

Low-Cost Sonobuoy for Passive Acoustic Detection and Classification of Marine Vessels

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Introduction

This 420-hour professional experience project proposes the design and evaluation of a low-cost, embedded hydrophone system for passive acoustic detection and classification of marine vessels. The research focuses on instrumentation design, embedded digital signal processing, and acoustic feature-based classification under realistic deployment conditions.

The Australian Maritime Strategy 2035 prioritises the defence of Australia's coastline, with particular emphasis on uncrewed systems supporting anti-submarine warfare (ASW) [1]. Surface and subsurface vessels generate acoustic signatures through propulsion, which can be exploited for detection and classification [2]. In littoral environments, submarines exploit cluttered terrain and mask passive signatures within ambient noise, reducing the effectiveness of active and passive sonar. Passive underwater acoustic monitoring is therefore a well-established technique within deployable Shallow Water Surveillance Systems (SWSS) [3].

Problem Statement

Current areas of development in SWSS include rapid deployment, local real-time processing, and cost-effective manufacture. Existing rapid-deployment sonobuoys, while effective for deep water ASW, are typically high-cost, heavy, and single-use, with limited suitability for littoral surveillance [4]. Deployment often requires crewed aircraft or specialised rotary-wing uncrewed aerial systems, creating logistical and economic barriers to coast-wide coverage [5].

Recent advances in low-cost embedded computing have enabled autonomous acoustic sensing; however, significant challenges remain. These include achieving sufficient signal-to-noise ratios with inexpensive hydrophones, maintaining signal integrity in harsh environments, and executing reliable detection and classification on resource-constrained platforms. While prior studies demonstrate vessel classification using neural networks, K-nearest neighbours, Gaussian, and decision tree techniques [6], there remains limited practical evaluation of trade-offs between instrumentation quality & cost and classification accuracy & power consumption.

Aligned with Defence Innovation, Science and Technology priorities in Trusted Autonomous Systems and Information Warfare [7], this project proposes a Modular Economical Sonobuoy Heuristic (MESH). The system adopts a software-first, hardware-second design philosophy [8]. It emphasises hydrophone instrumentation, embedded digital signal processing (DSP), and autonomous interpretation, targeting deployment via low-cost, commercially available aerial platforms. Budget has been calculated with focus on achieving the objectives with minimal hardware cost.

This research addresses these gaps through controlled laboratory and field experiments assessing detection reliability and vessel discrimination performance in realistic coastal conditions.

Aims

The primary aim of this project is to design, implement, and experimentally evaluate a low-cost, autonomous sonobuoy capable of passively detecting and classifying marine vessels in shallow-water environments. The system seeks to balance instrumentation quality, embedded processing capability, power consumption, and classification performance within the constraints of a deployable and economical platform.

A secondary aim is to assess the feasibility of performing localisation of acoustic signatures through Time of Arrival trilateration algorithms communicated to a base station over LoRa. This would require three units. This secondary aim is an extension to the first and is not essential to be completed. If permitted, the scope can expand allowing for the secondary aim.

Both aims ensure relevance to contribute to future development of scalable and reusable passive acoustic surveillance systems suitable for coastal monitoring applications.

Objectives

To achieve these aims, the project will pursue the following objectives:

- Design and construct a low-cost hydrophone signal acquisition chain, including analogue amplification, filtering, and analogue-to-digital conversion, suitable for shallow-water passive acoustic sensing.
- Characterise the performance of the instrumentation through laboratory testing, including noise floor, frequency response, and dynamic range.
- Develop embedded digital signal processing algorithms for acoustic detection, spectral analysis, and feature extraction on a RPi platform.
- Implement and evaluate multiple acoustic classification techniques, including feature-based statistical and machine-learning approaches, with consideration of computational load and power usage.
- Conduct controlled laboratory experiments to validate detection and classification functionality using representative mechanical sound sources.
- Perform field trials in a realistic coastal environment to assess system performance for small marine vessels, including jet skis and inflatable rescue craft.
- Analyse trade-offs between hardware cost, signal quality, classification accuracy, and energy consumption to inform design decisions.
- Document results, limitations, and engineering insights in accordance with professional engineering standards.

Achieving these aims through the objectives would satisfy the Professional Experience Requirements for an Undergraduate Engineering Degree as stipulated by Engineers Australia.

