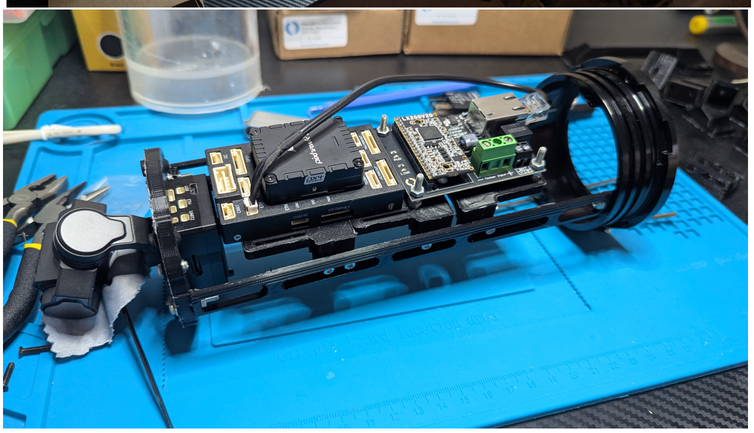


Figure 7: Top: Photo of home workshop with the 3d printed parts and initial assembly of the watertight enclosure.
Bottom: Close up of the internal electronics showing the Pixhawk 6X, PDB-XT60 and Fathom-X boards.

3.5 Hardware and preparation for Simulation

Currently no experimentation or testing has been done as the project is still in the design phase. Once the design is completed the project will move into phase 2, this will start in Solidworks where mass/inertial properties will be calculated for each component. The design will then be exported into a urdf file and imported into ros2/gazebo with a buoyancy plugin to validate the design. A ubuntu environment has be setup ready for this step. The method involves calculating the force required to achieve neutral buoyancy and adding enough volume to produce a buoyancy force equal to the offset force. Once the design is validated, a prototype will be built and tested in a pool environment after waterproof tests are done.

4 Project Management

4.1 Risk Assessment

A comprehensive risk assessment (RA), titled "Design of small scale Remotely Operated Vehicle - Underwater Robot" (ID: 18339), was submitted through the QUT HSE Hub to ensure the safety of all personnel and equipment. This document identifies the primary hazards associated with the project and, more importantly, establishes the formal control measures that will be implemented to mitigate them. The full RA document is attached in Appendix D.

The key risks and their corresponding mitigation strategies are summarised below:

- **Electrical Hazards (LiPo Battery):** The primary electrical risk involves the use, handling, storage, and charging of the 5200mAh 4S Lithium-Polymer (LiPo) battery. These batteries have a very high energy density and discharge rate, requiring strict protocols. The ROV's internal system is classified as "ultra low voltage" to comply with Australian standards.

  Storage: All batteries will be stored in designated fire-resistant LiPo bags or a battery cabinet, following consultation with S9 technical staff.

  Charging: Charging will only be performed in a designated, clear area using a purpose-built LiPo balance charger. Batteries will be monitored throughout the charging process and never left unattended.

  Handling: Only trained, designated operators may handle or connect the battery. A physical inspection for damage, swelling ("puffing"), or low voltage will be conducted before every use.

  Transport: Batteries will be transported in a safe, discharged state within fire-resistant bags.

- **Operational Hazards (Electronics and Water):** This risk category covers the hazards of operating a high-power electronic device in and around water, including the specific hazard of water leakage into the main electronics enclosure.

- **Leak Prevention:** A pre-operation checklist will be followed, requiring a visual and physical inspection of all O-ring seals, cable penetrators, and enclosure surfaces before every water-based test.
- **Leak Detection:** During initial submersion in the test tank, the ROV will be closely monitored for any signs of water ingress.
- **Electrical Safety:** The topside control station and power supply will be plugged into a Ground Fault Circuit Interrupter (GFCI) or Residual Current Device (RCD) protected outlet at all times.
- **Facility Safety:** Use of any testing facility (e.g., QUT pool, test tanks) will be done only after receiving formal approval from the appropriate facility manager or body.

– **Personnel and Training:** The experimental nature of the ROV presents a risk if operated by untrained personnel.

- **Designated Operators:** Operation is strictly limited to the designated and trained team members (Joshua Hecke, Tobias Fischer, and Scarlett Raine).
- **Induction Protocol:** Any other person must first receive a formal induction and practical training from a designated operator before they are permitted to operate the vehicle under supervision.

– **Chemical Hazards (Waterproofing Sealant):** The RA identifies potential hazards related to the use and storage of Dichtol waterproofing chemicals, which may be required to seal porous 3D-printed components.

- **Storage:** Should these chemicals be required, they will be purchased through S9 and stored in a designated, ventilated chemical storage cabinet as advised by technical staff.
- **Handling:** Application will be performed in a well-ventilated area (e.g., a fume hood) using the appropriate Personal Protective Equipment (PPE), including gloves and safety glasses.
- **SDS:** The Safety Data Sheet (SDS) for the chemical will be kept on-file and accessible in the lab.

Note on Waterproofing Chemicals: It should be noted that the Dichtol waterproofing chemical, while included in the RA for completeness, is not currently in use. This chemical was identified for potential future application if the 3D-printed components demonstrate water ingress or degradation after prolonged testing. Its use will be subject to the controls outlined above if and when it is required.

These measures are pending final review for endorsement, with procedures for chemical and battery storage being finalised with S9 staff.

5 Ethical Considerations

5.1 Code of Ethics

This project is conducted in accordance with the Engineers Australia Code of Ethics [8]. The application of these guiding principles throughout the project's progress is detailed below.

5.1.1 Demonstrate Integrity

Integrity has been a foundational principle in all project activities, ensuring honest and respectful conduct.

- **Honesty and Trustworthiness (1.2):** All project plans, design challenges, and progress have been communicated with transparency to supervisors and stakeholders. This commitment to openness ensures all involved parties remain fully informed of the project's status and direction.
- **Respect for Persons (1.3):** Input has been actively sought and respectfully considered from all stakeholders, including academic supervisors, technical staff, and peers. Every contribution is valued, regardless of an individual's specific technical background, fostering a collaborative project environment.

5.1.2 Practise Competently

The project has been undertaken with a commitment to technical competence and continuous professional development.

- **Maintenance of Skills (2.1):** To meet the specific design requirements of the ROV chassis, a proactive effort was made to expand personal capabilities by learning and utilising SolidWorks 2023 for the mechanical design, despite prior experience favouring other CAD platforms.
- **Acting on Knowledge (2.2):** All significant technical decisions, from component selection to control system architecture, have been evidence-based. These decisions are underpinned by a thorough review of relevant literature and direct consultation with knowledgeable stakeholders and subject matter experts.

5.1.3 Exercise Leadership

Leadership has been demonstrated through proactive, clear, and honest communication with all project participants.

