

Desktop Study: An Assessment of Available Whale Detection Technologies as Additional Management Procedures for the Regia 3D Marine Seismic Survey

Paul Miller

Millodon Consulting

Revision A

The views and opinions expressed in this document are those of the author and do not necessarily reflect the views of the Regia 3D MSS survey proponents or its sponsors.

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A list of most (but not all) of the sources of data used can be found in the References section at the end of this document.

Introduction

Klarite Pty Ltd (Klarite), on behalf of CGG Australia (CGG), has commissioned Millodon Consulting (Millodon) to conduct a desktop study on the available technologies, both current and in development stages, of systems designed to detect and alert the presence of marine mammals to aid in mitigation measures during seismic surveys.

CGG is planning a 3-Dimensional Marine Seismic Survey (3D MSS) offshore Victoria, to be conducted sometime during 2024. As part of the environmental management planning for the survey CGG is seeking to identify, procure and eventually deploy, suitable systems to mitigate interactions with Species of National Environmental Significance (SNES), with a particular focus on the Blue and Southern Right Whales, known to frequent the survey operational area at certain times of the year, or potentially even all year round.

The systems included within this study are being reviewed for suitability and practicality for consideration as Additional Management Procedures, in addition to those already defined and mandated in the Environment Protection and Biodiversity Conservation (EPBC) Act Policy Statement 2.1 - Interaction between offshore seismic exploration and whales. Additional Management Procedures are required in Australian waters where there is a moderate to high likelihood of encountering whales.

This study is not intended to be a full and thorough description of each system's operational or technical intricacies. Where available, URL links will be included to manufacturer's own web-based literature to better cover those subjects. The study is designed to help inform CGG on the most practical system, or combination of systems, to best reduce the risk of marine mammal interactions to as low as reasonably practicable (ALARP), based on information available in the public domain.

Assessment Summary

Millodon Consulting reviewed a range of different technologies for marine mammal detection that are either currently available or in advanced stages of development. Where there are multiple vendors for similar technologies each vendor's equipment was assessed independently.

Detection Technologies Considered

The range of technologies considered for review consisted of the following: -

1. Passive Acoustic Monitoring (PAM)
    a. Towed streamer PAM
    b. Supplementary vessel towed PAM
    c. Fixed/tethered PAM buoys
    d. Unmanned/Uncrewed Surface Vessels (USV)
    e. Unmanned/Autonomous Underwater Vessels (UUV/AUV)
    f. Distributed Acoustic Sensors (fibre optic)
2. Satellite imagery
3. Aerial surveys
    a. Manned Aircraft
    b. Drones
4. Camera-based monitoring systems

Assessment Criteria

Assessment of each system was based on five simple criteria: -

- Availability
- Prior deployment histories and reported effectiveness.
- Practicality of implementation
- Safety & environmental concerns
- Cost versus benefit

Assessment Results

The following list includes assessment summaries of each detection technology or methodology, as reviewed by the author. Systems have been either deemed worthy of implementation or further investigation/consideration, or rejected based on safety and environmental concerns or failing the cost versus benefit criteria.

1. Towed streamer PAM using Sercel's QuietSea in-streamer PAM hydrophones and QuietSea monitoring and automatic detection software is a proven and tested solution that will already be installed and operational on the survey vessel prior to mobilisation. It is recommended the QuietSea system be fully deployed and operational throughout the survey activity. Dedicated PAM Operator personnel, either CGG or contracted, would be considered necessary, with a minimum requirement for full-time PAM monitoring during the hours of darkness.

2. If using supplementary PAM vessel(s) the use of the Seiche towed PAM hydrophone arrays and onboard recording/analysis equipment is considered both practical and cost effective. However, the cost and associated risks of additional vessels and crew need to be considered against the potential benefits gained.

3. Tethered buoy PAM to provide real-time remote monitoring using data telemetry to an onshore or offshore monitoring hub is considered a feasible option. It would appear that the bandwidth requirements for real-time audio frequency spectral signal data via satellite is prohibitive for onshore monitoring at any significant distance offshore, but the use of VHF radio, 2.4GHz Wifi or GSM cellular phone are common options for local telemetry back to a monitoring vessel.

   All buoy-based PAM systems reviewed have the ability to operate autonomously, with real, or near real-time monitoring possible remotely from the buoy. The Sercel manufacture PAM buoy is, at time of writing, still in its late development stage but could be deployed pre-survey for sea trials and performance testing.