Scope

This project is scoped as an applied engineering investigation focused on the design and evaluation of a prototype passive acoustic detection and classification system rather than the development of a defence-grade sonobuoy. The work emphasises engineering feasibility, experimental validation, and performance trade-offs under realistic constraints.

The scope includes:

- Design and implementation of a low-cost hydrophone-based acoustic sensing front end.
- Embedded software development for real-time acoustic acquisition, digital signal processing, and feature-based classification.
- Evaluation of multiple classification techniques with respect to accuracy, computational complexity, and power consumption.
- Notification of blacklisted acoustic signatures to a base station through LoRa.
- Laboratory testing to detect acoustic signatures of appliance. Limited field deployment to detect acoustic signatures of jet skis and inflatable rescue boats.
- Analysis of system performance, limitations, and scalability for future development.

The scope excludes:

- Active sonar transmission or acoustic emission.
- Long-term unattended deployments beyond short experimental trials.
- Secure communications, encryption, or Defence-classified systems.
- Detection or classification of submarines or military platforms.
- Large-scale sensor networks or multi-node data fusion.

The project is intentionally constrained to a single-node, passive sensing architecture to ensure depth of engineering analysis within the 420-hour professional experience timeframe, while still delivering outcomes relevant to scalable shallow-water surveillance systems.

Significance

This study is significant as it advances the practical deployment of economical, autonomous underwater acoustic surveillance systems for littoral environments. From an applied perspective, it supports scalable and reusable monitoring solutions relevant to coastal

security, maritime safety, and environmental awareness, reducing reliance on high-cost, single-use sonobuoys. From a theoretical perspective, the research contributes to understanding trade-offs between hydrophone instrumentation quality, embedded processing complexity, power consumption, and classification accuracy within resource-constrained systems. These insights inform the design of future low-cost passive acoustic sensing architectures that balance performance with deployability and endurance.

Proposed Methodology and Research Design

This project employs a systematic engineering design and investigation methodology aligned with Engineers Australia Stage 1 standards [9]. It integrates instrumentation design, embedded signal processing, and experimental validation, informed by a targeted literature review of marine acoustics and passive sensing, to address a real-world shallow-water detection and classification problem.

A hydrophone signal acquisition chain will be designed and implemented, comprising analogue front-end amplification, filtering, and analogue-to-digital conversion. Laboratory bench testing will characterise the system's noise floor, frequency response, and dynamic range to assess the impact of instrumentation choices on signal quality. Embedded DSP processing algorithms will then be implemented on a low-cost single-board computer, specifically a Raspberry Pi (RPi) platform, incorporating time-domain detection, frequency-domain analysis, and acoustic feature extraction. Refer to the Appendix 1 for a proposed software and hardware design. Python software development for the RPi shall occur through VSCode and published on GitHub, Electronic development through KiCad, and Mechanical development through Autodesk Inventor.

Preliminary data collection will be conducted in a controlled laboratory environment using acoustically distinct household appliances, such as stick blenders and kitchen mixers, operated in a pool to emulate different mechanical sound sources. These experiments will enable early evaluation of detection reliability and source discrimination. Subsequent field testing will be undertaken in collaboration with the Nowra Culburra Surf Life Saving Club (NCSLSC), focusing on the classification of small marine craft, including jet skis and inflatable rescue boats, based on their passive acoustic signatures.

System performance will be evaluated using multiple criteria, including detection and classification accuracy, false positive rate, computational load, and power consumption. Iterative refinement of both hardware and software components will be used to identify engineering trade-offs, informing the feasibility of the proposed Modular Economical Sonobuoy Heuristic (MESH) system.

Project Supervision and Oversight

Jonathan Walsh is a DSP student at the University of Wollongong and a member of NCSLSC. This project will be academically supervised by Dr Son Lam Phung, Associate Professor in DSP at the University of Wollongong, whose expertise in signal processing and machine learning supports the acoustic analysis and classification components. Colin Lawrence, President of the NCSLSC and former Head of Navy Engineering, will provide oversight of

field access, safety, and practical field-testing considerations, with no contribution of Defence-specific knowledge. This arrangement ensures academic rigor while maintaining appropriate professional and ethical boundaries.