- **Effective Communication (3.3):** Professional and effective communication has been maintained with a diverse group of stakeholders, including researchers and laboratory technicians. Through clear emails and meetings, critical information and expert advice have been solicited honestly and efficiently, acknowledging the reliance of the project on their expertise.

5.1.4 Promote Sustainability

The design and documentation process has been mindful of the project's long-term impact and future use.

- **Balancing Present and Future Needs (4.3):** To ensure the project's longevity, components have been selected with consideration for their long-term availability, mitigating risks of future obsolescence. Furthermore, a strong emphasis has been placed on thorough documentation, ensuring that the project's outcomes and learnings are accessible and can be effectively utilised by future students and researchers.

5.2 Sustainability Considerations

The development of the SubbyROV platform has incorporated sustainability considerations throughout the design and component selection process. The project's sustainability is assessed across three key pillars: environmental, economic, and social, ensuring a responsible approach to engineering that extends beyond the project's immediate technical goals.

5.2.1 Environmental Sustainability

Environmental sustainability has been a primary driver in the selection of materials and the operational design of the ROV.

- **Material Selection:** The ROV's chassis is constructed from anodised aluminium Item profile. Aluminium is not only durable and corrosion-resistant, extending the vehicle's operational lifespan, but it is also highly recyclable. The primary enclosure and thruster bodies are made from robust polymers designed for longevity in harsh marine environments, minimising the need for replacements and reducing potential waste.
- **Energy Efficiency:** The power system was designed for maximum efficiency to prolong operational time and reduce the frequency of battery charging cycles. As detailed in the power budget analysis, components such as the Pixhawk flight controller and the APISQUEEN U2 MINI thrusters were selected for their favourable power-to-performance ratio.
- **Minimal Operational Impact:** As an electrically powered vehicle, the ROV produces no direct emissions. Its small size and low-noise thrusters are intended to minimise disturbance to marine life during research and demonstration activities.

5.2.2 Economic Sustainability

The long-term economic viability of the platform is ensured through a modular and repairable design philosophy.

- **Modularity and Reusability:** The use of a standardised Item Profile frame is a cornerstone of the design's economic sustainability. This modularity allows for the simple addition, removal, or repositioning of components, such as sensors, manipulators, or buoyancy blocks. This means the ROV is not a static design but an adaptable platform that can be reconfigured for future projects and research questions without requiring a complete rebuild, thus maximising the return on the initial investment.
- **Repairability and Maintenance:** The reliance on Commercial-Off-The-Shelf (COTS) components from reputable suppliers like Blue Robotics and HolyBro, as listed in the Bill of Materials, simplifies maintenance and repairs. Standardised parts are readily available, reducing downtime and lowering long-term maintenance costs compared to a system built with fully custom, one-off components. This is further backed the use of 3D printed parts for mounting components, allowing for inexpensive and rapid replacement if damaged or in need of modulation.

5.2.3 Social and Educational Sustainability

Beyond its technical function, the ROV is designed to be a long-lasting educational and research tool for QUT.

- **Platform for Future Research:** As outlined in the project proposal, a primary goal of this project is to create a testbed for future research and student projects within the university. The adaptable nature of the ROV ensures it will remain a relevant and valuable asset, facilitating hands-on learning in marine robotics, control systems, and sensor integration for subsequent student cohorts.
- **Knowledge Transfer:** The documentation of this project, including this report, serves to transfer knowledge to future teams. The use of widely adopted hardware like the Pixhawk and accessible software frameworks ensures that future students can readily build upon the work completed, fostering a continuous cycle of innovation and learning.

6 Resources and Stakeholder Engagement

6.1 Codes, Regulations, and Standards

Given the project's current scope as an experimental platform for controlled environments, such as a QUT testing tank, adherence to specific commercial or maritime standards has not been a primary design constraint. Future development, particularly for deployment in natural waterways such as rivers or coastal waters, will require a review and application of relevant standards relevant to marine equipment and environmental protection.

Despite the experimental nature, proactive safety measures aligned with general robotic best practices have been integrated. Notably, a physical emergency stop has been incorporated into the operator control unit. This feature, absent in many commercial off-the-shelf ROV kits like the BlueROV2, provides a reliable, failsafe method to de-energise the thrusters, significantly enhancing operator and equipment safety during testing.

Furthermore, the use of high-energy Lithium Polymer (LiPo) batteries introduces specific hazards. All handling, charging, and storage procedures for these batteries will strictly adhere to Queensland University of Technology (QUT) regulations for on-campus laboratory work. These protocols are explicitly addressed and managed within the project's formal risk assessment to ensure safe operation.

6.2 Stakeholder Input

The project's direction and progress have been significantly shaped by continuous input from key stakeholders. This collaborative approach ensures the project remains aligned with its objectives, technically sound, and compliant with safety protocols.

6.2.1 Primary Stakeholders

Tobias Fischer (Project Supervisor): Mr. Fischer's role has been crucial in the conceptual and design phases of the project. His expert evaluation of design iterations and proposals for alternative simulation and modelling approaches have been instrumental. This guidance has been key to validating the design, particularly in balancing the competing constraints of vehicle size and operational runtime, ensuring the final product will meet its core performance targets.

S9 Workshop Technicians: The technical staff at the S9 workshop have provided essential logistical and safety oversight. Their contributions to sourcing and ordering components have been vital for maintaining the project schedule. Furthermore, their expertise in evaluating the safety of critical systems has been indispensable. A notable instance was their input regarding the use of a high-discharge LiPo battery. Their requirement for a detailed risk assessment *prior* to the battery's procurement has reinforced a safety-first culture within the project, ensuring all component selections are rigorously justified and safely implemented.

6.2.2 Future Stakeholders

As the project transitions from initial development (Phase 1) into prototyping and testing (Phase 2-3), the scope of stakeholder engagement will expand.

QUT Facilities and Personnel: Preparations will be made to engage with the facility managers of the QUT pool and to induct secondary operators, such as Scarlet Raine, who will be involved in future testing.

Collaborating Research Teams: The ROV is being developed as a potential payload-carrying platform for other research groups. Discussions with Tobias Fischer's other research teams are planned for Phase 3. These engagements will be critical for demonstrating the vehicle's capabilities and its effectiveness as a tool for their specific applications, which will directly influence the project's overall impact and potential for future use.

7 Conclusion

This report has detailed the significant progress achieved in the initial phase of the small-scale Remotely Operated Vehicle (ROV) development project. The primary objectives of this phase—comprehensive literature review, detailed mechanical and electrical design, and component procurement—have been successfully met. A robust literature review has informed a set of key design themes, guiding the project towards established and effective methodologies in ROV construction.

