The University of Western Australia

Autonomous Surface Vehicles (ASV) Project

Design, build and upgrade of supporting hardware and collection of oceanographic data

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Abstract

Since 2017 The University of Western Australia has pursued the goal of creating an autonomously guided, near-unlimited range surface vehicle capable of circumnavigating Rottnest Island [1]. Significant work was completed in 2020 to re-design the hull and overhaul/upgrade all control systems and wiring. The new vessel is now known as Autonomous Surface Vehicle (ASV) [2].

Due to its robust nature, low running costs and flexible payload carrying capacity, the ASV received genuine interest from external parties and departments within the University to autonomously collect survey data for research and commercial purposes. After initial attempts at using/testing the ASV, it became clear that the current vessel did not have a supporting network of hardware that allowed for timely and consistent deployment.

This thesis takes the perspective of a Mechanical Engineer in upgrading the ASV and designing the subsystems that are needed to make the ASV easily and readily deployable to prepare it for use in the broader academic or commercial context.

The project method involved a review of current literature and assessing the current state of the ASV to determine the areas of priority for upgrades and implementation of new features. Designs were created using modern manufacturing techniques such as 3D CAD modelling, CNC Machining and 3D Printing.

The design process and implementation of notable upgrades will be described as follows, project status and review, design and construction of transport equipment, design and construction of a ground control station – power pack, upgrades to the radio communication system, integration of client sensors, testing and results, final assessment, and further work.

The new supporting hardware makes the ASV readily deployable. It can now be used in any location and be in the water, ready for testing at a fraction of the time of previous iterations. The integration of sensors and testing verifies the ASV as a capable platform for collecting data for research purposes.

Contents

1. INTRODUCTION

1.1 Background & internal literature review

The Solar Powered Autonomous Boat project began in 2017, intending to create an autonomously guided near unlimited range watercraft capable of undertaking a circumnavigation of Rottnest Island [1].

The original hull consisted of three PVC tubes connected through aluminium fasteners with a marine-grade solar panned laid on top. The project was known as the Solar Powered Autonomous Raft (SPAR), shown in Figure 1: SPAR Initial Design. All electronics were housed inside the PVC tubes, and two blue robotics thrusters propelled the raft. The original design achieved its goal of being made from predominantly 'off the self' components and was able to follow simple waypoints on water [1].

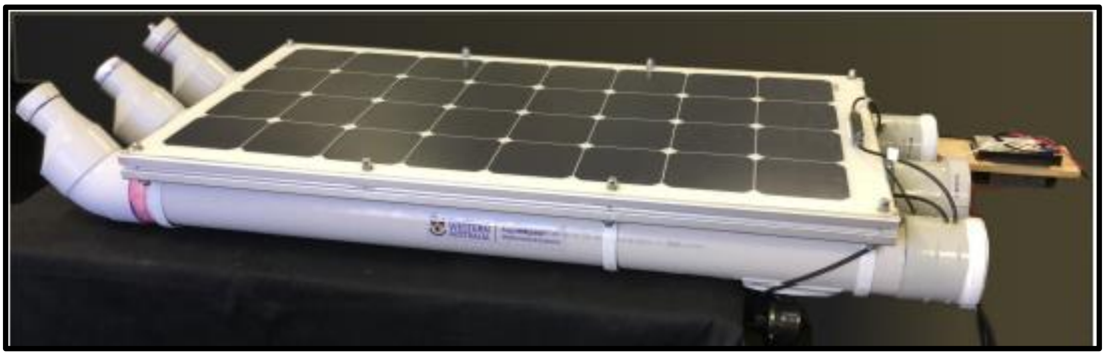


Figure 1: SPAR Initial Design. [1]

Over the next two years, the SPAR became known as the Solar Powered Autonomous Boat (SPAB). The later projects made various hardware improvements and verified the SPAB's capability by conducting significant testing in the swan river [2]. Notable changes to this design included the addition of a 3G Modem and a Raspberry Pi to address previous telemetry and communication issues [3].

In 2019 Coleman verified the value of using the SPAB for research purposes by adding client sensors, including a temperature sensor and camera [4]. However, the SPAB did not achieve the final goal of ocean testing due to issues with hull design, hardware and software, causing significant delays [4].

Also, in 2019 another project was undertaken simultaneously to build a single page web application that could be used to report collected data and control the boat online[5]. The webpage was functional but, due to time constraints, never thoroughly tested with the sensors of the SPAB [5].

In 2020 the ASV underwent significant design and hardware changes and considering these changes is now known as the Autonomous Surface Vehicle (ASV) [6]. The original hull was abandoned and replaced with the current 'catamaran-style hull' shown in Figure 2, the hull is built from polystyrene foam-lined with epoxy and fibreglass [6]. In addition to a new hull, the ASV was outfitted with an upgraded *Pixhawk 2 Cube* autopilot system, *Raspberry Pi*

3B+ and an *RDF900+* ultra-long-range modem to address previous issues surrounding long-range communication with the ASV [6].

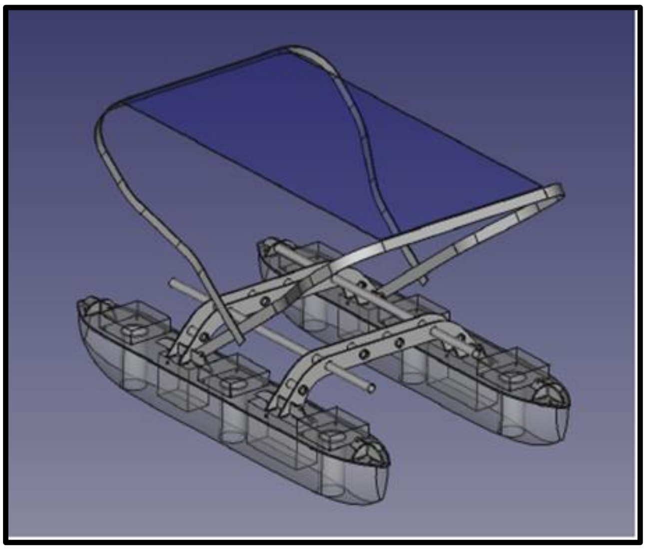


Figure 2: Current ASV Hull and Super Structure. [6]

The new ASV design underwent limited testing in the swan river, and Constant provided detailed documentation of potential areas for improvement [6]. These include;

Steerable thrusters: Adding a servo motor and above deck-belt driven steering gear. The thrusters would provide the ASV with an additional degree of freedom of 'sway' and allow it to perform station keeping.

Upgrade the Battery Monitoring System: Reconfigure the Solar power wiring and add a second power module to deduce how much power is being produced through the solar panels. Perform more extended tests to assess the autonomy of the autopilot system in terms of power consumption.

Client Instruments: Addition of instruments such as a salinity & Ph meter, vertical underwater camera, sonar for depth sounding. For these instruments to efficiently collect and present data online, the addition of a companion computer and full integration with the web server software would also be necessary.

Navigational Instruments: Install a forward-looking range finder for primary collision avoidance. Integrated mission planning using Garmin Navionics and Ground Control software. Additional navigation lights and wind sensors.

Testing Program: Undertake long-range missions in sheltered waters such as Henderson Port before moving to open sea missions. Fully tune motor drive, testing all control modes, reporting of power systems data and test ROS and companion computer integration.

1.2 Additional literature & state of the art

1.2.1 Small Low-Cost ASVs

An analysis of the ASVs that inspired this project, such as the *Sea Charger*, *Scout*, *Wave Glider* and the *Solar Voyager*, has been well documented by the previous UWA students involved in this project, in particular Borella [2]. Like the SPAR, many of the early ASVs were characterised by modifying existing hulls and using off the shelf components such as kayaks or sailing hulls to dramatically reduce the cost of the ASV [7, 8]. The more successful ocean crossing ASVs are powered through green energy, either wind, solar or wave (or a combination) and are all built with hulls and materials mimicking existing ocean craft such as foam, aluminium, or fibreglass [7, 9].

The decision to upgrade to the current design of a catamaran, with 'wells' inserted into each hull for different monitoring devices and a readily accessible control box, is justified in literature [10]. However, the most significant benefit of such an ASV design is that it can be modified for multi-mission applications and supports a stable/large payload for its size [10, 11].

Recent iterations of the small catamaran-style ASV include the *Catabot* from students at Dartmouth College USA. The design uses the same Blue Robotics T200 motors on each hull for propulsion and the Pixhawk for control [12]. The *Catabot* was able to couple the Pixhawk with a companion computer and successfully integrate on deck sensors such as a GPS/Compass, LiDAR, IMU, RGB Camera and below deck sensors of an underwater camera and sonar. Interestingly the study presented the optimal position of the motors for sensor data quality and general ASV motion[12]. They also highlighted the importance of repeat testing to tune the control algorithm for a specified data collection activityn[12].

A slightly more complex ASV which the UWA ASV project can draw inspiration from, is that of the *HydroNet ASV*, which shares a very similar hull design with modular 'wells' for sensors and hardware [13]. The *HydroNet ASV* used a modular control system architecture. For example, the 'Obstacle Avoidance Module' involved a Laser Scanner, Sonar and Altimeter connected to an initial Titan board and then related to the main Titan PC104 control board. Other control modules present were the 'Localisation Module', 'Communication Module' and 'Low-Level locomotion Module' [13].

A more robust 'long-endurance' ASV created by researchers from the Norwegian University of Science and Technology proposed a three-tiered level control system for their wave-powered ASV [14]. Level 1 consisted of System Monitoring and a 'Fall-back Autopilot', which could control the primary power and propulsion systems. Level 2 contained advanced navigation capabilities ad collision avoidance, and Level 3 included the scientific data collection systems. Due to the long-range nature of this ASV, the Level 3 control system was able to sit in standby mode until it was needed, saving power. In worst-case scenarios, the Level 3 and Level 2 functionalities can be disconnected without affecting level 1 systems [14].

1.2.2 Using an Autonomous Surface Vehicle to collect survey data

There is a growing case to support the use of Autonomous Surface Vehicles to collect survey or bathymetric data. The most significant advantage of collecting data with an ASV is reduced operating costs and capital investment. A smaller vessel can be deployed without an operating crew powered by renewable energy [15-17].

The nature of a small ASV such as the ASV can reach and survey areas unsuitable for larger surface craft due to shallow waters, unpredictable surface depth and the presence of rocks and obstacles[18, 19]. Iwen and M. proved that the ASV has a significant advantage in surveying shallow water due to its manoeuvrability, shallow draft, location of the transducer and ability to take measurements at a constant speed and straight lines[18].

Using an IoT style network in which five water quality sensors were connected through a custom connection tool (Sensors Bridge), researchers at the Mississippi State University were able to capture and send data through a cellular network to visualise the data in real time and negate the need to use sensor specific software[17], the network diagram is shown below Figure 3.

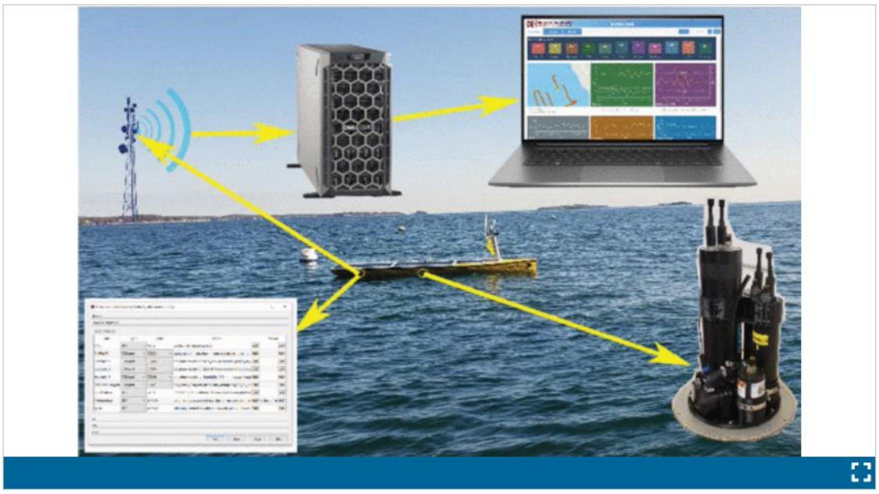


Fig. 1.
Architecture of the real-time water quality and visualization system.

Figure 3: IoT network to produce 'real-time' water quality monitoring and visualization system. [17]

1.2.3 Active Collision Avoidance

To safely navigate in an offshore environment, the biggest hurdle that many commercial ASVs are attempting to overcome (including the ASV) is a secure collision avoidance system that integrates with the International Rules for Prevention of Collisions at Sea COLREGs. Two decades ago, research began to highlight the difficulty and considerations that would need to be addressed to conform to the rules of COLREGs[20]. Early research was focused on developing sensors such as sonar to recognise potential hazards in an operating environment[21] and has grown into integrating multiple marine instruments with a more significant focus on developing the decision-making algorithms that conform to COREGs[22].

In 2014 researchers performed the first successful on-water tests of a new collision avoidance algorithm that seamlessly integrated with COLREGs[23]. The use of velocity obstacles (VOs) determined which side the USV should pass and allowed the COLREG's situational manoeuvres to be integrated naturally as an additional constraint parameter[23].

A more recent study proposed a multiobjective optimisation approach (MOP) to the decision-making algorithm[24]. The essential advantage of such an approach was it was also able to prioritise manoeuvres and integrate good decision making or seamanship, such as changing course over speed in an evasive situation. This study also critiqued previous approaches such as fuzzy logic, artificial potential fields and interval programming, claiming they do not scale well when tested in scenarios with multiple ships and conflicting COLREGs rules[24].