Proposed Timeframe

Timeline designed with concordance to the Engineers Australia Stage 1 standards. *Estimated Hour log.xlsx* in the Appendix 3 expands on the components.

Phase	Start Date	End Date
Literature Review & Requirements Definition	29/06	6/07
System Architecture & Trade Study	7/07	11/07
Analogue Front-End & Instrumentation Design	13/07	21/07
Embedded Software & DSP Implementation	22/07- 27/07	20/11- 25/11
Controlled Experimental Testing	26/11	2/12
Field Deployment & Operational Testing	3/12	6/12
Analysis, Documentation & Professional Reflection	7/12	14/12

Proposed Budget

The *Estimated Cost, Weight, and Time.xlsx* budget in the Appendix 2 expands on the components. Consequently, \$280 is requested.

TOTAL	Est Cost (AUD)	Est Weight (g)	Est Delivery Time (Days)
System and setup	\$283.48	1128	60
System (excluding Makerspace parts)	\$278.83	-	-

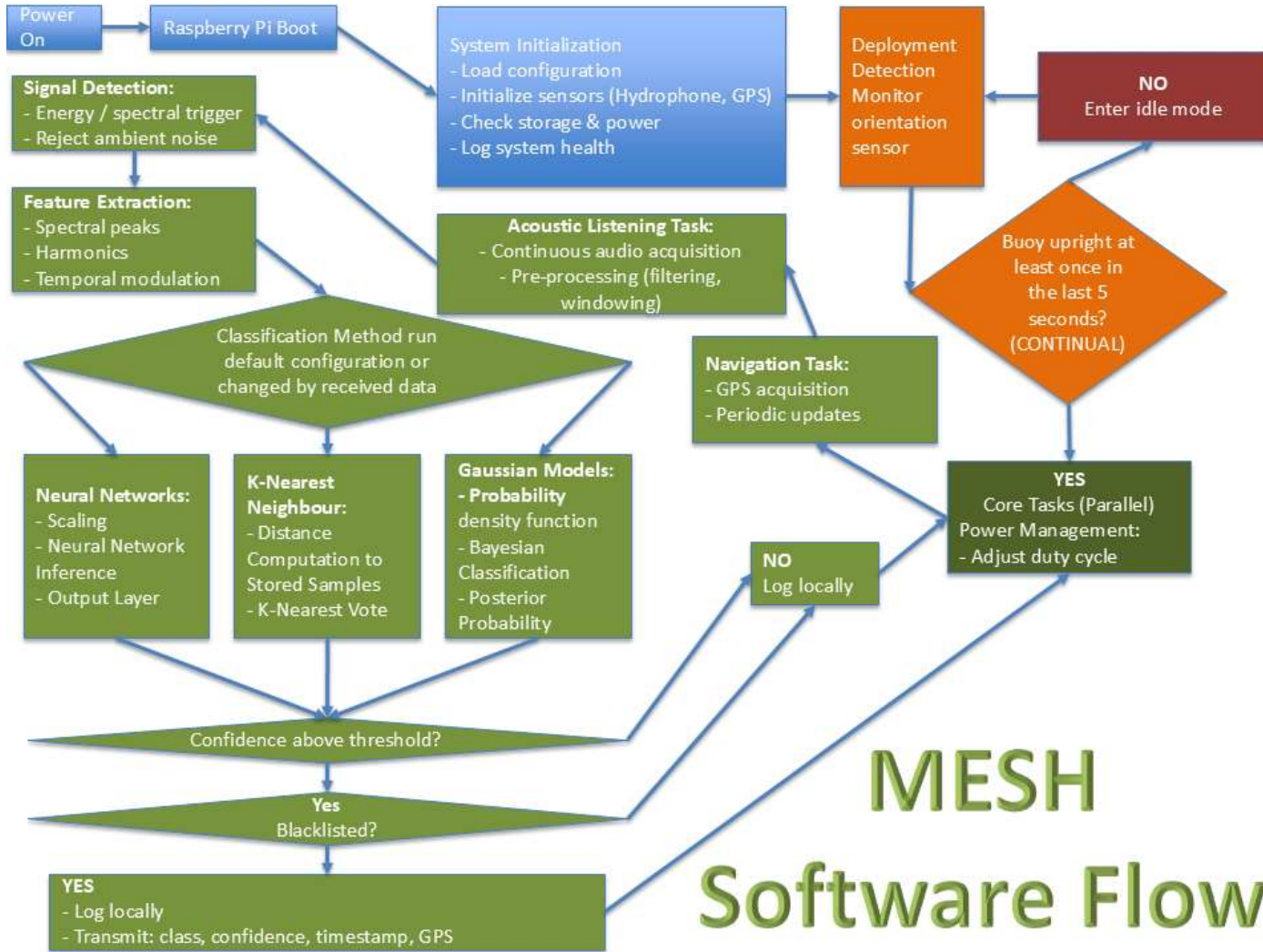
References

- [1] P. Jones and J. Parker, *A Maritime Strategy for Australia: AMS 2035*, University of New South Wales (Canberra), 2025.
- [2] R. J. Urick, *Principles of Underwater Sound*, Third ed., Westport, Connecticut: Peninsula Publishing, 1983.
- [3] EDTAS, “Remote Undersea Surveillance: Insights Paper,” 2022.