The mechanical design, finalised in CAD and visualized in Figure 4, provides a compact and modular frame centred around a 3-inch series watertight enclosure. The vectored thruster configuration has been selected to reduce power requirements and meet size constraints. All major electronic components, including the Pixhawk 6X flight controller and APISQUEEN U2 MINI thrusters, have been specified and sourced, as documented in the Bill of Materials. A thorough power budget analysis confirms the theoretical viability of the system, estimating an operational runtime of approximately 30 minutes with the selected 5200mAh LiPo battery under typical cruising conditions. With the design finalised and the majority of components now on hand, the project is well-positioned to transition from the theoretical design phase to the physical assembly and integration phase.

8 Future Work

The subsequent stages of the project will focus on the physical realisation and empirical validation of the designed system. The work is divided into two distinct phases: system integration and testing.

8.1 Phase 2: Assembly and System Integration

The immediate next step involves the complete physical assembly of the ROV. This will begin with the construction of the aluminium frame and the mounting of the thrusters and watertight enclosure. Concurrently, the internal electronics tray will be assembled, integrating the Pixhawk 6X, Power Distribution Board (PDB), Fathom-X interface board, and Electronic Speed Controllers (ESCs).

Key tasks in this phase include:

- Mechanical assembly of the frame and propulsion system.
- Wiring of all internal electronic components, ensuring correct power and signal paths.
- Installation and sealing of the cable penetrators for the thrusters and tether.
- Flashing the Pixhawk controller with the ArduSub firmware and performing initial "on-the-bench" configuration and sensor calibration.
- Establishing a successful communication link between the topside control station and the ROV via the Fathom-X tether interface boards.
- Simulating the ROV in a virtual environment using ROS2 and Gazebo to validate the control algorithms and buoyancy behaviour prior to physical testing.
- Conducting a comprehensive review of the risk assessment to ensure all new hazards introduced during assembly are adequately mitigated.
- Designing buoyancy modules to achieve neutral buoyancy, based on the final mass properties of the assembled vehicle.

8.2 Phase 3: Testing, Tuning, and Deployment

Once assembly is complete, the project will enter the critical testing phase. This will be conducted in a controlled environment, such as QUT and private swimming pools, to ensure safety and allow for iterative adjustments.

The objectives of this phase are:

- **Waterproofing and Ballasting:** The ROV will undergo initial leak testing. Following this, it will be carefully ballasted with weights and buoyancy additions to test the simulated neutral buoyancy and a stable trim.
- **System Identification:** Initial manual control tests will be conducted to gather empirical data on the vehicle's dynamic response. This data will be crucial for developing an accurate mathematical model of the ROV's behaviour, which is a prerequisite for advanced controller design.
- **Controller Tuning:** The Proportional-Integral-Derivative (PID) control loops within the ArduSub/PX4/GCU firmware will be systematically tuned to provide responsive and stable manual control across all degrees of freedom.
- **Operational Validation:** The ROV will be tasked with performing a series of manoeuvres to validate its performance against the original project objectives. This includes tests for depth-holding, heading-holding, and general manoeuvrability.
- **Autonomous and Payload Testing:** If time permits, basic autonomous waypoint navigation will be tested. Additionally, the vehicle's capability to carry and operate a simple payload, such as a camera or environmental sensor, will be evaluated.

– **Documentation and Handover:** Comprehensive documentation of the assembly, configuration, and testing procedures will be compiled. This will ensure that future users can effectively operate and maintain the ROV platform.

Successful completion of these phases will result in a fully operational and tested ROV platform, ready for future research and demonstration applications.

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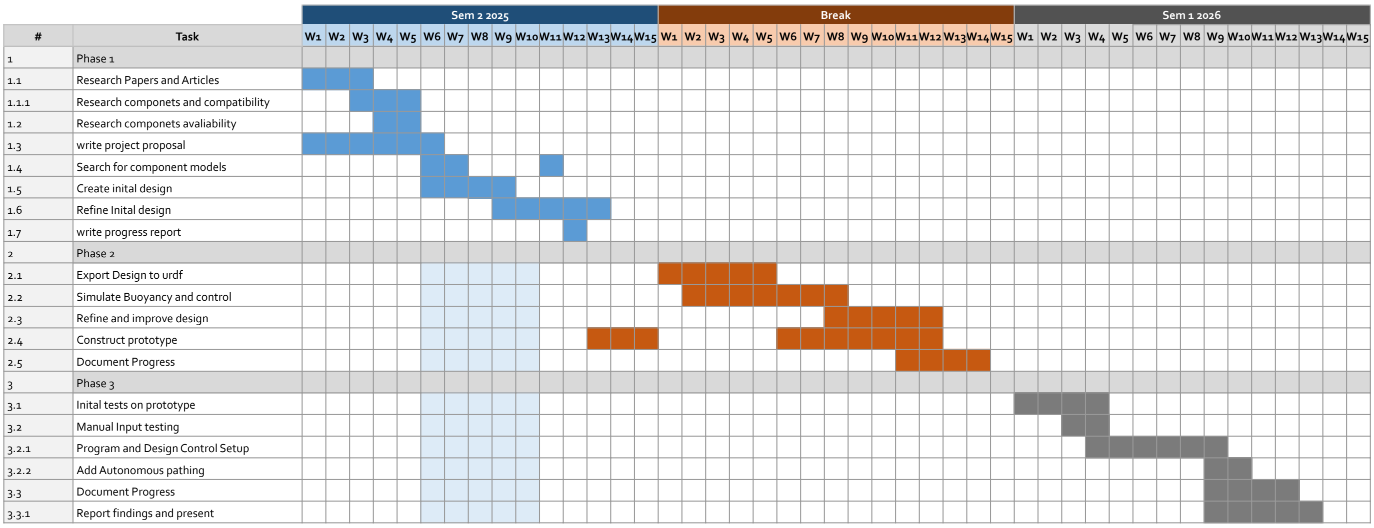
A Project Timeline