The previous claim was also supported when a specific study was undertaken to quantitatively assess the performance of current collision avoidance algorithms [25]. In the scenarios, three vessels were placed in a multi head-on-collision where each was approaching at 120 degrees. This type of scenario, whilst unlikely but not impossible, was able to quickly overwhelm the (VO) based system tested and produce very slow indecisive evasive manoeuvres[25].

Another exciting development is the use of the Automatic Identification System (AIS) to integrate with and tune collision avoidance systems. The AIS network provides a framework for ships to share navigation data automatically[26]. The data includes;

- ‘dynamic data’: latitude, longitude, position accuracy, time, course speed and navigation status.
- ‘static data’: name, dimensions, type, draft, destination and estimated arrival time [26].

The International Maritime Authority (IMO) has now mandated AIS to be used by all vessels above 300GT, commercial ships and fishing boats[27], creating a valuable source of navigation and collision avoidance data. The AIS data also creates testing scenarios based on historical AIS navigation data[27], which can be used for deep learning of AI-based COLREG-Compliant navigation systems[28-30].

A recent comprehensive study found that COLREGs were never designed to be used by ASV and have been successful due to human interpretation and decision making[22]. The study outlined all the critical Fuzzy Variables which will provide the inputs into the autonomous decision-making process. They include *Risk Features*, *Traffic Features*, *Weather & Conditions* and *the Navigation States*. For example, the Risk Features account for collision risk, grounding risk and the risk of time delays caused by changing course[22].

1.3 Strengths and weakness analysis

The previous UWA projects made significant headway towards the goal of creating a functional SPAB that could conduct large ocean crossings[1, 2]. The recent overhaul of the design provides a competent platform that is more in line with commercial ASVs', Constans' design significantly increased the functionality and capabilities of the ASV and progressed the project to a stage and standard in line with recent research [6].

The original goal of circumnavigating Rottnest Island was an exciting challenge; however, it was not achieved due to practical and time constraints. It is of the opinion of the author that the Rottnest Island goal should be sidelined in favour of more practical/achievable researched-based goals such as reliable data collection and surveying of protected areas. All projects besides Borella [2] were characterised by a lack of significant testing to prove the capabilities of the SPAB and the reliability of the supporting software and hardware.

The current research into collision avoidance systems is fascinating as it is now solving the issue of integration of ASV with other vehicles and will soon allow for the rapid commercialisation and rollout of ASVs in this space. Integrating an AIS transmitter into an ASV designed for research purposes would make the ASV visible to all commercial craft and personal watercraft, instantly reducing the risk of collision. On a higher level, the ASI data could be integrated into a COLREG-Compliant navigation system to eliminate the risk.

The only disadvantages of ASV systems are their ability to process and store data onboard the platform and the associated power constraints of running an onboard computer or other devices under navigation [15, 31]. These disadvantages are being solved by developing custom data processing tools that enable real-time processing, transmitting and visualisation of the collected data [18, 20][17, 31].

The data collection research shows how powerful an ASV platform can be with the opportunity to be customised to specific research needs [32]; it proves the common conception that ASVs will likely take over as the preferred research vessel due to their reduced operating costs. This research highlights the importance of the UWA ASV project in terms of the broader academic context. It shows how an ASV could be used across multiple faculties to collect data, increasing inter-faculty collaboration, and learning opportunities.

2. SCOPE

2.1 Problem statement

The research and design of autonomous surface craft began as 'hobbyist' style challenges [2] and has developed into a growing commercial space with significant advantages over legacy survey methods [15, 16, 19].

The current ASV has significant potential to embed itself in recent research and provide a platform for novel contributions to this space in the form of data collection via surveying, sampling and integrated data processing and visualization software.

The challenge of this project is to solve the issues preventing the ASV from being used as a competent, autonomous research vessel. The problems include ease of deployment, lack of data collection abilities, and documented testing.

2.2 Project Aims

The project aims are based on solving the issues presented in the problem statement above and achieving the overall goal of improving the ASV to the point where it can be used as a reliable and capable autonomous research vessel. The detailed steps to achieve the overall goal consist of the four areas of upgrades/improvement presented below.

Section 1: Improve transportation of the ASV
The ASV must be easily transportable. It is intended to be used at remote locations which may not have convenient access to the water body, such as a boat ramp or jetty. The current ASV was built as a standalone platform and did not have any sporting transport systems such as a trailer.

Section 2: Design-Build & Test' Ground Control Station' hardware
The Ground Station equipment, namely the laptop, the wireless radio and antenna and other devices, needed to be powered by a portable power station that would be easily deployed by two persons.

Section 3: Upgrade Communication Systems
The original communication system had been verified. However, as presented in Section 1.3, it would be a fantastic addition to improve these capabilities so that the ASV is capable of processing more comprehensive data sources, talking with other equipment and providing significant data collection through live video streaming and or live mapping.

Section 4: Integrate and test Oceanographic sensors
Implementation and documented testing of oceanographic sensors, such as sonar, to collect bathymetric data are necessary for verifying the ASV’s capabilities as a research vessel.

3. DESIGN

3.1 Transportation System

3.1.1 Requirements & Constraints

The first issue presented was the transporting of the existing ASV to and from the designated testing site. See Appendix 6.2.1 Test 1: UWA Pool for details. Initially, the ASV had no dedicated transportation system and was being transported on a mobile workbench. After the initial test, it was found that the portable workbench was not suitable for transporting the ASV and a dedicated cart needed to be designed.

The constraints were designing a cart to suit the existing shape and size of the ASV and fit within the sporting asset of a van.

3.1.1.1 Acceptance Criteria

- Easily deployed and transported.

- Suitable for remote outdoor environments.

- Integrate into existing transport assets such (van).

- Deployable by one-two persons max.

- Low Cost.

3.1.2 Approach

It was identified that a readily available 'off the shelf' garden-style cart would meet all the above requirements and would fit all acceptance criteria presented above. This would be significantly cheaper than manufacturing a cart and would reduce the overall cost of the project. The cart could then be modified to suit the van and the ASV. The cart purchased was a Gorilla Cart 170L Steel Mesh Cart and is available at bunnings costing $200[1].

Figure 4: Carrier cart- as purchased.

The initial CAD design for the cart involved keeping the base of the garden cart and adding a complete superstructure in which the ASV would rest in line with the garden cart, providing elevation and protection for the propellers, it is shown in Figure 5.

[1] Gorilla-carts-170l-steel-mesh-cart

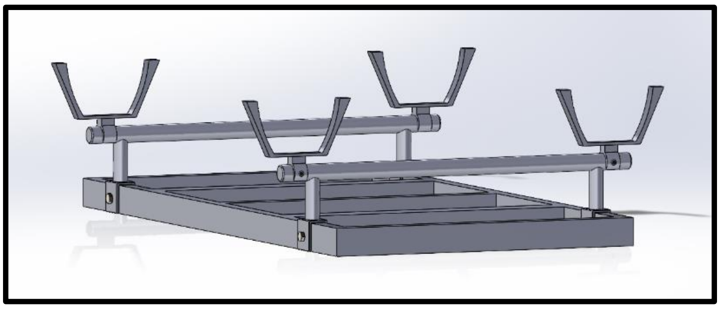


Figure 5: Initial design for carrier cart.

After purchasing the cart and measuring the height and clearance of the ASV, it was decided to machine four saddles and bolt these to the side of the cart. The saddles would allow the ASV to rest horizontally and would fit within the measured profile of the back of the van.

To solve deployment issues, it was decided to design a ramp for the back of the van, which would mean that the ASV wouldn't need to be removed from the cart when loading and unloading, saving time during transport.

3.1.3 Final Design

Using a CAD Model from the original hull design, the saddles were modelled in 3D to allow for an 'interference style' fit to ensure the boat would not move when traversing offroad conditions. The profile was cut using the flatbed 3-AXIS CNC machine out of 25mm Acetal, which was then bolted straight to the side of the cart. Figure 6: 2-D Profile of the saddleFigure 6 shows the curved inner of the face of the saddle that matches the hull profile of the ASV.

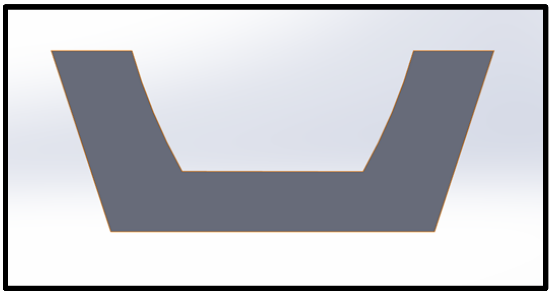


Figure 6: 2-D Profile of the saddle.

Figure 7: Saddle connection to cart & fit with ASV.

Once installed on the cart, foam tape was added for cushioning and improved friction preventing the ASV from moving once on the cart, see Figure 7. The fit between the cart and the ASV was strong enough to negate the use of additional strapping once positioned. The advantages of this design over the initial design, are a reduced centre of gravity and increased resting footprint in which the ASV's weight is more evenly distributed.

The ramp was built using two aluminium PFC channels 150X5mm. The aluminium channels were selected based on the width of the wheels and are strong, lightweight and rustproof. The connection between the ramp and the back of the van needed to be adjustable and removable, and so it was decided to use hinges. To seamlessly instal the hinges on the van, a 3D resin printed part was created which matched the profile of the hinge and would allow the tires to roll over the assembly without puncture, see Figure 8.

Figure 8: Proposed ramp design & 3D printed hinge.

Due to issues with the 3D printer a second hinge was not printed and so the ramp was never fully installed on to the back of the van.

3.2 Ground Control Station – Powerpack

3.2.1 Requirements & Constraints

Despite appearances, the ASV is not a 'stand-alone' asset and needs a supporting ground control station (GCS) to navigate autonomously. Initially, the current GCS for the ASV consisted of a computer running *QGroundControl* software, the *FrSky* RC remote, the *RDF900+* radio emitter and the *RTK GPS*[6]. To conduct long-range tests, these devices need to be powered from a mobile power source that is readily deployable and suitable for outdoor environments. During the third test, (See Appendix 7.5.3 Test 3 Lake Cooge), the GCS was powered using a battery resting on the ground with loose and disorganised wires exposed to the elements. This approach was deemed unprofessional and unsafe it, therefore, had to be rectified through the design of a powerpack before further testing could be undertaken.

To address this issue, a ground control station power pack was designed and built to support the powering of these devices and the implementation of other devices if necessary.

As will be discussed, the casing, battery and inverter were donated to the project and integrating these, and other electrical components were the primary constraint of the design.

3.2.1.1 Acceptance Criteria

- Ability to charge and power multiple devices for long periods.

- Ability to be deployed remotely.

- Ability to be recharged from a renewable source (solar power).

- Ability to operate safely.

- Ability to handle adverse weather conditions and transport conditions.

- Present professionally.

3.2.2 Approach

The GCS power pack was designed around the donation of three major components that is the battery, the inverter, and the casing (a recycled musical instrument transport case). The casing was a crucial component in the power pack as it would provide a robust, weatherproof casing that would protect all the internal electronics. It was envisioned that the GCS power pack would also double as a laptop stand to allow for access to charging ports and create a mobile desk when operating.

The donation of the shell, battery, and inverter reduced the cost of production significantly. However, they imposed a significant constraint in terms of fitting and securing all electrical components within the casing.

By chance, the battery and the inverter managed to fit inside the casing, and so the challenge was the design and build of a Front Plate, Back Plate, Internal Plate and Top Plate that would secure all electronics and enclose the power pack. An image of the donated components and starting point of the design is presented in Figure 9 below.

Figure 9: Donated Components: Casing, Battery & Inverter

The Front Plate and the Back Plate were machined from 13mm thick acetal. The first step was to model each electrical component in 3D and then use this general arrangement model to ensure that all parts had enough clearance for internal wiring. The 3D model also allowed for visualisation of the order of operation of each component, and it was chosen that they would be arranged in sequence from right to left. The general arrangement model for the Front Plate is shown in Figure 10 below.

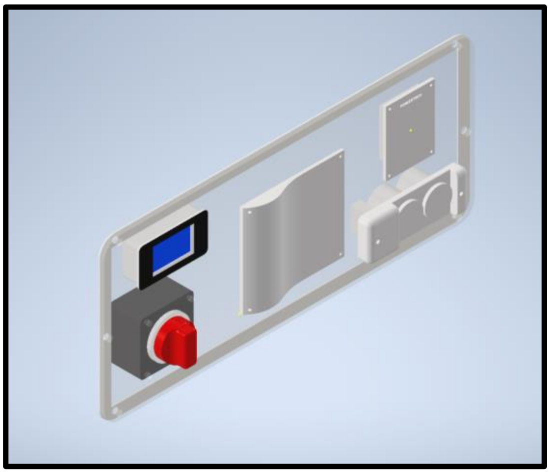


Figure 10: General Arrangement of the Front Plate and associated electrical components.

Once the arrangement was confirmed, each component was projected onto the part to create perfect 'cut-outs' with a +0.5 mm allowance to ensure ease of instalment. Figure 11 shows the final model of the Front Plate.

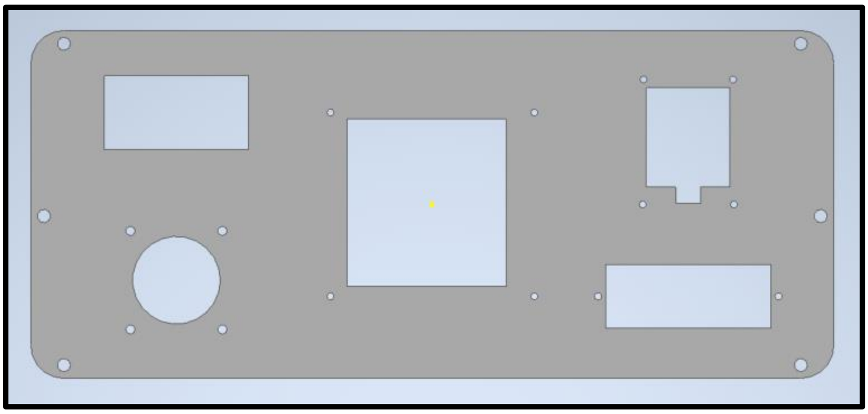


Figure 11: Final CAD model of the Front Plate.