- [4] The Navy League, “THE RAN’S 725 SQUADRON SEAHAWK ‘ROMEO’,” *THE NAVY*, vol. 75, no. 3, p. 36, 2013.
- [5] Militär Aktuell, “Schiebel: S-100 dropped sonobuoys at “Repmus”,” 16 October 2024. [Online]. Available: <https://militaeraktuell.at/en/schiebel-s-100-dropped-sonobuoys-at-repmus/>. [Accessed 01 January 2026].
- [6] T. Meir, M. Tsionskiy, A. Sutin and H. Salloum, “Decision Learning Algorithm for Acoustic Vessel Classification,” vol. Supplement 4, no. Article 3, April 2012.

- [7] Australian Department of Defence, “Defence Innovation, Science and Technology Priorities,” Australian Department of Defence, Canberra, 2024.
- [8] R. Laird, “How to Ramp Up ADF Capabilities in the Near Term? A Perspective from Anduril Australia,” *Second Line of Defence*, 21 October 2022. [Online]. Available: <https://sldinfo.com/2022/10/how-to-ramp-up-adf-capabilities-in-the-near-term-a-perspective-from-anduril-australia/>. [Accessed 01 January 2026].
- [9] Engineers Australia, “Stage 1 competency standard for professional engineers,” November 2019. [Online]. Available: <https://www.engineersaustralia.org.au/sites/default/files/2022-07/stage-1-competency-standard-professional-engineer.pdf>. [Accessed 4 February 2026].