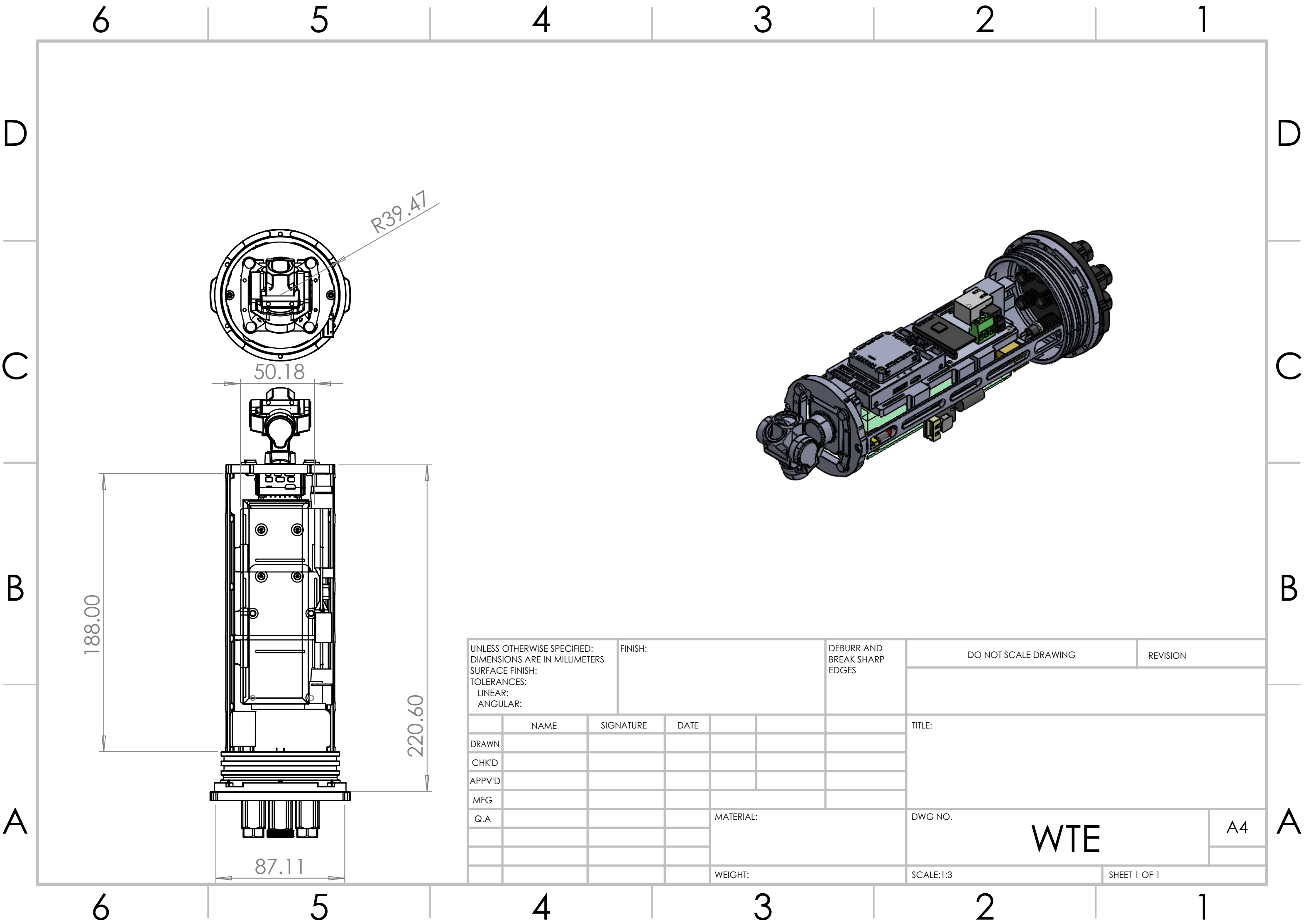
The project timeline is detailed in the Gantt chart below. The schedule outlines the key phases from the initial proposal through to the planned final testing. Phase 1, encompassing literature review, design, and procurement, has been successfully completed. The project is currently at the beginning of Phase 2.

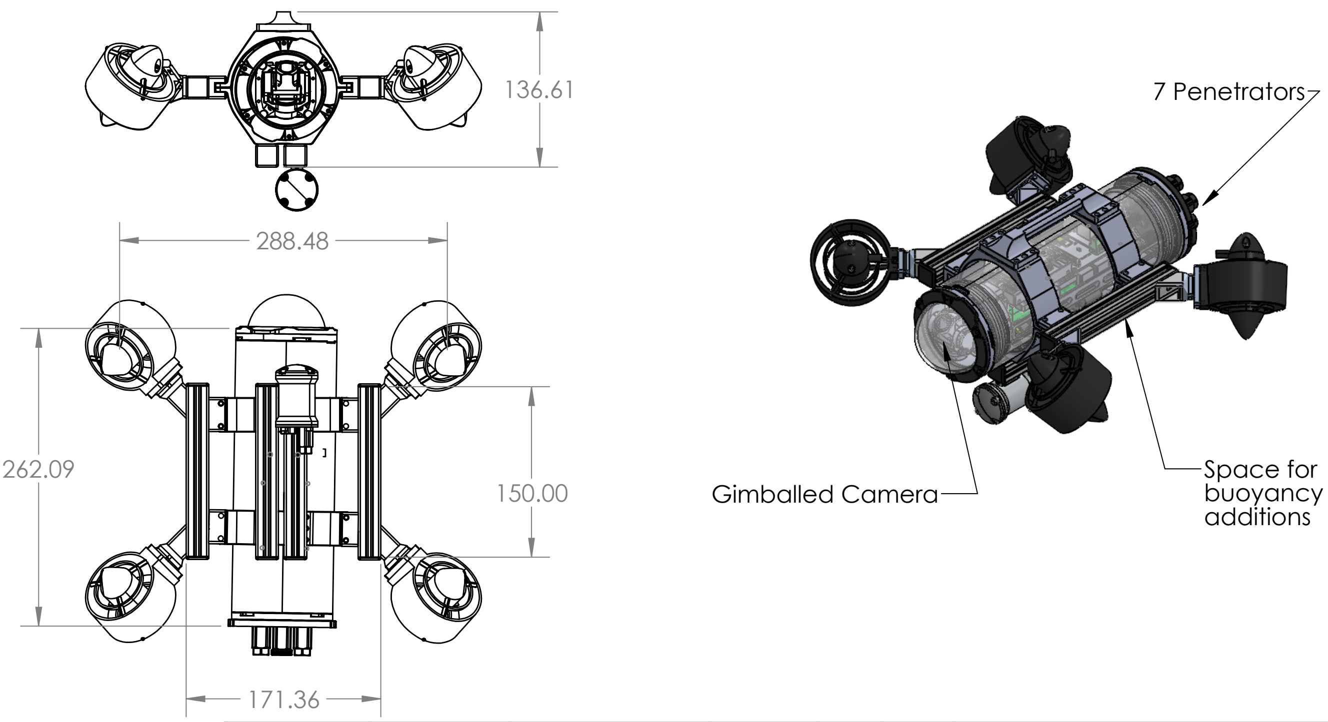
GANTT CHART

PROJECT TITLE		COMPANY NAME	QUT
PROJECT MANAGER		DATE	16/10/2025



B Technical Drawings





		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			SubbyROV
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE A DWG. NO. Drawing REV 4
NEXT ASSY	USED ON	FINISH	MM			
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:5 WEIGHT: SHEET 1 OF 1

C BOM (Full)