Using this model, a 2D 'iges'. file was created of the face of the plate and then imported into the CNC machining software *HEEKS CAD*. From the 2D export, each sketch pattern, i.e. the outer profile, holes and component cutout, was broken down into individual components to derive machining operation. The software allows for settings of each of the machining operations to be inputted and then creates a final profile operation which is exported as a G-Gode file. See Figure 12 below for an example of the tooling path created and saved as G-Code for the Front Plate.

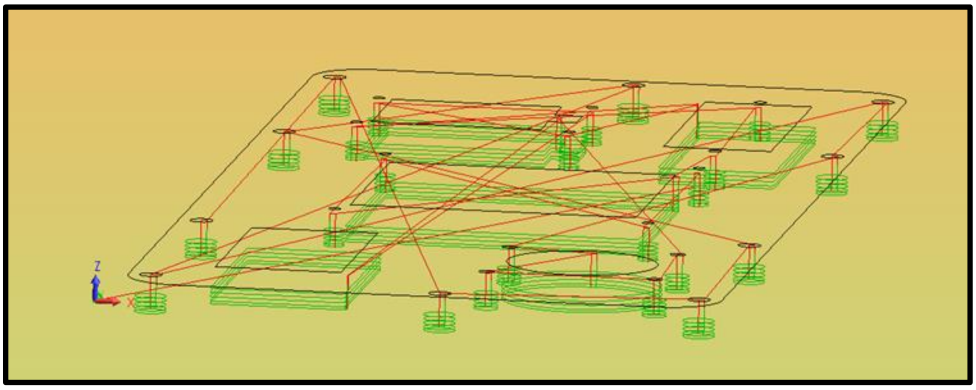


Figure 12: Tool path generation ready for machining.

Once the tool path was created, the raw material was secured to the CNC flatbed to ensure no movement would occur during operation. Once connected, a process is known as 'proving out' the part was undertaken. It is a dry run with no milling tooling fixed to ensure there were no bugs in the programme and that there would be no collisions with the end mill and the bed of the machine. See Figure 13 below for an example of the set-up and milling operations of the 3-Axis machine.

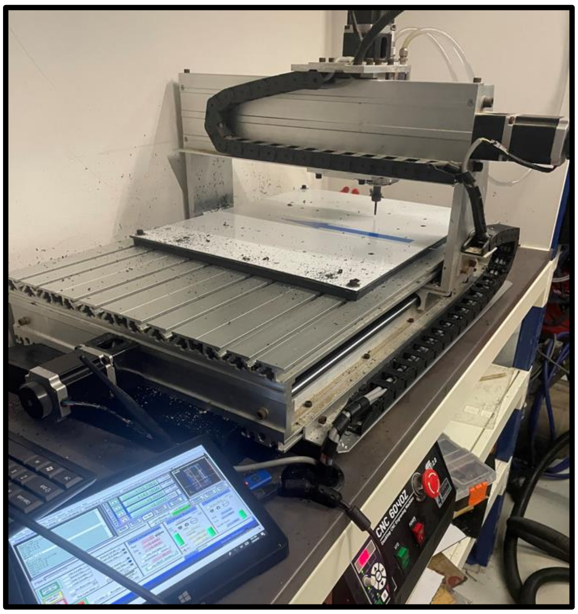


Figure 13: Operational set-up during CNC machining.

Once the machining was completed, the plate was secured to the casing and the components to the plate using various stainless-steel fasteners. The same design process was repeated for the Back Plate, Top Plate, and additional Internal plate to secure the inverter.

The battery weighs around 15kg and, due to size constraints, had to be placed upright inside the shell to secure the battery to the shell 5mm thick Steel Flat Bar was bent to form a secure bracket that was bolted to the underside of the shell with external steel brackets to provide support for the bolts. The bracket was then painted for corrosion protection. See Figure 14 below, showing the battery mounting brackets.

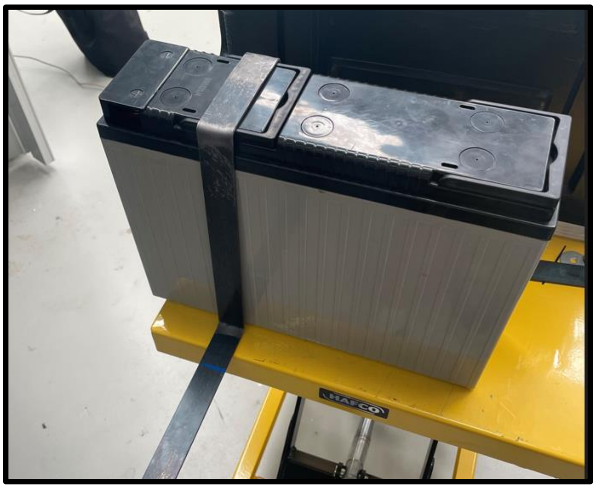


Figure 14: Battery mounting brackets.

3.2.3 Final Design

The final design of the GCS power pack is presented in detail in Figures 15 – 17 below. Refer to Table 1: Power Pack condensed electrical components for more information about each electrical component and its naming sequence.

The Front Plate (Figure 17) of the power pack is designed for start-up and operation. It contains all switches relating to the controls of the power pack, and notable features include the battery monitor, which can display current, voltage, power, and battery capacity. Other features are the switchboard which can reduce the load on the battery by isolating components such as the fan, and the inverter control, which can isolate the inverter and reduce load when using only 12V devices. The thicker 25MM material for the Top Plate provides a robust workstation/desk and can support a large laptop and mouse, see Figure 15.

Figure 15: GCS power pack.

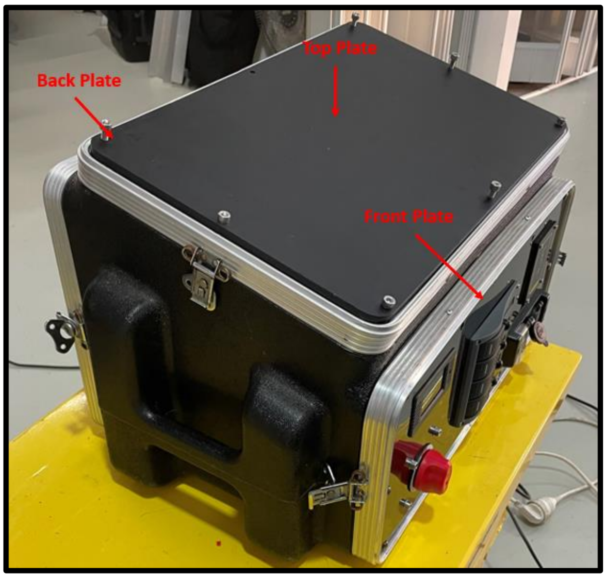


Figure 16: Isometric view of the power pack.

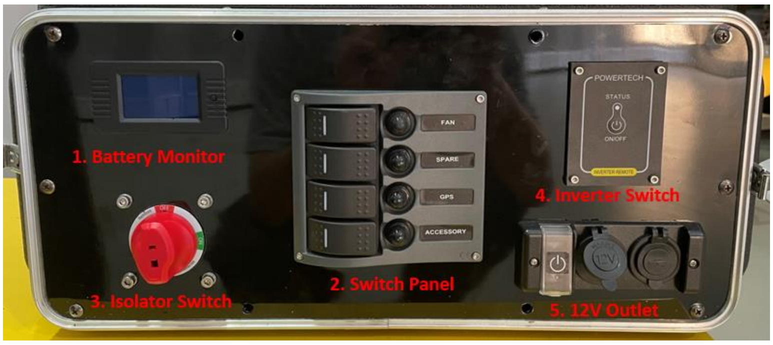


Figure 17: Detailed view of the Front Plate.

The back of the power pack (Figure 18) was designed for reduced accessibility and intended to function as the inlet/outlet powering connections. It contains a 4-Port 240v outlet capable of powering multiple ground station support devices such as a laptop. The 12V Outlet can power devices such as the wireless radio and the *Ubiquiti airMAX Bullet M5 See Communication Systems*. Other features include the circuit breaker, which adds a layer of safety protection to the device.

Figure 18 Detailed view of the Back Plate.

A Graphical wiring diagram is presented in Figure 20. The key features of this design are the internal shunt which sits in line with the negative terminal and provides battery monitoring information to the device, Figure 20. There is also an in-line fuse to provide protection to other electrical components in the event of a short.

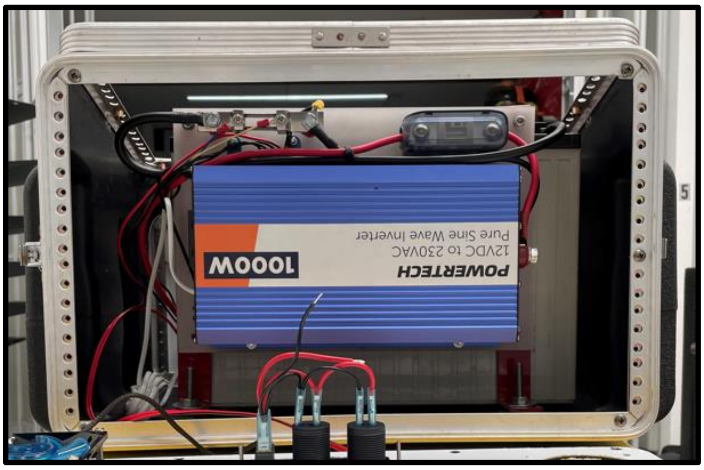
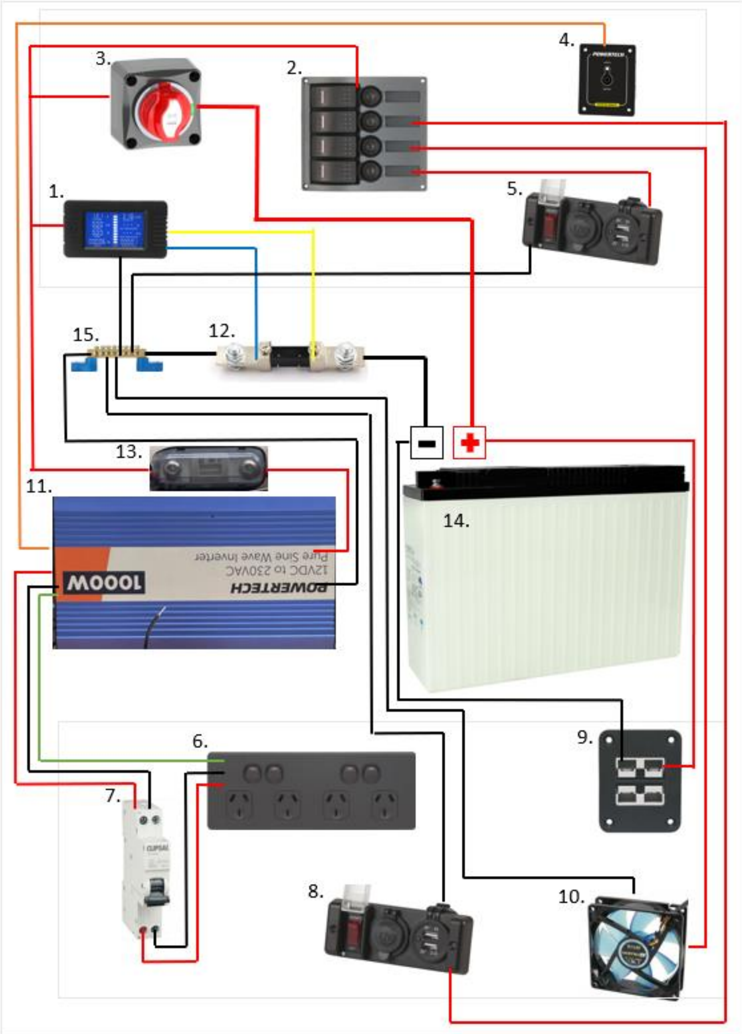


Figure 19: Internal components of the GCS power pack.



1. Battery Monitor
2. Switch panel
3. Isolator Switch
4. Inverter Switch
5. 12 Outlet
6. 240V outlet

7. Circuit Breaker
8. 12V Outlet
9. Charging Inlet
10. Cooling Fan

11. DC/AC Inverter
12. BM Shunt
13. Fuse
14. Power Supply
15. Bus Bar

Figure 20: Power pack - graphical wiring diagram.

Table 1: Power pack - electrical components list.

Location	No.	Description	Component Name
Front Plate	1	**Battery Monitor**	200A 6.5-200V DC Power Battery Meter
Front Plate	2	**Switch Panel**	4 Way IP66 Marine Switch Panel
Front Plate	3	**Isloator Switch**	2-Position 275A Battery Isloator Switch with AFD
Front Plate	4	**Inverter Switch**	Remote Control kit for Modified Sinewave Inverter
Front Plate	5	**12V Outlet**	USB & 12V Cigarette Lighter Power Socket
Back Plate	6	**240V Outlet**	DELTA - S-Line Quad Power Point - 6264B
Back Plate	7	**Circuit Breaker**	GEN3 G600010 Residual Current Circuit Breaker
Back Plate	8	**12V Oulet**	USB & 12V Cigarette Lighter Power Socket
Back Plate	9	**Charging Inlet**	Panel Mount with Anderson 50A Connector
Back Plate	10	**Cooling Fan**	90mm Super Long-Life Low-Noise MagLev Bearing Case Fan
Internal	11	**DC/AC Inverter**	1000W Power Tech 12VDC to 240VAC Pure Sine Wave Inverter
Internal	12	**BM Shunt**	200A 75mV DC Current Divider Shunt Resistor
Internal	13	**Fuse**	ANL In-Line Fuse Holder
Internal	14	**Power Supply**	Fusion CBF12V100H 12V 100Ah AGM Battery
Internal	15	**Bus Bar**	8 Positions Terminal Grounding Strip Bus Bar Block DC250V 110A

3.3 Communication Systems

3.3.1 Requirements & Constraints

As was presented in Section 1.2.2, in particular [18], for an ASV to be deemed as a capable offshore survey platform, it needs to be connected through a reliable communication link capable of transmitting substantial amounts of data over long distances.