Appendix 1

Proposed software design



MESH Software Flow

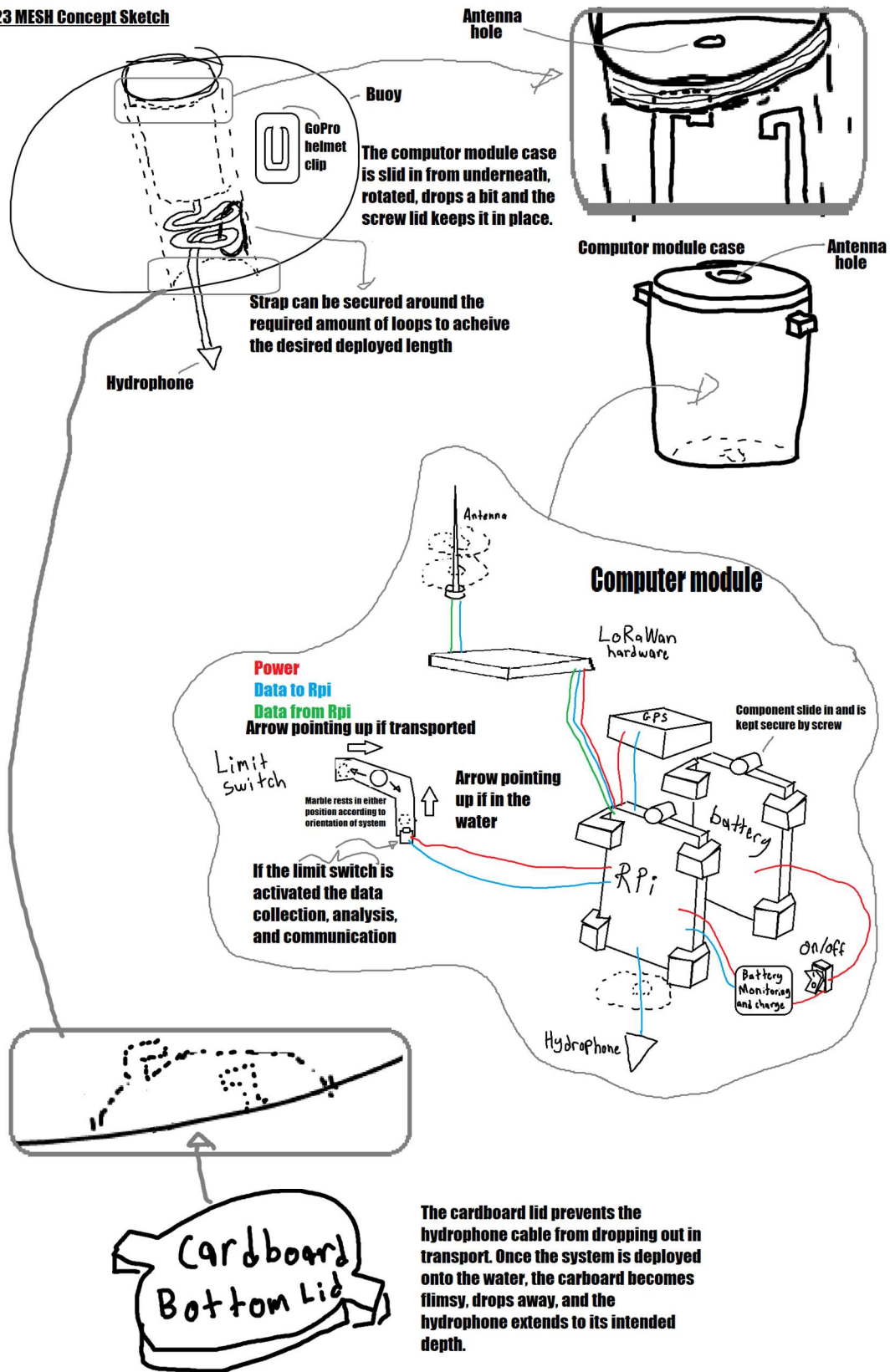


MESH_Software_Flow.pptx

[GitHub Repository.](#)

Proposed hardware design

260123 MESH Concept Sketch



Appendix 2

Estimated Cost, Weight, and Time.xlsx



Estimated Cost,
Weight, and Time.xlsx

TOTAL	Est Cost (AUD)	Est Weight (g)	Est Delivery Time (Days)
System and setup	\$283.48	1128	60
System (excluding Makerspace parts)	\$278.83	-	-

Component	Est Cost (AUD)	Est Weight (g)	Est Delivery Time (Days)	URL
Raspberry Pi 4 (4GB)	\$ 80.00	50	10	https://core-electronics.com.au/raspberry-pi-4-model-b-2gb.html?staticblockpopup=rpi_mixed
Hydrophone transducer (PZT)	\$ 30.00	15	15	https://www.aliexpress.com/item/1005005532825972.html
Power supply adapter (USB-C 5V 3A)	\$ 2.14	60	11	https://www.aliexpress.com/item/1005005703532263.html
LoRa module (node)	\$ 16.29	15	15	https://www.aliexpress.com/item/1005006539361701.html