#	Item ID	Sub-System	Part Name	Description	Manufacturer / Supplier	Part Number / SKU	Qty.	Unit Cost ($AUD)	Total Cost ($)	Weight (g)	Total Weight (g)	Status	Purchasing Link	Notes
	1	Propulsion												
	1.1		SQUEEN U2 MINI 1.3Kg Underwater Thruster 16V 13		underwaterthruster	U2 mini	4	63.65	254.6	210	840	Arrived	Link	ll sourced from sa
	1.2													
	2	Electronics												
	2.1		Pixhawk 6X + Mini Baseboard + PM02	FLAG	Dr.Uav / HolyBro	6X-ICM-45686-5	1	300	300	50	50	Arrived	Link	ne by, ensure its 6
	2.2		atek Systems PDB XT60 W/ BEC 5V / 12V 2oz Copp		dronesxpress	PDB-XT60	1	36	36	7.5	7.5	On Order	Link	cheaper source el
	2.3		Fathom-X Tether Interface Board		Blue Robotics	BR-100178	2	212.15	424.3	100	200	Arrived	Link	Need 2
	2.4		Tattu 5200mAh 4s 35c Lipo Battery Pack		NextFPV	TA52004S35	2	99.95	199.9	435	870	ON HOLD	Link	you can find altern
	2.5		Automotive Relay, 12V dc Coil Voltage, 90A Switchin		Rs	915-6644	1	7.99	7.99	14	14	Arrived	Link	
	2.6		Switch		Blue robotics	BR-100433	1	42.43	33.944	20.5	20.5	Arrived	Link	
	2.7		XF-Z-1MINI		UmmanedRC		1	363.98	363.98	69	69	On Order	Link	
	2.8		Assorted connections + Wires		Misc		0	0	30	0	0	S9/Custom		
	4	Frame & Enclosure												
	4.1		Fathom ROV Tether		Blue Robotics	BR-100985-050	1	379.29	303.432	600	600	Arrived	Link	slim 50m
	4.2		Watertight Enclosure		Blue Robotics	WTE-VP	1	521.96	417.568	736	736	Arrived	Link	See image ->
	4.3		150mm Item Profile	FLAG	Item		4		0	72	288	On order	Link	
	4.4		item end caps	FLAG	Item		8		0	0	0	On order	Link	
	4.5		T nuts Item	FLAG	Item		20		0	2	40	On order	Link	M4 Stainless stee
	4.6		Penetrators 7.5 HC(7.0+0.3mm)		Blue Robotics	BR-100870-175	4	19.74	63.168	14.5	87	Arrived	Link	it to account for t
	4.7		Clamps		Blue Robotics		4	66.83	213.856	161	966	Arrived	Link	
	5	Buoyancy												
	5.1		?						0		0			
	5.2		?						0		0			
	6	Fasteners												
	6.1		M3				10	0	0	0	0	S9/OWS		
	6.2		M4				20	0	0	0	0	S9/OWS		
	7	Payload												
	7.1		Lumen Subsea Light		Blue Robotics	BR-100857	1	265.52	212.416	118	118	Arrived	Link	
	7.2													
	8	3D Printed	PLA filament		Anywhere		1	20	20	0	0	@ o Block/home		
	8.1		RailMount A-D		Custom		4	0	0	16	64	@ o Block/home		
	8.2		Rails		Custom		2	0	0	11	22	@ o Block/home		
	8.3		CircularMount		Custom		1	0	0	21	21	@ o Block/home		
	8.4		SideMount		Custom		4	0	0	6	24	@ o Block/home		
	8.5		Thruster Mount		Custom		4	0	0	13	52	@ o Block/home		
	8.6								0		0			
							TOTALS:		2881.154		5089			
		WTE Item	Weight(g)											
		Tube	442											
		Flange 2x	162											
		Hole cap	93											
		Dome	39											
		total	736											

#	Item ID	Sub-System	Part Name	Description	Manufacturer / Supplier	Part Number / SKU	Qty.	Unit Cost ($AUD)	Total Cost ($)	Weight (g)	Total Weight (g)	Status	Purchasing Link	Notes
			Tether Weight	Item weight										
		Ratio kg/m	0.012	0.48										
		Amount m	50	0.15										
		Total g	600	72										

D Full Risk Assessment

Risk Assessment : 18339 (Pending Endorsement)

Customer Details:-

Owner:	Josh Hecke (joshua.hecke@connect.qut.edu.au)	Review:	Yes
Email:	joshua.hecke@connect.qut.edu.au	Endorsement:	Yes
Assessment Type:	Plant/Equipment	MAPS ID:	
Division/Faculty:	Faculty of Engineering	QUT Team:	School of Electrical Engineering & Robotics
School/Depart:	School of Electrical Engineering & Robotics	QUT SubTeam:	
Start Date:	8/25/2025	Est End Date:	6/25/2026

Title: Design of small scale Remotely Operated Vehicle - Underwater Robot

Description: This is an risk assessment to support the design of a new small scale ROV on campus.

The primary risks relate to electrical safety during development, manual handling, operation, electrical safety including charging and packing and storage for travel.

Only Tobias Fischer, Joshua Hecke and Scarlet Raine will be able to operate this device during development and testing, due to its experimental nature. Other team members can operate this vehicle after contacting said operators and receiving a induction.

Main Risks-
5200mAh 14v LIPO Battery Use and Handling
Operation and Handling around water
IF USED
Safe use and Storage of Dichtol Waterproofing
Ensure-
S9 lab techs are aware of LIPO presence if battery is on campus for safe storage and charging.

In addition to this risk assessment, Approval of any commercial areas(i.e qut pool) needs to be organized with the appropriate body accordingly.

Location Details:-

Campus	Building	Floor	Room	Addional Info
Off Campus				These are operated on-water in the field at approved locations(A key example would be QUT Pool or Personal Pool)
Gardens Point	S Block	Level 11	1145-Post-Graduate Lab.	Mobile Robots Lab Soldering Station

Hazard Details:-

Haz ID	Hazard	Cause of Harm	What could go wrong	L	C	Risk Score	Hide Items
79996	Slip-Trip-Fall	Slippery surfaces	Slipping getting in and out of boat, on boat ramps or on shore close to water.	Possible	Minor	Low	
		Control	Hierachy: Administration Control: Assess conditions before moving around location. Must wear suitable footwear according to location (e.g. shoes, or wet booties). Only hop onto boat once fully secured. Do not run. Use multiple people to carry equipment on shore or loading boat.				
79997	Plant and Equipment	Operation	Rotating propellers - cuts, injuries, equipment in motion.	Unlikely	Minor	Low	
		Control	Hierachy: Engineering Control: For the BlueRov, the remote operator interface controls the motors and touching any control will disable the system and put it into idle mode.				
		Control	Hierachy: Isolation Control: On the BlueRov, the motors have shrouds minimizing the possibility of accidental contact with the propellers.				