In the previous iteration of the ASV project, the addition of the RDF9000+ long-range modem addressed and solved most communication issues [6]. However, it does have limitations in data communication speeds.

In line with the overall goals of this project, it was anticipated the ASV would need an improved communication system to collect and communicate substantial amounts of data for processing and visualisation.

3.3.1.1 Acceptance Criteria

- Ability to transmit large amounts of data wirelessly.

- Long-range.

- Weatherproof

3.3.2 Approach

To improve the communication and data transmitting capabilities of the ASV, the decision was made to purchase and integrate two *Ubiquiti airMAX Bullet M5 GHzTM*[2] (Bullet M5) wireless radios and integrate them into the ASV and the GCS. The Bullet M5 is a high-powered radio suitable for transmitting large amounts of data over long distances fast. It has an airspeed of +100 Mb/s, and the Bullet M5 operates in the 5Ghz band, which further improves data transmitting capabilities compared to the 2.4Ghz band.

When compared to the original RDF900+ Modem, which had an air data speed of 250kbps and a line-of-site range of 40km, the Bullet M5 will increase data transmitting speeds and capability.

Although the 902-928MHz frequency can penetrate objects better than the 5GHz band, it was determined that in current and future missions, the ASV will be within a line-of-site and will be over water with little obstructions between the GCS and the ASV; therefore, data transmitting speeds were favoured over signal projection.

Each bullet M5 was paired with a Laird Technologies 4.9-5-875 GHz Omnidirectional Antenna (S490WB)[3].

[2] Ubiquiti - Bullet M5 data sheet
[3] Antenex-Laird-Technologies-Antennas-Catalog

3.3.2 Final Design

Both the attachment of the Bullet M5 to the GCS was trivial and involved a thorough connection between the antenna and radio and a simple bracket attached to the side of the existing controls box, respectively, see Figure 21: Bullet M5 Radio - Physical connection between GCS and ASV.

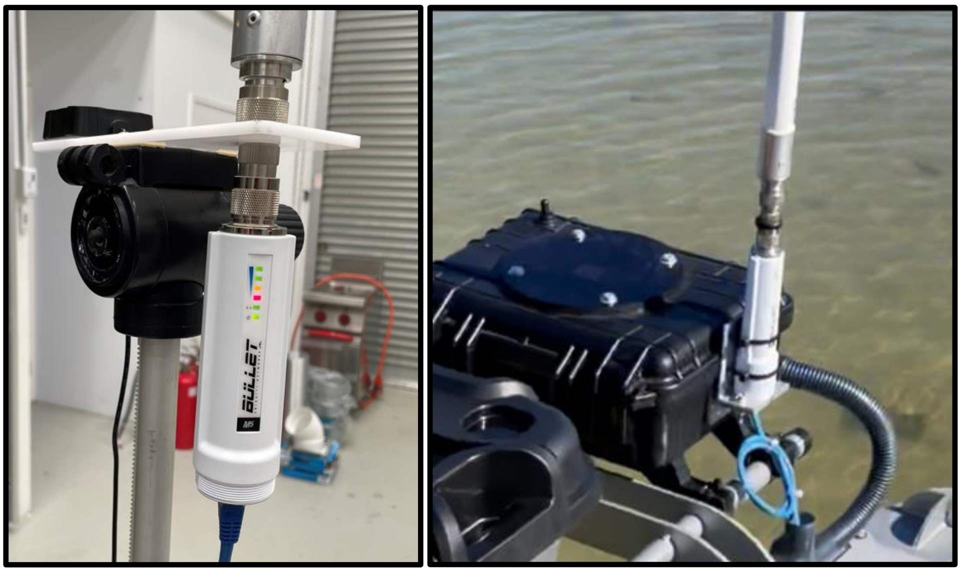


Figure 21: Bullet M5 Radio - Physical connection between GCS and ASV.

Although the physical connection was trivial, establishing a network connection between the CGS and the ASV was not. It presented as a significant issue and caused substantial delays in undertaking field testing see 7.5.2 Test 2: Yangebup Workshop.

Although the exact cause is still unknown, it appeared that the Bullet M5 could not establish a dynamic DNS server between the client and access point. To test a potential solution, a Wi-Fi router was integrated into the GCS, which acted to establish the server and appeared to fix the issue. Both the computer controlling the QGroundControl software and the GCS Bullet M5 were connected via ethernet to the modem, see Figure 21 as opposed to a direct ethernet connection from the Bullet M5 to the GCS computer.

Figure 22: Wi-Fi modem used to rectify communication issues

3.4 Bathymetric Sensors

3.4.1 Requirements & Constraints

Based on research presented in Section 1.2.2, it can be inferred that a valuable and immediate application for the ASV would be to use it to collect bathymetric data in areas not suitable for current manned survey operations. The most basic sensors needed to collect this data and produce a topographical depth map are a sonar, temperature sensor and GPS coordinates. Also presented in Section 1.2.2 was the need to communicate this data via a live link to the GCS for processing and visualisation purposes.

The constraints of such a system would be to integrate it into the existing ASV hardware and software applications, notably not to interfere with the current operational capabilities of the ASV and, worst case, sink the vessel. Another notable design constraint was time due to this section being undertaken late into the project.

Acceptance Criteria

- Capable of collecting meaningful & accurate bathymetric data.
- Integration to ASV hardware.
- Integration to ASV software and operation systems.
- Capable of networking with other sensors and software systems.
- Timely procurement and installation to allow for testing.

3.4.1 Approach

The first choice for integrating bathymetric sensors into the ASV was to identify the network they would operate. It is anticipated that future projects will add additional sensors to the ASV, and ideally, all sensors should be able to transmit data via a live link. For this reason, the NMEA 2000 network was chosen.

The National Marine Electronics Association (NMEA) created the NMEA 2000 network to allow the integration of devices from different manufacturers using a multiple-talker, multiple-listener data network. The network is the standard protocol that allows modern marine electronics to communicate with each other.

The second consideration was to find a transducer to integrate into the ASV. Ideally, a basic depth transducer could have been purchased and integrated into the Pixhawk System or the Raspberry Pi. However, due to time constraints, this option was avoided. Instead, a second-hand depth sounder was purchased as it would remove the need for the creation of additional electric hardware and could be used to collect data in a timely fashion.

3.4.2 Final Design

The final design consisted of the six components outlined in Table 2 there numbering conventions are repeated in Figure 23 and Figure 24.

The Lowrance HDS-7 Gen 1 is an older model compared to the new GEN3. However, it was chosen as it was the cheapest Fishfinder & Chartplotter that had a resolute NMEA 2000 port. Current Fishfinders and Chartplotters with networking capabilities start at around $2000 and can increase well into the tens of thousands which was well outside the budget constraints of the project.

Table 2: Components List - Bathymetric Sensor network.

No.1	Description	Product Name
1	Wi-Fi Router	NMEA 2000 Wi-Fi Router YDNR-02
2	Fishfinder & Chartplotter	Lowrance HDS-7 Gen1
3	NMEA 2000 Backbone	Lowrance NMEA 2000 Cable Starte Kit
4	Transducer	Lowrance HST-WSBL 83/200HDS Transducer
5	Power Supply	12V 1.3Ah Sealed Lead Acid (SLA) Battery
6	Housing	Ezy Storage Bunker Heavy Duty Storage Tub - 20 L

Figure 23: Baythmetic sensor network using the NMEA2000 protocol.

The Wi-Fi Router was integrated into the system to create a data collection network that could transmit live data over the Bullet M5 radios to the GCS computer. Being an older model, the HDS-GEN7 chart plotter did not have internal Wi-Fi capabilities, however, most modern versions do[4].

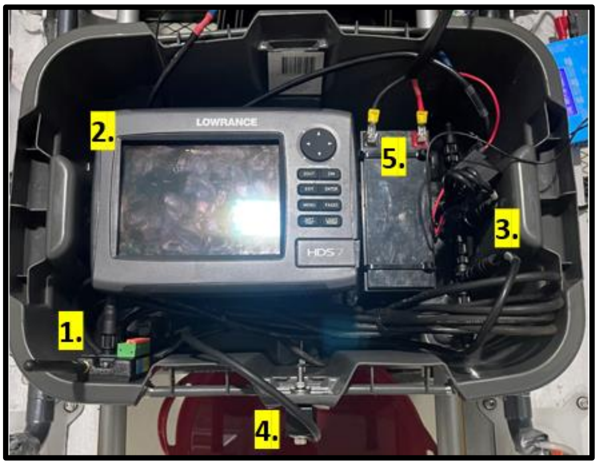


Figure 24: Layout of the bathymetric sensor network inside the casing.

[4] Lowrance - Fishfinders & Chartplotters - HDS7 GEN3

The entire sensor network was encapsulated in a plastic container, see Figure 24 to provide essential protection from the outdoor environment. However, it is not entirely waterproof and will need to be upgraded as a priority for future projects.

Figure 25: Connection of the transducer to the rear of the ASV.

The transducer was placed in between the two hulls of the ASV at a depth of 300mm, see Figure 25, to ensure they would not interfere with the sonar output.

4. RESULTS & DISCUSSION

4.1 Testing Summary

Throughout the project, five tests have been documented, and details for each test are presented in Appendix 6.5 Testing. Tests 3-5 were successful in providing essential data and results, and Test 1 and Test 2 were documented and included in the report to highlight issues faced when attempting testing and the resulting designs produced to solve these problems.

A notable omission from all Tests was the solar panel, previously used to power the ASV. Unfortunately, during Tests 3 and Test 4, the wind was too strong to deploy the solar panel and would have significantly impacted navigation capabilities. During Test 5, the solar panel could have been attached. However, the goal was to collect data and verify automation systems and therefore, it was omitted.

A summary of each test is presented below.

Test 1: Emphasised the need to upgrade the transport systems.

Test 2: Highlighted the importance of stable and reliable communication systems.

Test 3: First testing of the communication system and automation and control system. Emphasised the need for a custom-designed & built powerpack. Highlighted the need for repeated testing to tune the autopilot system.

Test 4: First testing of the Sonar Equipment, learning experience in how to best capture and process the data from the Fishfinder and Transducer. Improvements were made to tuning the autopilot systems.

Test 5: Verification of testing of the Autopilot systems. First capture of meaningful bathymetric data.

4.2 Designed components: Performance against acceptance criteria

4.2.1 Carrier Cart & Ramp

In all 'in-water-tests' (Test 3-5), the cart was successful in fulfilling all the acceptance criteria outlined in Section 2. When transported within the van, it removed the need to lift the boat manually and reduced the chance of damaging the boat during transport. It was able to traverse 'of the road' and was incredibly suited to launching the boat in the lake as it could be submerged into the water like a conventional boat trailer. See Figure 26. After three tests over several months and immersing the cart during each test, there were no visible signs of corrosion.

Figure 26: The carrier cart & ASV fitting within the constraints of the van & the carrier cart submerged during launching of the ASV.

4.2.2 CGS Powerpack

The powerpack was phenomenally successful against the criteria of being robust and mobile. It could be transported in several positions, and all components, including the battery, remained fastened in place see Figure 27. The powerpack was capable of being used for extended periods and, after Tests 4 & Test 5 still had +80% of battery capacity remaining. The connection of the solar blanket during Test 5 also enables near unlimited running time.

The cost of all components of the powerpack was reduced as much as possible and, due to the custom nature of the device, would have been cheaper than buying a complete 'off-the-shelf' component if such one exists.

Figure 27: GCS Powerpack during transport.

4.2.3 Bathymetric Sensor Network

Using the external box, the sensor network was protected from the elements however, unlike the existing control box is in no way waterproof. The battery was suitable for testing and would enable power for up to 3-5 hours. However, there is no existing battery monitoring system. Integrating the power supply of the ASV to power the sensor network is very possible and should be made a priority. Considering the network was not able to connect to the Bullet M5, and transmit data wirelessly it did not meet the required acceptance criteria, however it is still thought possible with further testing.

4.3 Automation and Controls of the ASV

Test 3 provided data as to how poor the ASV autopilot system was performing initially. See image Figure 28 below. Although the conditions were windy see 7.5.3 Test 3 Lake Coogee, the ASV was constantly overcorrecting and was not able to travel in straight lines between the waypoints see Figure 28. Navigation under these parameters was much slower than possible due to the constant corrections and inability to travel in straight lines. Tuning the autopilot system was a priority for Test 4 and Test 5.