Li-ion battery pack (1260110)	\$ 10.89	60	60	https://www.aliexpress.com/item/1005007611232592.html
Microphone cable (5m)	\$ 34.98	50	2	https://www.amazon.com.au/Outdoor-Lights-Waterproof-Connectors-Extension/dp/B07SZPZ769
32–128 GB high-end SD card	\$ 19.00	5	0	https://www.cheapchips.com.au/sandisk-ultra-microsdxc-uhs-i-64gb
Hydrophone buffer PCB	\$ 35.00	14	14	https://www.jlielectronics.com/diy-accessories/p48-hi-z-piezo-buffer/
Urethane resin (small kit)	\$ 12.00	500	14	https://www temu.com/au/-16-9oz--kit-clear-and-non-yellowing--self-leveling--1-1-casting-and--for--making-art-n-and-epoxy--g-601100807235659.html
Battery BMS / protection board	\$ 5.05	12	12	https://www temu.com/au/18650-battery-charging-module-type-c-port-charging-circuit-board-charging-board-suitable-for-3-6-3-7v-lithium-batteries-and-polymer-lithium-battery-charge--protection-featuring--functions-g-605811124354884.html
XLR male connector	\$ 3.10	12	12	https://www temu.com/au/black-metal-square-socket-for-audio-microphone-with-a-3-pin-xlr-male-connector-for-mixers-g-601100497829551.html
Limit switch (orientation detect)	\$ 1.42	10	10	https://www temu.com/au/electronic-building-block-q89-collision-switch-microcontroller-module-limit-sensor-switch-robot-g-601105626658695.html
GPS module (external)	\$ 7.69	10	10	https://www temu.com/au/-gy-neo6mv2-neo-6m-module-featuring-an--kit-for-with--and--in-robotics-g-601103014730725.html
On/off switch	\$ 1.48	10	10	https://www temu.com/au/one-piece-of-on-off-stop-switch-for-chainsaws-4500-5200-5800-and-45-52-58cc-suitable-for-replacement-of-spare-parts-g-601100220306963.html
USB to LoRa Data Transfer Module, Based On SX1262, Suitable For Data Acquisition In Industry And Agriculture	\$ 19.79	30	14	https://www.aliexpress.com/item/1005010333249217.html

Hydrophone mold / misc	\$ 1.00	50	14	Makerspace
Misc wiring/connectors/heat shrink	\$ 0.50	20	1	Makerspace
Enclosure / buoy housing	\$ 3.00	200	1	Makerspace
Fasteners (Rubber Band)	\$ 0.05	5	1	Makerspace
Sealants / grommets	\$ 0.10	50	1	Makerspace
Not counted in system weight.				

Appendix 3

Estimated Hour log.xlsx:



Estimated Hour log.xlsx

Date	Day	Start	Finish	Total	Running Total	Phase	Plan
29/06/2026	Monday	8:00:00	17:00:00	9:00:00	9:00:00	Literature Review & Requirements Definition	Passive sonar Shallow water acoustics Vessel acoustic features Deriving functional requirements: Frequency range Minimum SNR Power budget Deployment constraints Writing system requirements and constraints
30/06/2026	Tuesday	8:00:00	17:00:00	9:00:00	18:00:00		
1/07/2026	Wednesday	8:00:00	17:00:00	9:00:00	27:00:00		
2/07/2026	Thursday	8:00:00	17:00:00	9:00:00	36:00:00		
3/07/2026	Friday	8:00:00	17:00:00	9:00:00	45:00:00		
4/07/2026	Saturday	8:00:00	17:00:00	9:00:00	54:00:00		
5/07/2026	Sunday	0:00:00	0:00:00	0:00:00	54:00:00		
6/07/2026	Monday	8:00:00	17:00:00	9:00:00	63:00:00	System Architecture & Trade Study	Selecting hydrophone type (piezo vs electret) Designing analogue front-end: Gain staging Filtering (anti-aliasing, band-pass) ADC selection and sampling rate justification Bench testing: Noise floor measurement Frequency response testing Iterating design based on test results
7/07/2026	Tuesday	8:00:00	17:00:00	9:00:00	72:00:00		
8/07/2026	Wednesday	8:00:00	17:00:00	9:00:00	81:00:00		
9/07/2026	Thursday	8:00:00	17:00:00	9:00:00	90:00:00		
10/07/2026	Friday	8:00:00	17:00:00	9:00:00	99:00:00		
11/07/2026	Saturday	8:00:00	17:00:00	9:00:00	108:00:00		
12/07/2026	Sunday	0:00:00	0:00:00	0:00:00	108:00:00		
13/07/2026	Monday	8:00:00	17:00:00	9:00:00	117:00:00	Analogue Front-End & Instrumentation Design	Time-domain detection FFT-based spectral analysis Feature extraction (band energy,
14/07/2026	Tuesday	8:00:00	17:00:00	9:00:00	126:00:00		
15/07/2026	Wednesday	8:00:00	17:00:00	9:00:00	135:00:00		