79998	Manual Tasks	Posture - sustained/awkward/static	During deployment on shore/surface: - awkward posture (kneeling, squatting, balancing etc) - bending/twisting - duration of work - load handling - long standing/sitting - muscular force exerted - repetitive movement	Unlikely	Moderate	Medium	
		Control	Hierachy: Other Control: Take regular breaks, Keep area tidy, Position body (and maneuver boat) to life appropriately Use the handles on the equipment				
79999	Electrical	<50 volts AC/<120 volts DC	Fire or damage to batteries due to charging or discharging	Possible	Minor	Low	
		Control	Hierachy: Administration Control: After being approved/checked by lab tech, operators can now keep batteries on their person and conduct charging in designated charging areas in s11.				
		Control	Hierachy: Administration Control: Follow the operating manual for the chargers and ASVs				
		Control	Hierachy: Engineering Control: Only use official supplier and tagged chargers.				
		Control	Hierachy: PPE Control: Ensure batteries are charged and transported in lipo safe bags				
		Control	Hierachy: PPE Control: Fire extinguisher and/or fire blanket at working site.				
80000	Other	General assembly, building and installation of sensors and payloads.	- injury due to misuse of tools - pinch points	Possible	Minor	Low	
		Control	Hierachy: Administration Control: Standard operating procedures General assembly of the main hull and location of pinch points are clearly marked. An online SOP for the ASVs is maintained (QUT wiki). Each participant is aware and has access to these manuals and the latest is attached to this risk assessment.				
		Control	Hierachy: Administration Control: Training and education Ensure each participant is appropriately trained for the tools and equipment they are using and if required inducted into the work-zone.				
80001	Fieldwork	Other	Public hazards Unauthorized persons approach the vessel during operation such as swimmers or canoes. - knocking someone into the water - collision with a swimmer - collision with another vessel - public interfering with the vessel	Rare	Minor	Negligible	
		Control	Hierachy: Administration Control: Standard Operating Procedures Follow the SOP and exception permit requirements for notifying the public and locations for operation.				
		Control	Hierachy: Engineering Control: The overall mass is to be kept low so that there is minimal kinetic energy in any collisiot. Ensure all motors are shrouded and the shrouds are intacts.				
		Control	Hierachy: Isolation Control: Remote control devices All vessels have at least one level of wireless estop of wireless e-Stops. For the BlueRov2, the first is a hardwored heartbeat which must be maintained from the shore to allow power to the motors. The other is the remote control unit (e.g., RC controller or tablet) which can manually overide the computer and when switched off will also trigger the e-Stop.				

80001		Control	Hierachy: Isolation Control: The test location will be selected (moved within the site) to areas where there are no public visible or planned to be in the area. Conditions of applicable permits will be followed. If possible, on inland water storages, select sites that have no public access and seek approval from the land owners.				
80003	Fieldwork	Other	Working near water - drowning - slipping and falling - cuts from debris in the mud (e.g. broken glass, sharp rocks	Unlikely	Major	Medium	
		Control	Hierachy: Administration Control: Prepare and train for emergency response Details of the trained first-aiders made aware to the team on arrival at site as well as the location (in-vehicle) of the emergency contacts and closest hospital.				
		Control	Hierachy: Administration Control: Standard operating procedures The captain on boarding the boats will advise the team and crew of the standard operating procedures for all aspects of working at sea. This includes location of life□jackets, procedure for man overboard. These procedures are documented on-board the vessels and placards are placed around the vessel. For people that cannot swim or are uncomfortable around the water, they are encouraged to wear life-jackets whenever working near the edge of the boat.				
		Control	Hierachy: Administration Control: WAM-V SOP - Initially, the boat will be assembled on the waters edge following a visual inspection of the area and assessment of water depth. With a bow rope attached, the boat will be carried until the the stern is in the water (approximately 5 inches deep) and then pushed from the bow until completely in the water. Recovery will involve remote controlling the boat to the shore bow first, dragging the boat back onto shore (lifting the bow slightly) until the rear handles are at the shoreline and then lifted onto shore. This means that only shallow water sites are needed				
		Control	Hierachy: PPE Control: Each participant will wear enclosed footwear to allow walking at the water edge without risk of cutting feet due to debris and with enough grip to minimise slipping.				
		Control	Hierachy: PPE Control: Ensure suitable and fit for purpose life-jackets are available for all personal. These must be worn whilst on the boats when required by the skippers and vessels operating procedures.				
80004	Manual Tasks	Setting up equipment/furniture	Strains and sprains. Lifting equipment and transport cases for launching from shore.	Unlikely	Minor	Low	
		Control	Hierachy: Administration Control: Assess weight and size of load. Use more people to lift if awkward, slippery or unable to lift. Use trolleys on campus.				
		Control	Hierachy: Other Control: General assembly of the main hull and location of pinch points are detailed in the manufacturers manual (see attachment). Each participant is aware and has access to this manual.				
80005	Electrical	<50 volts AC/<120 volts DC	General hazard: Working with ultra low voltage DC (5-24Volts) Electrical equipment such as electric motors and sensors. - low voltage shock - burns - electrical fires	Possible	Minor	Low	
		Control	Hierachy: Administration Control: Ensure all participants working with low-voltage electrical are trained in the use of the equipment and have the appropriate laboratory inductions if required to undertake the work.				
		Control	Hierachy: Administration Control: Follow procedure for installation and removal of batteries. Ensure the equipment is turned off before installation or removal.				

80005		Control	Hierachy: Administration Control: Keeping equipment and plant well maintained. Use only fit-for purpose equipment. Ensure all wiring is documented and appropriately labelled where necessary.				
		Control	Hierachy: Isolation Control: Isolation switches and/or quick release plugs/connectors (such as Anderson or XT connectors) for isolating power to the components being worked on.				
		Control	Hierachy: Other Control: Fire extinguisher and/or fire blanket at the work site. Also LiPo safe bags for transporting and charging LiPo batteries				
		Control	Hierachy: PPE Control: Ensure batteries are charged and transported in lipo safe bags				
80006	Other	Loss of robot during missions	- Losing contact with the robot during missions - Leaking of water into robot	Unlikely	Minor	Low	
		Control	Hierachy: Administration Control: Standard operating procedures The missions are planned such that the ROV will operate in within a defined range. The ROV are tethered and in loss of power the robot can be located and most likely retrieced using the tether. In the event of leaking of water into the ASV, the robot should have sufficient remaining buoyancy to remain at the surface In the event of a leaking robots, the batteries have been selected to minimize risk of fire or explosion and on recovery the robot will be isolated for up to 3 hours to ensure no fire risk before further handling.				
		Control	Hierachy: Administration Control: The Operation of the ROV in navigable waters are covered under the AMSA Specific Exemption permit. This has requirements in the equipment required such as radios for alerting people in the vacinity, markings and the use of a ground control station (tablets and/or computers).				
		Control	Hierachy: Other Control: The BlueRov have a hearthbeat sent over the teather. The operational status and approximate possition are always known wihin a few meters.				
80008	Electrical	Operation of electrical equipment	Burn, Shock, Breathing in solder fumes	Possible	Minor	Low	
		Control	Hierachy: PPE Control: Ensure Glasses and extraction fan are used when soldering.				
		Control	Hierachy: PPE Control: When handling parts and chemicals ensure gloves are warn and safety gear including masks are worn.				
80178	Chemicals	Handling and use	*This chemical may not be used* Use of non-hazardous dichtol for waterproofing 3d parts. Standard handling risks include inhalation, skin contact, eye contact	Possible	Minor	Low	
		Control	Hierachy: Administration Control: The chemical will be stored in s9 store when not in use and be lent out when used in s11. To be returned at end of use				
		Control	Hierachy: Isolation Control: Remove risk by storing in carefully closed container upright with lid on tight				