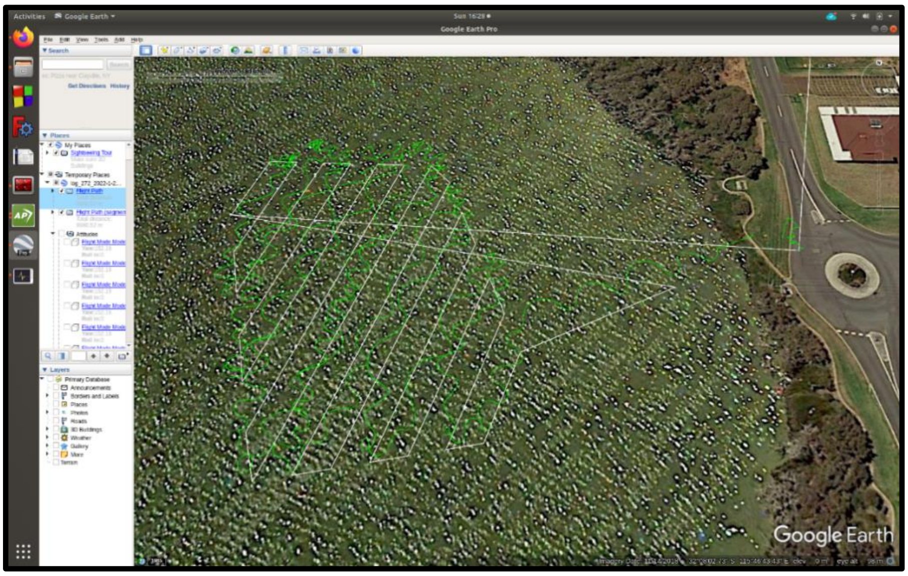


Figure 28: Waypoints and routes from Test 3

During Test 4, the ASV was initially performing like Test 3, with navigation characterised by overcorrection, shown in Figure 29. The ‘survey scan’ style waypoints (which are ideal for bathymetric data collection) were abandoned in preference for a simpler/shorter route to allow for the repeated testing see Figure 30.

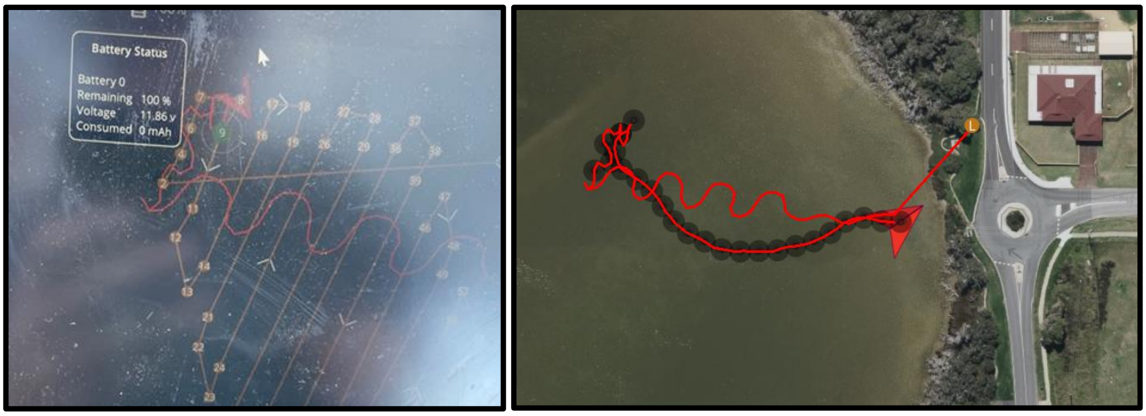


Figure 29 Initial navigation during Test 4.

Figure 30: Updated waypoints during Test 4.

During Test 4, the tuning of the autopilot system was conducted by varying the following parameters L1 The NAVL1_DAMPING ratio was increased from 0.6 to 0.8. and the NAVL1_PERIOD was increased from 20s to 35s. These changes appeared to improve the navigation as shown in Figure 30. However, the ASV was still undergoing a loop at the waypoints to correct the heading before preceding the next way point.

In Test 5 the way points were again updated to the route shown in Figure 31. The WP_RADIUS was increased from 1m to 3m, which solved the previous issue of the ASV undergoing a correction loop at the waypoint. In Route 2 the final parameters were as follows;

- NAVL1_PERIOD: 38s
- NAVL_DAMPING: 0.88
- NAVL1_XTRACK: 0.0015
- WP_RADIUS: 3m

These parameters showed considerable navigation improvement shown in Figure 32. As stated previously and outlined in Appendix 6.6.1, more field testing is needed to fully tune the ASV's autopilot system.

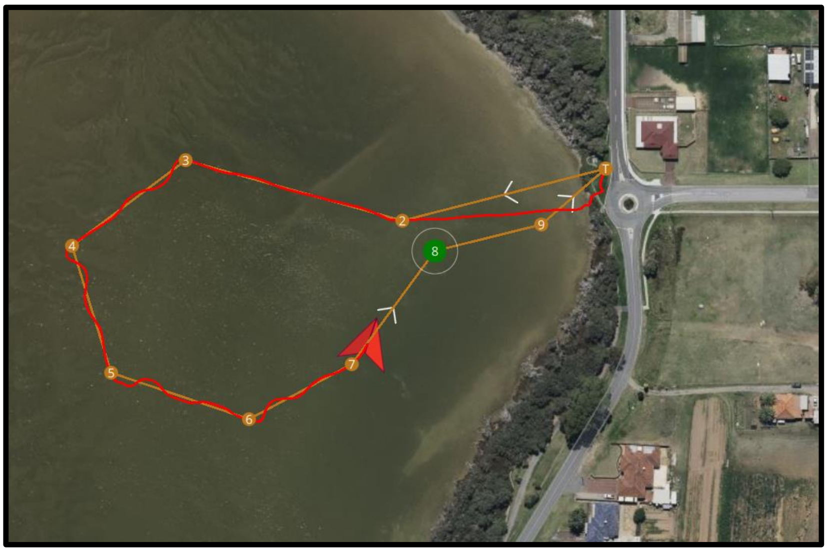


Figure 31: Test 5 waypoints and Route 1.

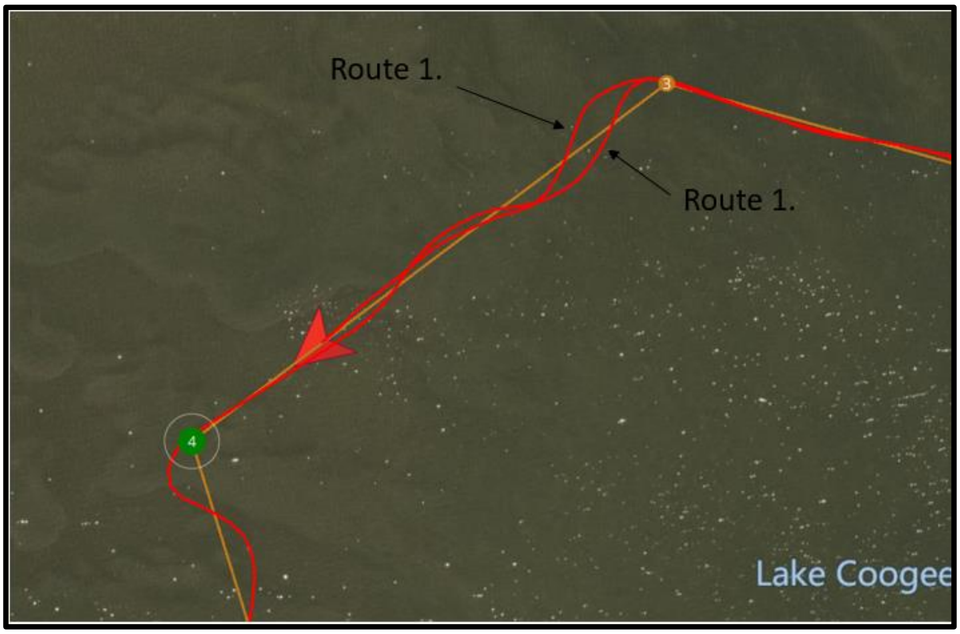


Figure 32: Test 5, Route 1 vs. Route 2.

4.3 Bathymetric Data Collection & Processing

During Test 4, the sonar data collection settings were not enabled correctly, and so no meaningful data was collected, however, it was an important learning and trial experience to prepare for Test 5.

During Test 5, the Fishfinder was able to collect three sets of bathymetric data named LAKE3-01, LAKE3-02 and LAKE3-03. The transducer collects records of the bathymetric data internally and is only able to export the data to a memory card as a '.sL2' file, which is a binary format specific to Lowrance chart plotters. Using an online file conversion software, it was possible to convert the data to CSV and extract data such as Longitude, Latitude, and depth.

Due to the time constraints and original data being in the form of a not readily accessible file, the processing of and visualising of the data collected was made much easier using a dedicated 3D-mapping software available online. The REEFMASTER software supports the input of sL2 files and can overlay the data on an interactive map, a 2-D bathymetric plot and a 3-D bathymetric plot shown in Figure 33.

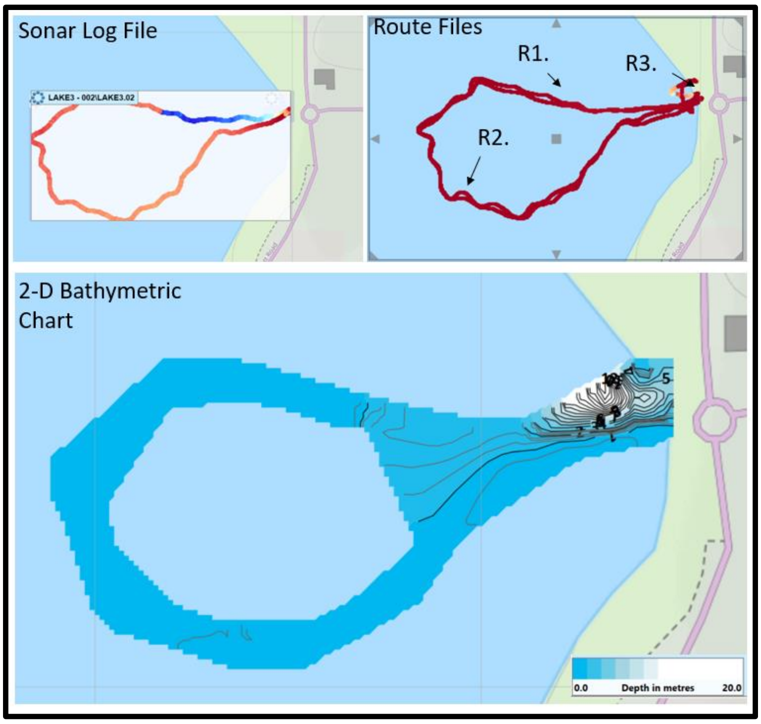


Figure 33: Sonar Logs presented on the REEFMASTER Software.

Figure 33 shows the three Sonar Logs collected during Test 5, overlayed on a 2D map of the testing area, Lake Coogee. From this figure, the routes taken during Test 5 were not suitable for bathetic data collection, and future tests should opt for the survey scan flight plan.

Even with the unsuitable flight plan, it is interesting to note that some meaningful data was collected. The 2-D Bathymetric chart in Figure 33 shows that most of the Lake is less than a meter deep and, therefore, without adjustments and changes to the depth transducer, it will not produce exciting data. The area in the left of the screen appears to show a significant increase in the depth of the Lake and is presented in detail in Figure 34.

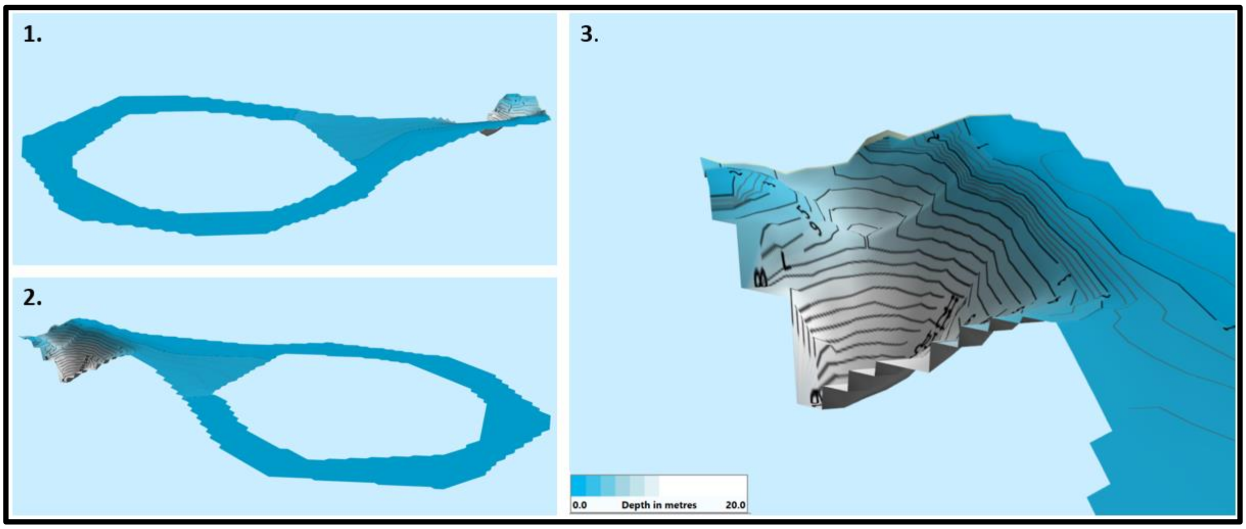


Figure 34: 3-D Depth Plot of Sonar Data from Test 5.

Based on the scale presented in Figure 34, the Lake would appear to approach a depth close to 20m; considering the depth of the rest of the Lake, this is unlikely that these measurements are accurate. However, a recent google image of this area of the Lake presented in Figure 35 does show an apparent increase in the depth of the Lake due to potential runoff caused by rainfall. Considering the significant rain and flooding Perth experienced last winter, it is possible that this erosion has increased, and the data collected is in some form accurate in identifying a significant area of increased depth.

Figure 35: Google Image of interest area of the lake.

Repeated testing and tuning/verification of the bathymetric sensor network would have to be undertaken before the data could be presented as dependable. However, it does confirm the ASV's capabilities in conducting meaningful research operations.