16/07/2026	Thursday	8:00:00	17:00:00	9:00:00	144:00:00		harmonics, spectral centroid)	
17/07/2026	Friday	8:00:00	17:00:00	9:00:00	153:00:00			
18/07/2026	Saturday	8:00:00	17:00:00	9:00:00	162:00:00			
19/07/2026	Sunday	0:00:00	0:00:00	0:00:00	162:00:00			
20/07/2026	Monday	8:00:00	17:00:00	9:00:00	171:00:00			
21/07/2026	Tuesday	8:00:00	17:00:00	9:00:00	180:00:00		Optimising algorithms for: CPU load Memory usage Power consumption Profiling performance on Raspberry Pi Documenting trade-offs	
22/07/2026	Wednesday	8:00:00	17:00:00	9:00:00	189:00:00	Embedded Software & DSP Implementation	Designing test methodology Running pool experiments with controlled sound sources Collecting and labelling data Evaluating detection accuracy and false positives Refining algorithms based on results	
23/07/2026	Thursday	8:00:00	17:00:00	9:00:00	198:00:00			
24/07/2026	Friday	8:00:00	17:00:00	9:00:00	207:00:00			
25/07/2026	Saturday	8:00:00	17:00:00	9:00:00	216:00:00			
26/07/2026	Sunday	0:00:00	0:00:00	0:00:00	216:00:00			
27/07/2026	Monday	8:00:00	17:00:00	9:00:00	225:00:00			
Total Mid Year Hours. Recommence in Summer Break					225:00:00			
20/11/2026	Friday	8:00:00	17:00:00	9:00:00	234:00:00			
21/11/2026	Saturday	8:00:00	17:00:00	9:00:00	243:00:00			
22/11/2026	Sunday	0:00:00	0:00:00	0:00:00	243:00:00			
23/11/2026	Monday	8:00:00	17:00:00	9:00:00	252:00:00			
24/11/2026	Tuesday	8:00:00	17:00:00	9:00:00	261:00:00			
25/11/2026	Wednesday	8:00:00	17:00:00	9:00:00	270:00:00			
26/11/2026	Thursday	8:00:00	17:00:00	9:00:00	279:00:00	Controlled Experimental Testing	Running pool experiments with controlled sound sources Collecting and labelling data Evaluating detection accuracy and false positives Refining algorithms based on results	
27/11/2026	Friday	8:00:00	17:00:00	9:00:00	288:00:00			
28/11/2026	Saturday	8:00:00	17:00:00	9:00:00	297:00:00			
29/11/2026	Sunday	0:00:00	0:00:00	0:00:00	297:00:00			
30/11/2026	Monday	8:00:00	17:00:00	9:00:00	306:00:00			
1/12/2026	Tuesday	8:00:00	17:00:00	9:00:00	315:00:00			
2/12/2026	Wednesday	8:00:00	17:00:00	9:00:00	324:00:00			
3/12/2026	Thursday	8:00:00	17:00:00	9:00:00	333:00:00	Field Deployment & Operational Testing	Deploying system in real coastal conditions Recording acoustic data from RWCs	
4/12/2026	Friday	8:00:00	17:00:00	9:00:00	342:00:00			
5/12/2026	Saturday	8:00:00	17:00:00	9:00:00	351:00:00			

6/12/2026	Sunday	8:00:00	17:00:00	9:00:00	360:00:00	Analysis, Documentation & Professional Reflection	and IRBs Evaluating real-world performance vs lab results	
7/12/2026	Monday	8:00:00	17:00:00	9:00:00	369:00:00		Analysis, Documentation & Professional Reflection	Comparing performance vs requirements Identifying limitations and future improvements Writing technical documentation and reflection
8/12/2026	Tuesday	8:00:00	17:00:00	9:00:00	378:00:00			
9/12/2026	Wednesday	8:00:00	17:00:00	9:00:00	387:00:00			
10/12/2026	Thursday	8:00:00	17:00:00	9:00:00	396:00:00			
11/12/2026	Friday	8:00:00	17:00:00	9:00:00	405:00:00			
12/12/2026	Saturday	8:00:00	17:00:00	9:00:00	414:00:00			
13/12/2026	Sunday	0:00:00	0:00:00	0:00:00	414:00:00			
14/12/2026	Monday	8:00:00	14:00:00	6:00:00	420:00:00			
PEX Hours Obtained								

END OF PROPOSAL