80178		Control	Hierachy: Other Control: General information In all cases of doubt, or when symptoms persist, seek medical advice. If unconscious but breathing normally, place in recovery position and seek medical advice. Following inhalation Remove casualty to fresh air and keep warm and at rest. In case of irregular breathing or respiratory arrest provide artificial respiration. Following skin contact Remove contaminated, saturated clothing immediately. After contact with skin, wash immediately with plenty of water and soap. Do not use solvents or thinners. Wash contaminated clothing before reuse. After eye contact Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Seek medical advice immediately. Following ingestion If swallowed, rinse mouth with water (only if the person is conscious). Seek medical advice immediately. Keep victim calm. Do NOT induce vomiting. Self-protection of the first aider First aider: Pay attention to self-protection! Most important symptoms and effects, both acute and delayed Symptoms In all cases of doubt, or when symptoms persist, seek medical advice. Indication of any immediate medical attention and special treatment needed First Aid, decontamination, treatment of symptoms.				
		Control	Hierachy: PPE Control: gloves, eye protection, respiratory protection				
80320	Electrical	Design/modification	Water could enter electrical storage containers causing damage and potential shock. This is due to waterproof seals failing or not being sufficient	Possible	Moderate	Medium	
		Control	Hierachy: Elimination Control: Try to use certified/standard waterproofed containers (BlueRov product) where possible and only use custom made containers where necessary				
		Control	Hierachy: Engineering Control: Ensure all waterproof containers are tested multiple times at the required depth before being used to store components.				
83411	Electrical	Operation of electrical equipment	Lipo Battery 5200mAh 14V -Overcharging- can cause damage and fires -Storage- Storing LiPo batteries in inappropriate temperatures or locations can affect their performance and safety -Thermal Runaway-A dangerous process where a battery overheats and cannot cool down, leading to fire, explosion, and toxic fumes -Physical Damage- Punctures, fractures, or tears in the battery casing can lead to internal short circuits, increasing the risk of fire	Possible	Moderate	Medium	
		Control	Hierachy: Administration Control: Ensure days notice before any use,s9 techs will prepare accordingly.				
		Control	Hierachy: Administration Control: For Handling, Lab Techs in s9 control the charging and storage of LIPOs. This is non-negotiable as the methods already in place for safe storage, charging and testing.				
		Control	Hierachy: Elimination Control: Check resistance between battery input terminals and ensure no shorts or low resistance before use to ensure max output is not placed on system.				

83411		Control	Hierachy: Engineering Control: Before the battery is in operation ensure use in the system doesn't heat up the battery to a safety critical range. This is done through safe testing and calculations to ensure constant high draw causes heat				
		Control	Hierachy: Engineering Control: Don't run the battery down below 20% capacity.				
		Control	Hierachy: Isolation Control: Ensure when the battery is in use and/or exposed that there is a safe distance/exclusion zone. Especially for initial testing and research.				
		Control	Hierachy: Isolation Control: The LIPO will remain inside a LIPO Bag during transport at all times. Ensure it is collected like this.				

Participant Details:-

Participant Name
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Tobias Fischer (tobias.fischer@qut.edu.au)	Pending
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Approval Details:-

ID	Approval	Approver Name	Approval Status
21769	Risk Assessment Endorsment required for Risk Assessment#18339	Tobias Fischer (tobias.fischer@qut.edu.au)	Approved
22118	Risk Assessment Approval required for Assessment #18339	Firuz Zare (f.zare@qut.edu.au)	Cancelled
22165	Risk Assessment Endorsment required for Risk Assessment#18339	Tobias Fischer (tobias.fischer@qut.edu.au)	Pending

Note Details:-

Subject	Note	Category	Created Date	Created By
Reviewer Note	Hi Josh, Overall well done and comprehensive RA! - I've added Scarlett Raine as a participant as she's leading a lot of our marine robotics work, please update description accordingly. - Other team members need to contact operators + get induction - Remove everything boat related from the RA (loss of robot, ...), this is out of scope for this RA. If boat operation will happen in the future, we'll need to submit a separate RA. - Need to add water leakage as hazard + appropriate controls; describe tank etc. - Need to provide detailed information on where chemicals will be stored (Krishna to advise) - Need to provide detailed information on where batteries will be stored (Krishna to advise) - Change "low voltage" to "ultra low voltage" to be consistent with regulation Let me know if you have any questions. Best, Tobi	Customer Notes	9/19/2025 10:29:17 AM	Tobias Fischer (tobias.fischer@qut.edu.au)

Reviewer Note	Happy to accept this for now but maybe some additions would help further readings. Make it clear that the batteries used are not LIPO. I was sent a link to a Li-Ion battery which is a much safer chemistry. I would get Shaun and or S9 involved asap to get him in the loop for chemical purchase and storage. I think ultimately the users will be the ones requesting the chemicals for purchase and then involve S9 for the storage.	Customer Notes	9/19/2025 10:29:17 AM	Steven Bulmer (steven.bulmer@qut.edu.au)
Endorser Note	Hi Josh, I am happy to endorse this as soon as 1) Scarlett has been added to Project Description, and 2) You consider Steve's comments about chemicals/battery descriptions. Best, Tobi	Customer Notes	9/19/2025 10:29:17 AM	Tobias Fischer (tobias.fischer@qut.edu.au)

E Original Literature Review (from Project Proposal)

E.1 Introduction

Unmanned Underwater Vehicles (UUVs) have become indispensable tools for a vast range of applications, including oceanographic surveys, infrastructure maintenance, and military defence [7, 21]. As technology has advanced, these vehicles have evolved from simple teleoperated platforms into complex autonomous systems capable of executing sophisticated missions [7]. However, the literature reveals that a significant portion of research and commercial development has focused on large-scale, work-class vehicles or highly specialised Autonomous Underwater Vehicles (AUVs), which are often financially and logistically inaccessible for educational institutions or rapid prototyping research [25]. This is due to the cost of setting up demonstrations with large scale ROV and larger ROV designs call for larger scale prototyping solutions which may not be realistic. This has created a gap for small-scale, low-cost, and modular ROV platforms that are not only suitable for demonstration but are also powerful enough to serve as testbeds for advanced control and perception algorithms. The aim of this review is to explore the current state-of-the-art in small-scale ROV design by analysing key themes in existing literature, thereby identifying best practices and informing the design methodology for a novel research platform.