5. CONCLUSION

5.1 Conclusion

The aim of this project was to solve the issues solve issues surround transport and deploy ability of the previous iteration of the project, to achieve the overall goal of improving the ASV to the point where it can be used as a reliable and capable autonomous research vessel.

The design and build sections of the project were successful in meeting their required acceptance criteria and did dramatically increase the overall capability and usability of the ASV. The carrier cart and ramp improved the deployment and transport of the cart and enabled timely testing. The GCS Powerpack was essential in providing an organised and safe method for powering the supporting GCS infrastructure. The only downside to designing and building the Powerpack was the significant amount of time spent on the process, reducing the time spent on data collection, however, it was deemed essential for safe and organised deployment and testing of the ASV and, therefore a worthy contribution.

Although somewhat rudimentary, the integration of the depth sensors and collection of bathymetric data presents a cost-effective, user-friendly solution to data collection and paves the way for further research/upgrades to be made in this area.

The field-testing regime could have been improved in terms of producing well planned, repeated tests with formal experimental documentation and results. However, as presented, it can still be considered valuable as a ‘proof of concept’ and was successful in confirming the capabilities of the ASV as an autonomous data collection vessel.

Due to the presented design and build improvements and testing to verify their success, the ASV project is now at a fascinating stage. Refer to the below topics of further investigation, in particular the specialisation specific projects, to see just how many applications the ASV could have.

5.2 Further Investigation topics

Networking all Bathymetric Sensors:

Using the existing hardware as is, the immediate upgrade would be to link the Wi-Fi Modem to the Bullet M5 radio, and to explore the other functionality of the modem such as the live gauges. These outputs could also be integrated into the QGroundControl software, presenting a live data feed, and fully utilising the capabilities of the Bullet M5 radio. A more compressive approach would be to re-build a custom single web page server capable of live streaming the NEMA 2000 data.

Testing Regime

From the results presented, the ASV is now at an exciting stage in which it can be comprehensively tested. An entire project could be dedicated to the creation, documentation, and testing of both the autonomous capabilities of the and its ability to collect bathymetric data.

In the current state, the ASV project is very suitable for a team of engineering students to conduct work. Potential projects that could be undertaken simultaneously include and are not limited to;

Electrical Engineering:

Upgrade and thoroughly test the current battery and battery monitoring systems on the ASV. Integrate and test sensor arrays into the power production/consumption of the ASV's battery and solar panel. Test an upgrade solar charging capabilities and complete documentation of all electrical and power systems.

Mechanical Engineering:

Review the operation hardware and seaworthiness of the current ASV, design and implement changes to the catamaran hull structure, including the addition of keels more streamlined hull profile and test its effect on autonomous navigation.

Mechatronics Engineering:

Complete tuning, testing, and documentation of the autopilot controls. Upgrade, implement and test the operation of different thruster configurations, such as bow thrusters, to perform complex navigation techniques such as station keeping and docking manoeuvres.

Environmental Engineering & UWA Oceans Institute:

Use the ASV and GCS to design and perform detailed environmental or oceanographic surveys, work with leading industry partners to use commercial grade sensors such as a side scanner, to conduct commercial bathymetric surveys and critically assess the ASV platform against manned survey operations.

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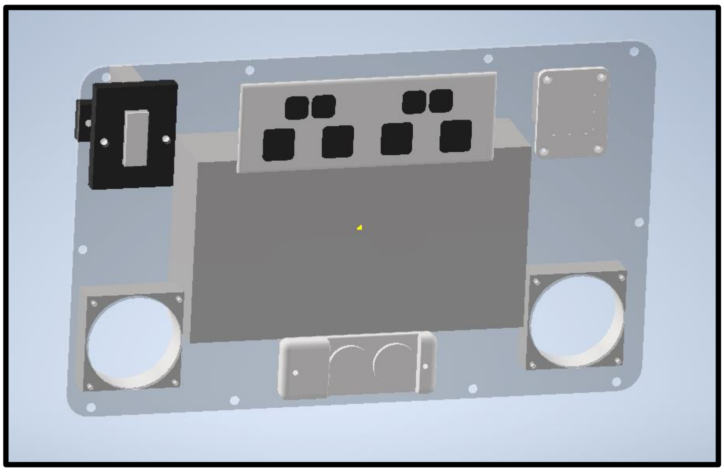
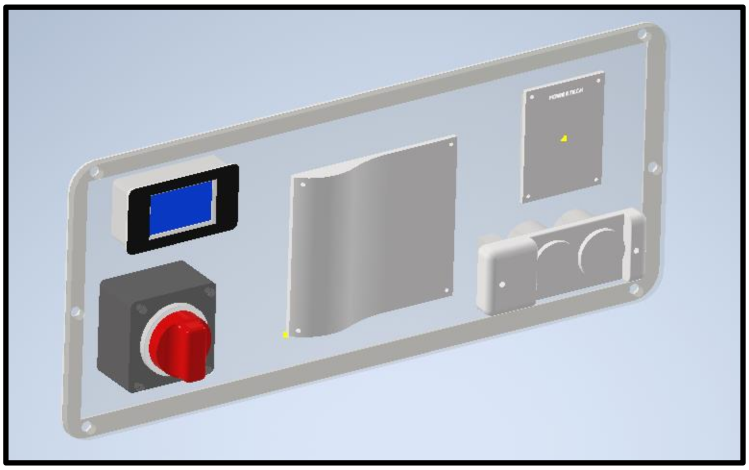
7. APPENDIX

7.1 Ground Control Station – Powerpack

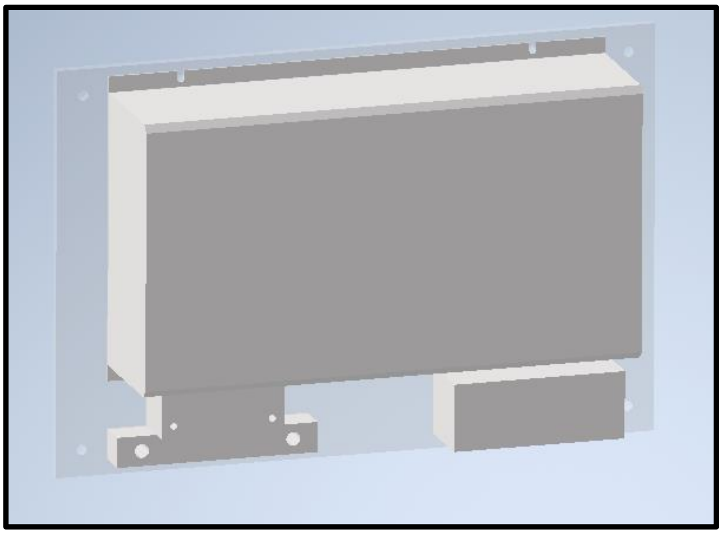
7.1.1 General Arrangement CAD Models



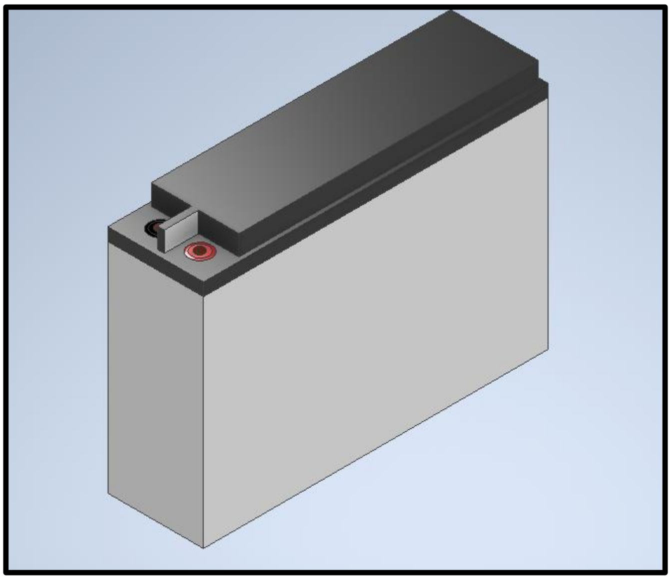
Geneal Arrangement CAD Model – BACK PLATE



General Arrangement CAD Model – FRONT PLATE



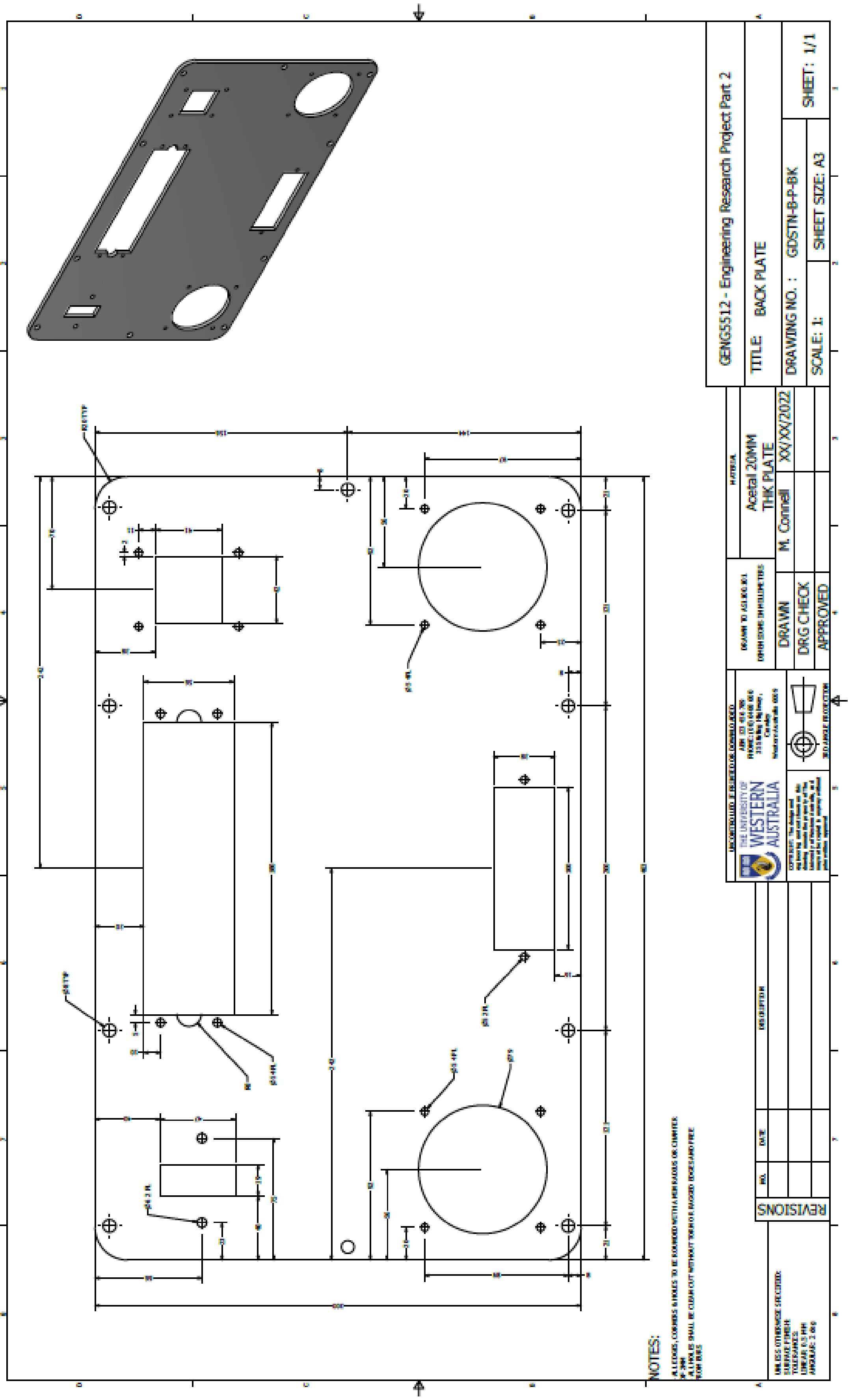
General Arrangement of internal plate



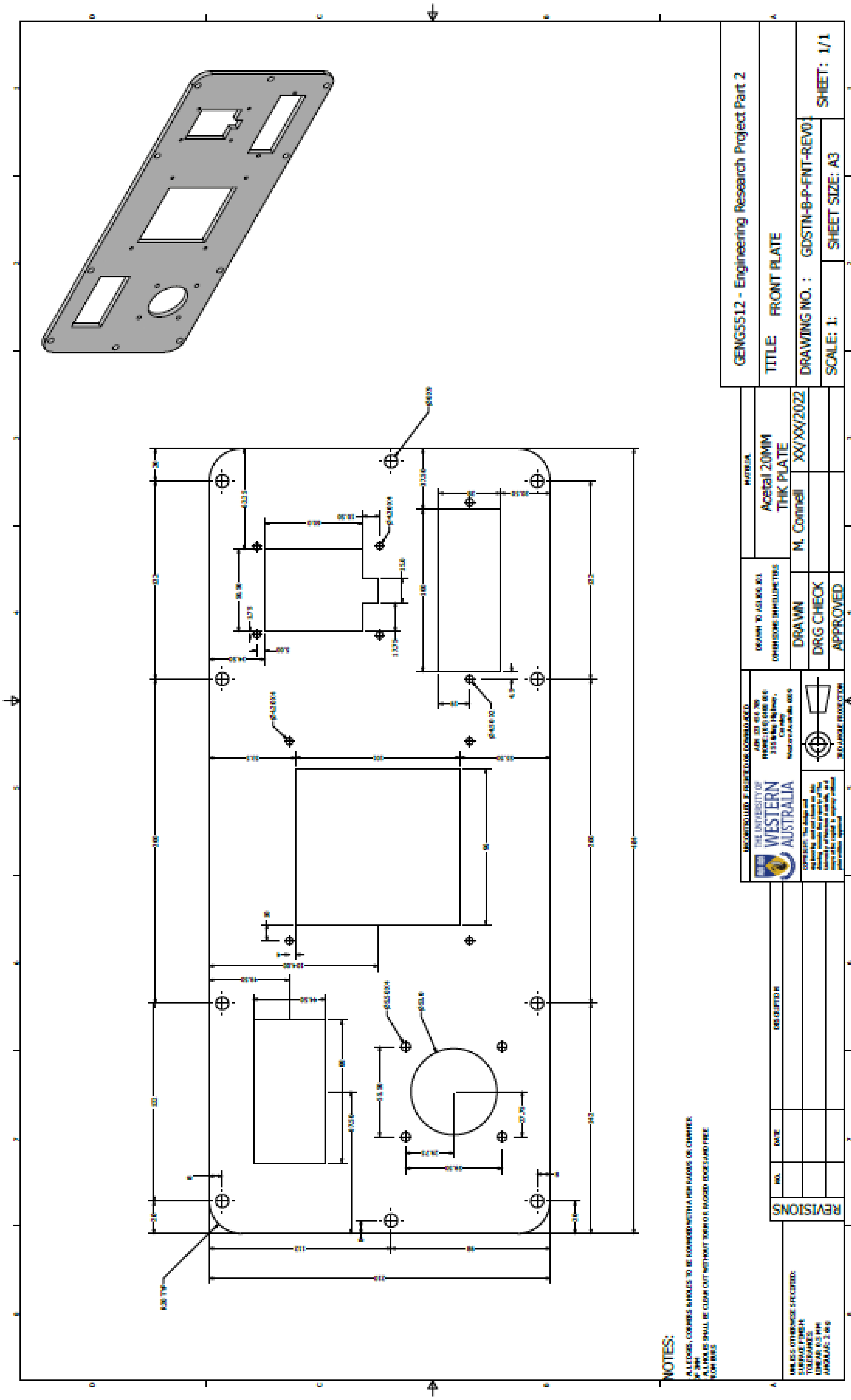
CAD Model Example – BATTERY

7.1.2 Engineering Drawings

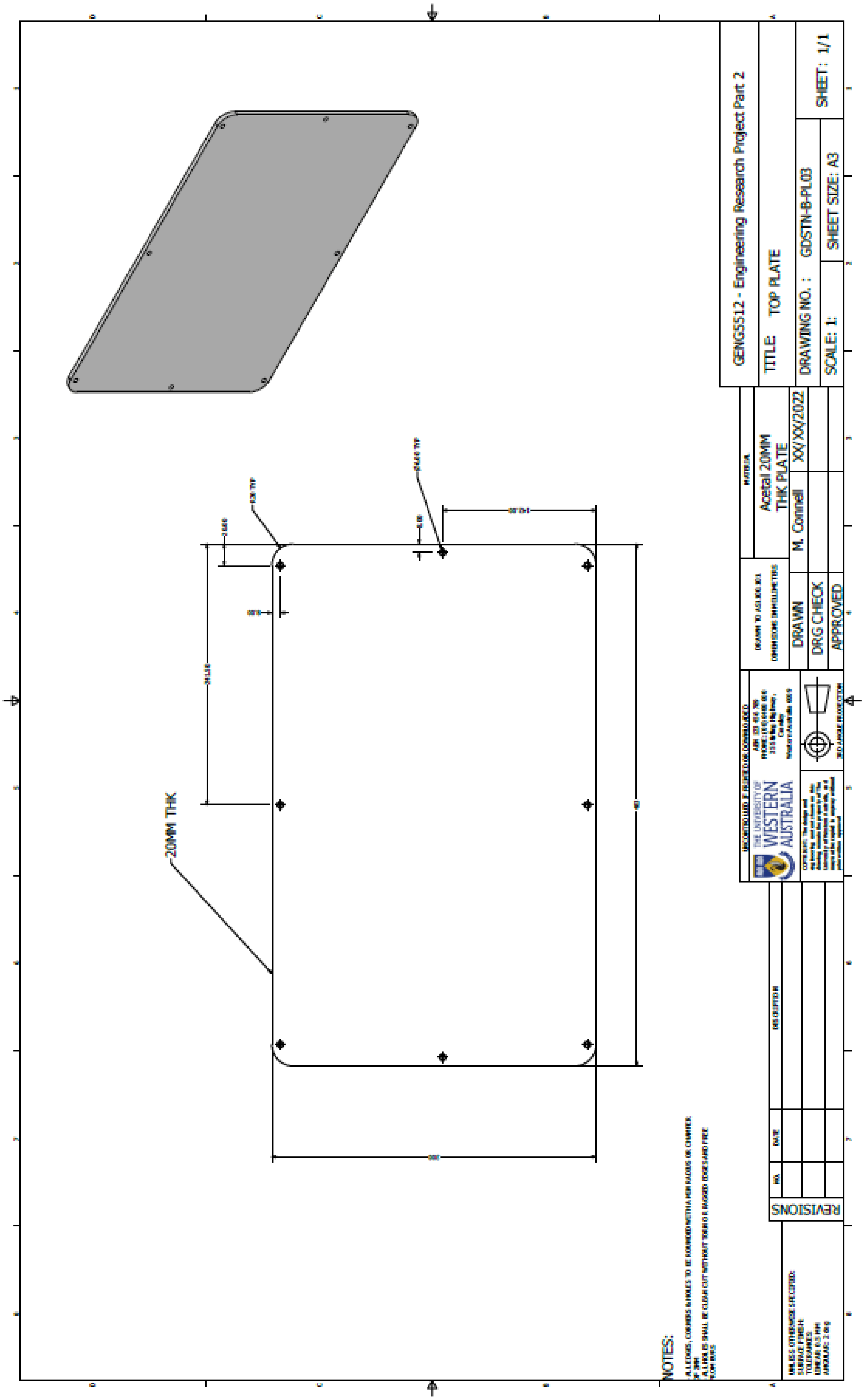
B.1 BACK PLATE- GDSTN-B-P-BK-REV1



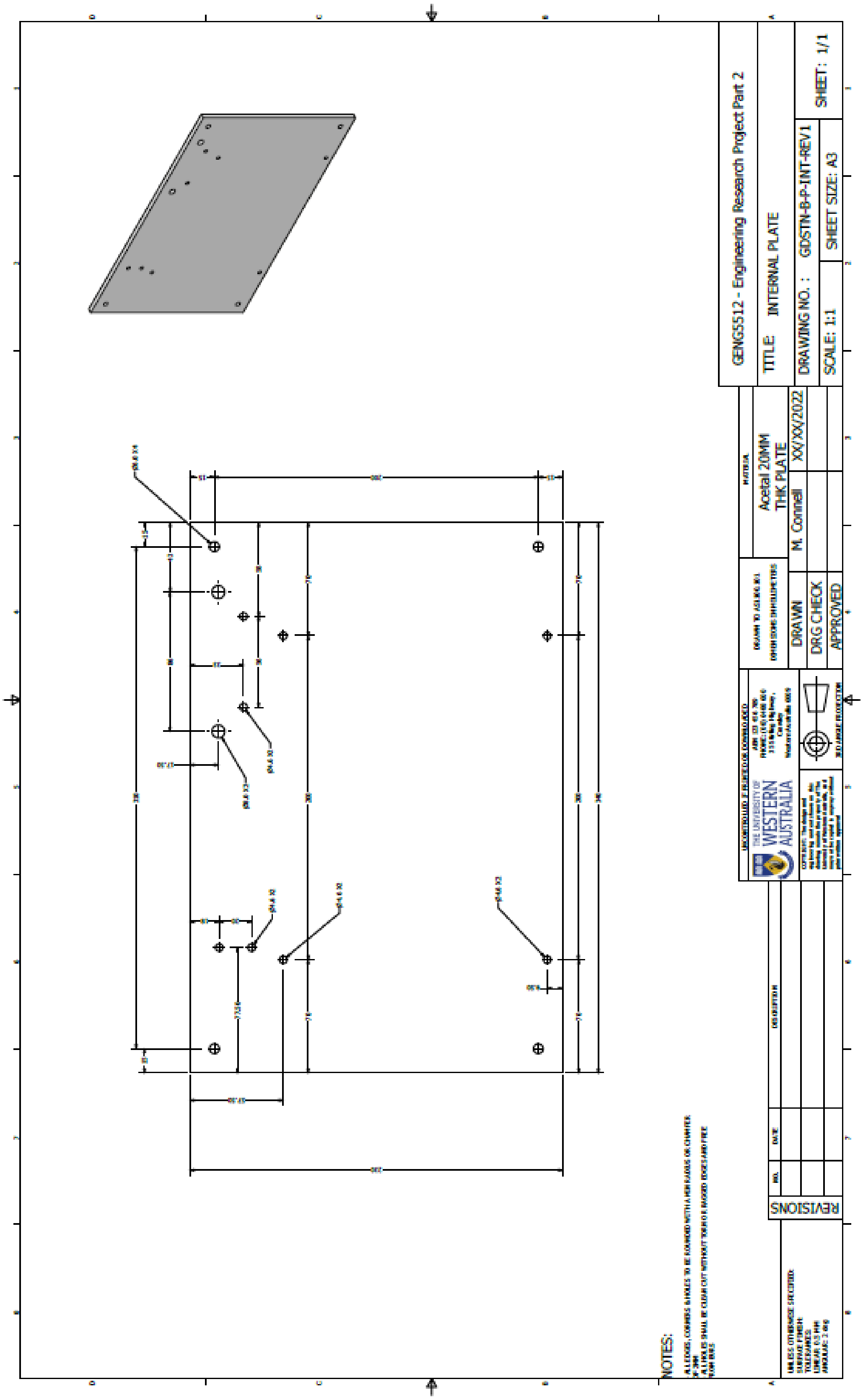
FRONT PLATE: GDSTN-B-P-FNT-REV1



TOP PLATE: GDSTN-B-PL03-REV1



INTERAL PLATE: GDSTN-B-P-INT-REV1



7.5 Testing Notes

7.5.1 Test 1: UWA Pool

Date: 04/10/2021

Location: UWA Pool

Weather Conditions: Wind Easterly 5-10knts

Aims:

Conduct a field test in the UWA pool to demonstrate the ASV autonomous navigation capabilities, for potential research partners.

Issues Faced:

Transport: The transport of the SAPB was conducted using a workshop bench with wheels. This meant that it could only be pushed very slowly and did not traverse well over uneven ground. The trip from the new robotics workshop to the UWA pool too over 25 minutes, (usually a 5-minute walk). The current transport system was clearly not suitable for outdoors or off-road environments.

Communication: The ASV did not activate when placed into the pool their appeared to be issues with the RDF900+ modem, there was basic connection however the motors would not engage to the 'armed' position.

Supporting Hardware: The test was conducted using a laptop which required power, there was no available power available near the UWA pool and so the test was to be conducted with limited battery and was limited by the charge of the laptop.

Results:

No results were taken due the ASV being inoperable. Lessons were learnt regarding the current state of the ASV and the improvement areas to address during the project.

7.5.2 Test 2: Yangebup Workshop

Date: 19/01/2022
Location: Yangebup Workshop – Lake Coogee
Weather Conditions: N/A

Aims:

Conduct an in-water test of the SAPB and verify its autonomous capabilities. Test the recent addition of the Bullet M5 Radio Transmitters.

Issues Faced:

Automation: To connect the new Bullet M5 wireless radios, the Raspberry-Pi card had to be wiped of all previous work. This meant that MAVProxy had to be reinstalled into the Raspberry Pi and a new code created to run the MAVProxy on start up of the Pasberry-Pi, which would ensure connection to the QGroundControl Software when the ASV was booted up. During this test the new code was not created in time to deploy the ASV and further research had to be undertaken to find a suitable solution.

Communication:

Attempts were made an installing and connection the two Bullet M5 wireless radios, however these were unsuccessful. They connect when one ethane cable was plugged into the workshop network however could not connect once plugged into the GCS laptop.

Results:

Due to connection issues between the new Bullet M5 wireless radios, and the need to run MAVproxy on start up to the Raspberry-Pi the ASV did not leave the workshop and therefore no results were achieved.

Photos:

Figure 36: Testing the communication systems and operation of MAVproxy on Start Up of the Raspberry Pi

7.5.3 Test 3 Lake Coogee

Date: 19/01/2022
Location: Lake Coogee
Weather Conditions: South Westerly wind 15-20knts

Aims:

Conduct an in-water test of the ASV and verify its autonomous capabilities. Test the recent addition of the Bullet M5 Radio Transmitters.

Issues Faced:

Hardware:

Poor connection with the Bullet M5 Radio system and its attachment to the ASV. The ground Station Set up was incredibly disorganized and somewhat dangerous. The battery was being used to power laptops with cables crossing over each other which needed to be tidied up.

Communication:

The Bullet M5 Commination system was connecting in the workshop when the receiver was connected to the workshops network, however in the field the system would not connect. Therefore, the ASV could only be pre-programed with mission data and waypoints and then left to conduct a mission unsupervised.