E.2 Methodology and Scope

The literature review was conducted using a systematic approach, focusing on peer-reviewed journal articles, conference papers, and technical reports from the last decade. The search was primarily conducted using the database IEEE Xplore, with keywords including "small-scale ROV", "underwater vehicle design", "ROV control systems", and "modular underwater robotics". The review is structured to cover key design themes, hardware and software selections, control system architectures, and system modelling approaches, providing a comprehensive overview of the current state of small-scale ROV research. The scope of this review is limited to reviewing current literature on ROV design methodology and hardware selections.

E.3 Key Design Themes

E.3.1 Chassis and Mechanical Design

The physical architecture of an ROV is a foundational design choice that dictates its hydrodynamic performance, modularity, and durability. The literature presents a clear dichotomy between open-frame and enclosed, torpedo-style chassis designs. Open-frame designs, such as those seen in the KCROV [6], MarmaROV [24], and eROV [5], are praised for their modularity, allowing for easy mounting of sensors, payloads, and thrusters. This configuration simplifies maintenance and is highly adaptable for research platforms. In contrast, streamlined, enclosed hulls are often selected to minimise hydrodynamic drag for greater efficiency and speed, as demonstrated by the MASUV-1 [13] and X4-ROV [29]. The thruster configuration is critical for maneuverability, with designs ranging from underactuated 3-thruster systems providing basic 3-DOF motion [27], to fully actuated 6 or 8 thruster systems enabling full 6 DOF control [15, 17]. The placement of thrusters in a vectored arrangement is common for achieving high agility, allowing for coupled control of surge, sway, and yaw from a set of horizontal thrusters [11, 25].

E.3.2 Material Selection and Waterproofing

Material selection directly impacts the vehicle's weight, durability, and operational depth. For low-cost educational platforms like the ArduinoSub and the vehicle proposed by Anwar et al. [2], PVC and acrylic are common choices due to their affordability and ease of fabrication. For more robust applications, designs progress towards aluminium frames and hulls [6, 21], with high-performance vehicles intended for deep-sea operation employing materials like carbon fibre and syntactic foam to achieve high strength-to-weight ratios [14]. Waterproofing remains a critical and persistent challenge. Standard solutions include O-ring seals for static enclosures and potted cable penetrators [17]. However, the literature presents several innovative approaches to overcome the limitations of these methods. The Jeff AUV uses a novel non-penetrative magnetic coupling to transmit torque from internal motors to external propellers, completely eliminating the need for a dynamic shaft seal [19]. The design by Tang et al. [23] also highlights custom-developed connectors as a significant improvement over permanently potting electronics, allowing for easier maintenance and repair. For the QUT demonstration ROV, waterproofing will be a key challenge due to its small form factor.

E.3.3 Hardware Selections

Propulsion and Sensing. The choice of thrusters and sensors is dictated by the vehicle's mission profile and budget. Propulsion systems range from modified low-cost($50) bilge pumps in budget designs [20] to commercially available, high-performance brushless DC thrusters like the BlueRobotics T200($350 per unit), which are noted for their power and reliability [5, 11]. Sensor suites vary significantly; educational kits may only include a basic Inertial Measurement Unit (IMU) and a camera [25], while advanced research platforms like EVA and Mesobot are equipped with a comprehensive array of high end high-cost sensors, including Doppler Velocity Logs (DVLs) for measuring velocity relative to the seafloor($12,500), USBL positioning systems for underwater localization($3000), and high-resolution waterproofed cameras for visual navigation($300) [16, 28].

Control Hardware. The selection of onboard electronics reflects a trade-off between cost, computational power, and development complexity. At the low-cost end of the spectrum, microcontroller based systems are prevalent. The D20-ROV and ArduinoSub, for instance, use an Arduino Mega 2560 as the central brain, which is sufficient for basic manual control and sensor interfacing [1, 27]. For more advanced capabilities, single-board computers like the Raspberry Pi are frequently adopted, as seen in the BlueRov2 and PolROV designs, providing a Linux-based environment capable of handling networking, video streaming, and more complex algorithms [11, 12]. High-performance vehicles designed for significant autonomy, such as EVA and Mesobot, employ multi-computer architectures with powerful CPUs and dedicated GPUs (e.g., Nvidia Jetson TX2) to process large volumes of sensor data in real-time [16, 28].

E.3.4 Software and Communication Frameworks

The software stack and communication architecture are integral to the ROV's functionality. For complex, modular systems, the ROS is the framework of choice, as seen in the Autonomous ROV for Marine Growth and the EVA hybrid vehicle [15, 16]. ROS is valued for its extensive libraries, hardware drivers, and robust inter-process communication, which significantly accelerates development time.

On simpler platforms, custom firmware is often developed in C++ within the Arduino IDE or using Python on a Raspberry Pi [25]. Open-source firmware like ArduSub, used in the VITA1 prototype, provides a powerful and well-supported alternative to developing a control system from scratch [10]. Communication is almost universally handled via a physical tether for ROVs, which provides both power and a high-bandwidth data link. This link is typically Ethernet over twisted pairs, though high-end systems may use fibre optics for greater bandwidth and distance [14].

E.3.5 Control System Architectures

Control strategies for underwater vehicles have matured from direct teleoperation to sophisticated autonomous behaviours [27]. The foundational control method discussed in much of the literature is the PID controller, used for fundamental tasks like depth-hold and heading-hold in vehicles such as the PolROV and Ariana-I [12, 17]. These controllers are well-understood and relatively simple to implement. However, due to the highly non-linear dynamics of underwater vehicles, more advanced techniques are often required for robust performance, especially in the presence of external disturbances like currents [27]. To address this, some designs implement Sliding Mode Control (SMC) for its robustness to parameter uncertainties [27], or Fuzzy Logic controllers which do not require a precise mathematical model of the system [9]. The Kambara AUV represents the cutting edge, employing model-free reinforcement learning to allow the controller to learn the vehicle's dynamics through trial and error, avoiding the need for an explicit model altogether [26].

E.3.6 System Modelling Approaches

The development of a control system is often preceded by system modelling to simulate and predict the vehicle's behaviour. A key distinction in the literature is the approach taken to derive this model. Many research-grade projects, such as the eROV and the spherical AUV by Zavari et al. [30], develop a comprehensive 6-DOF dynamic model from first principles. This process involves using CAD software to determine rigid-body parameters (mass, inertia) and Computational Fluid Dynamics (CFD) simulations to estimate hydrodynamic coefficients (drag, added mass) [5, 11]. This model-based design allows for extensive simulation and controller tuning before physical construction. An alternative, empirical approach is system identification, where experimental data from a physical prototype is used to derive a transfer function model. This was successfully demonstrated by Aras et al. [3] for the UTERG-ROV2, providing an accurate model for depth control without complex theoretical analysis. The choice of modelling approach represents a trade-off between theoretical rigour and the practicalities of physical testing.