Results:

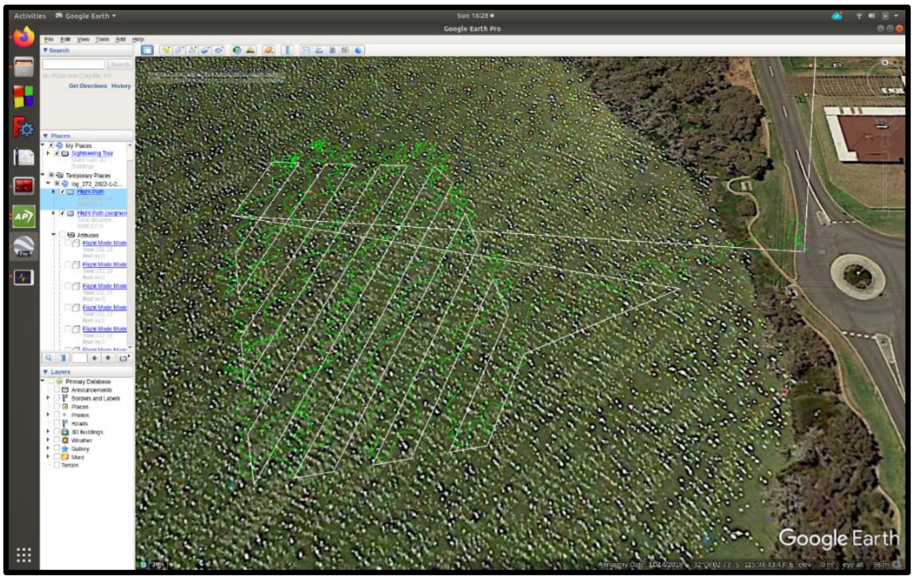
The ASV was deployed using the preprogramed route and successful completed the mission. However upon review of the log files it was shown that the automation and autopilot system need significant tuning.

After processing the telemetry log it was found that the autonomous navigation needed to be tuned to fix the poor navigation and waypoint route presented in **Error! Reference source not found.**.

Photos:

Disorganised/Un-safe Ground Control Station

Successful deployment of the ASV using the Carrier Cart



Waypoints and Navigation during Test 3

7.5.4 Test 4 Lake Coogee

Date: 14/05/2022
Location: Yangebup Workshop – Lake Coogee
Weather Conditions: South Westerly wind 15-20knts

Aims:

Conduct an in-water test of the ASV and verify its autonomous capabilities. Use the GCS to supervise the autonomous navigation and vary control parameters to experiment with tuning of the autopilot system.

Test the recent addition of the bathymetric sensors and the ability to connect via Wi-Fi with the Bullet M5 radios.

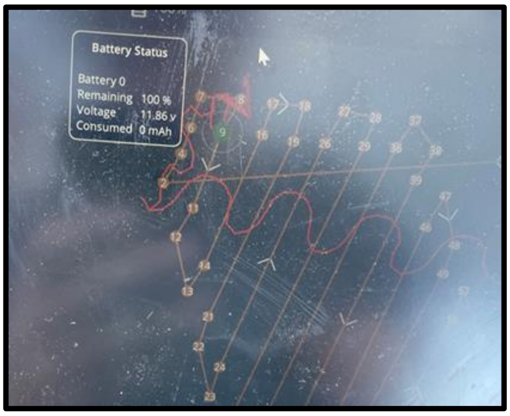
Issues:

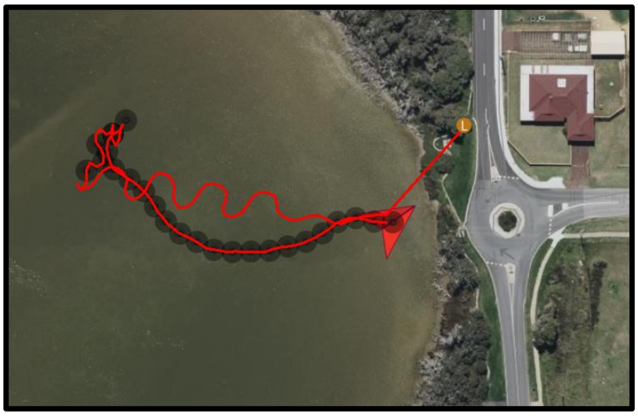
Communication: The bathymetric sensor network was not able to connect with the Bullet M5 radios. When switching between the Wi-Fi client and access mode of the Wi-Fi router connection was lost.

Results:

- The Sonar was successful at collecting bathymetric data.
- The ASV was able to undertake several routes present in the images below.

Route 01: An initial survey scan waypoint route used during Test 3, was initially inputted. However, it was shortly abandoned after it was see that the ASV was continuing to overcorrect when attempting to regain its course creating a similar path during test 3. The ASV was switched to manual mode and returned to the starting position for tuning and an update of the route.





Route 02: The waypoints were updated using the QGroundControl software and a simpler three-point triangle route was created.

The NAVL1_DAMPING ratio was increased from 0.6 → 0.8.

The NAVL1_PERIOD was increased from 20s → 35s.

Increasing both the above parameters appeared to correct overshoot however the ASV was still undertaking a ‘loop’ based route at the waypoint as presented in Figure 42.

Test 4 -Route2 Waypoints and trail

Route 03: The waypoints from Route 2: were maintained.

The NAVL1_DAMPING ratio was increased from 0.8 → 0.85.

The NAVL1_PERIOD was kept constant at 35s.

The overall tacking against the waypoints improved, however the AVV still underwent a loop at the waypoint shown in Figure 43.

Test 4 Route 3: Waypoints and Trail

Additional Photos:

Successful Mobility and deploy ability of the Ground Station & ASV

Ground Station - Powerpack Successfully powering multiple devices

7.5.5 Test 5 Lake Coogee

Date: 21/05/2022
Location: Lake Coogee
Weather Conditions: Easterly wind 0-5Knts.

Aims:

Conduct an in-water test of the SAPB and verify its autonomous capabilities. Test the recent addition of the Bullet M3 Radio Transmitters.

Issues Faced:

Communication:

Like Test 4, the Wi-Fi router could not connect to the Bullet M5 wireless radios, the issue was again finding a connection between the radio as it appeared the Bullet M5 could not create its own Wi-Fi network as an access point.

Results:

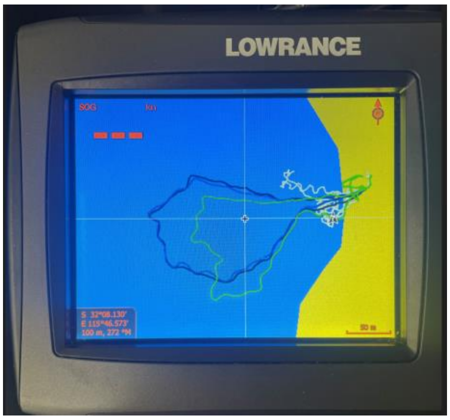
During the test four Routes were successfully navigated by the by the ASV.

During three of the routes Sonar data was collected and recorded into the internal memory of the hard drive.

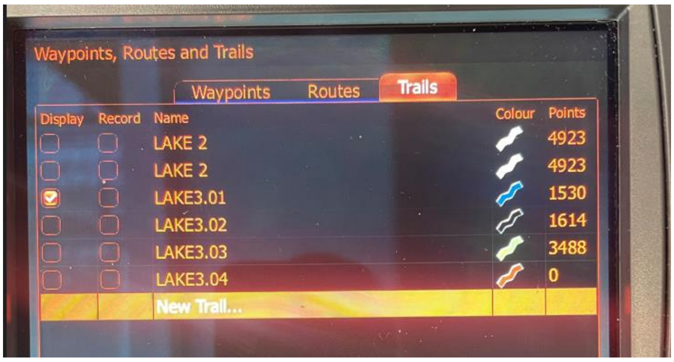
Photos:

Solar Blanket used to charge the GCS - Power Pack

ASV navigating on Lake Googe with perfect weather conditions



Routes 1,2,3,4 Plotted on the Chartplotter



Waypoints, Routes, and Trails stored on the internal memory of the Chartplotter

GCS – Powerpack enclosed during transport

GCS - Powerpack powering multiple devices and charging using the solar blanket

7.6 Additional Information and research

7.6.1 Tuning the Autopilot Navigation

The ASV is currently communicating via the MAVlink protocol and running the AdruRover4.0 stack. During Test 4 and Test 5, the GCS was running the QGroundControl mission planner software.

When running AdruRover4.0, the propulsion of the ASV is configured to the parameters presented in Table 3 below,

Table 3: Propulsion Parameters, Adapted from [6]

Parameter	Value
FRAME_CLASS	Boat
FRAME_TYPE	Undefined
SERVO1_FUNCTION	ThrottleLeft
SERVO1_TRIM	1100
SERVO2_FUNCTION	ThrottleRight
SERVO2_TRIM	1100
SERVO3_FUNCTION	Disabled
ARMING_CHECK	None
MOT_SAFE_DISARM	Disabled
FS_ACTION	Nothing
FS_THR_ENABLE	Disabled
FS_EKF_ACTION	Disabled

Initial set up and configuration of the ASV when using AdruRover4.0 is well document online and presented in[6]specifically for see Firmware[5] and Airframe[6].

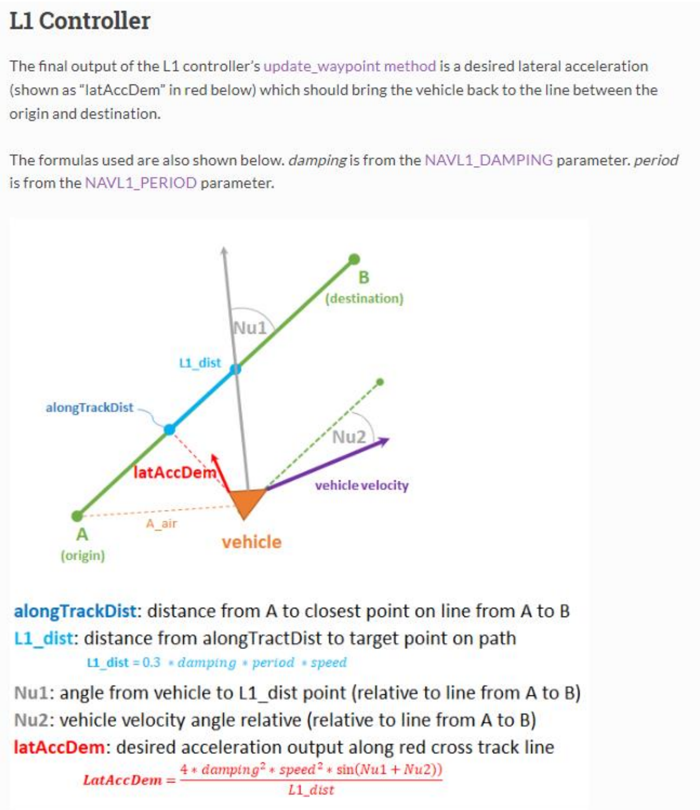
Varying the ArduRover parameters for tuning can be achieved through accessing *Vehicle Steup → Parameters*[7]*.* The setting for the ASV is running a (Slip skid differential drive), known as the Rover Setting.

[5] QGroundControl - Setup Firmware
[6] QGroundcontrol - Setup Airframe
[7] QGroundControl - Parameters

The lower-level *speed* and *turn* rate parameters should be tunned first before attempting higher level tuning. However, when tuning the ASV during Test 4 & 5, these parameters were neglected. (It is assumed that it would have had little impact on the control as unlike a drone or RC car, the ASV has negligible acceleration and operates at very low speeds on water <4knts).

Detailed information and steps on how to tune these parameters for future test is provided on the Adrupilot website; Turn Rate[8] and Speed and Throttle[9].

Higher level Navigation Tuning is based on varying the L1 Controller a summary of the controller parameters is presented below.



Summary of L1 Controller Parameters: Adapted from [33]

Detailed steps for initial tuning of the L1 Controller are again presented on the ArduPilot website. It is anticipated that the steps presented on the AdruPilot website for tuning the L1 Controllers will be less relevant for the ASV due to its low speeds and basic manoeuvring capabilities on water. However, a field test documenting the set-up and results of the process should be considered a priority before the ASV undertakes any further data sampling missions.

[8] Rover-tuning-steering-rate

[9] Rover-tuning-throttle-and-speed

A detailed view of each of the L1 Parameters varied during Test 4 and Test 5 is presented below.

NAVL1_PERIOD: L1 control period

Period in seconds of L1 tracking loop. This parameter is the primary control for agressiveness of turns in auto mode. This needs to be larger for less responsive airframes. The default of 20 is quite conservative, but for most RC aircraft will lead to reasonable flight. For smaller more agile aircraft a value closer to 15 is appropriate, or even as low as 10 for some very agile aircraft. When tuning, change this value in small increments, as a value that is much too small (say 5 or 10 below the right value) can lead to very radical turns, and a risk of stalling.

Increment	Range	Units
1	1 - 60	seconds

NAVL1_DAMPING: L1 control damping ratio

Note: This parameter is for advanced users

Damping ratio for L1 control. Increase this in increments of 0.05 if you are getting overshoot in path tracking. You should not need a value below 0.7 or above 0.85.

Increment	Range
0.05	0.6 - 1.0

NAVL1_XTRACK_I: L1 control crosstrack integrator gain

Note: This parameter is for advanced users

Crosstrack error integrator gain. This gain is applied to the crosstrack error to ensure it converges to zero. Set to zero to disable. Smaller values converge slower, higher values will cause crosstrack error oscillation.

Increment	Range
0.01	0 - 0.1

WP_RADIUS: Waypoint radius

The distance in meters from a waypoint when we consider the waypoint has been reached. This determines when the vehicle will turn toward the next waypoint.

Increment	Range	Units
0.1	0 - 100	meters

Figure 37: Navigation Parameters Varied during Testing Adapted from [33]

7.6.2 Running MAVProxy on Raspberry Pi Start up

STEP1: Download and Install MAVporxy onto the Rasberry Pi see AdruPilot Download and Installation[10] for detailed instructions.

STEP2: Usie root permissions to edit the r.c local file and create a start-up script, details here[11].

STEP3: Copy the below start up script, into the file and reboot, the code and file name used is presented below.

sh /home/pi/startup.sh

/home/pi .local/bin/mavproxy.py –force-connected - - master=/dev/ttyACMO –baudrate=115200

--out=udpbcast:192.168.1.255:1455 - - deamon

[10] Downloading and Installing MAVProxy
[11] Method 1: rc.local