   Seiche Ltd has a long history of PAM equipment development and their Modular Buoy Detection System has proven offshore performance for whale detections, though their effective use during seismic surveys has yet to be confirmed by Seiche. The Jasco Ocean Observer Buoy, like the Seiche offering, is a smaller, more light weight option (45Kg) than the large and relatively heavy (220Kg) Sercel Buoys, so would be more easily deployed and recovered. The Jasco Ocean Observer Buoy is also the only unit reviewed that can perform onboard, in-situ processing of detections, with the spectrograms converted to frequency contours for transmission via satellite to the survey vessel or to a shore-based monitoring station for confirmation of detections and relaying of detection information to the survey vessel.

   If a tethered buoy PAM system is to be considered as an option for the Regia 3D survey further investigation into the telemetry ranges involved and the number of buoys needed to provide a ringfence around the active survey area to detect whales entering. The Jasco Ocean Observer Buoy would appear to have the best options available for either onshore or offshore monitoring of detections.

   It is important to note that whilst the majority of the Regia 3D active survey area, as currently mapped, is in water depths of less than 200 metres, the south western survey margin does extend beyond the continental shelf and into water depths exceeding 1300 metres, including the West Tasmania Canyons Key Ecological Feature. Whilst not impossible, the use of tethered buoys in such depths does create additional logistics problems for deployment and recovery. It may, therefore, be worthwhile considering the use of a hybrid PAM array using a combination of tethered buoys in the shallower waters and unmanned surface vessels or underwater gliders in the deeper waters, in order to provide adequate detection coverage from all directions of approach.

4. If considering a hybrid deployed remote PAM array, in order to maintain consistency in monitoring and detection software and associated systems, it would be logical to look at unmanned vessels provided by the same manufacturer/vendor as the selected tethered PAM equipment. Seiche's Autonaut USV can carry the same PAM and telemetry payload as its Modular Buoy Detection System, whilst JASCO's use of the Slocum Autonomous Underwater Glider, integrated with the OceanObserver intelligent acoustic monitoring system is another viable option.

Both vessels can maintain station, within a given radius, by circling (or traversing straight line routes) around a target location. The Autonaut, being a surface vessel, can continually transmit its current location and accept new instructions via an Iridium satellite link. Real-time detection data can be transmitted continually through RF or Wifi link, with a resultant limitation in reception range from the survey vessel monitoring equipment based on the PAM system radio transmitter's effective range.

The Slocum Glider, being an underwater vessel, can only transmit positioning and detection data during preset surfacing periods. However, the Jasco OceanObserver system installed on the glider can, in contrast to the Seiche system, transmit in-situ processed detections to any location via Iridium satellite. However, there would be a variable delay between the vocalisation detection, processing and transmission of detection data to the monitoring station, either onshore or offshore. This may affect the usefulness of any detection if the transmission delay proved to be longer than the transit time of a whale into the active survey area. In any case, the use of a hybrid remote PAM platform array can be considered a feasible option for consideration during the Regia 3D MSS.

5. For manned aerial whale detection survey flights there are several air charter services located in Warrnambool, the closest commercial airport to the Regia 3D MSS survey area. Aircraft available include small, single engine propellor planes, like the Piper Cherokee 150, turboprops like the Pilatus PC-12, up to small private jets. There are currently no designated landing points for helicopters, although the Helicopter Emergency Medical Service (HEMS 4) is based at the airport. Although manned flights for whale detections have been assessed as an option for the Regia 3D MSS, it is felt that the operational limitations, such as bad weather groundings, added safety risks and significant costs of regular sighting flights during survey operations, does not warrant further consideration.

6. Aerial surveying for visual detection of whales using suitably equipped drones is considered a more practical, safe, and cost-effective method than manned aircraft visual detection. A suitably qualified drone pilot may need to be engaged for this option, or additional pre-survey training provided to MMO personnel for the chosen drone equipment. The use of a thermal image capable drones could also provide the option for low-visibility/night flights for visual detection.

   One drone reviewed for this study, the DJI Matrice 30T, is considered a very viable option due to its advanced features, including thermal imaging, extreme optical zoom capacities (200x), laser ranging, dual control capable, weather resistance and more. With the addition of the "DJI Dock" system the drone can operate semi-autonomously, returning to the weatherproof dock to recharge batteries. The author feels this drone warrants further investigation by the Regia survey proponents as an additional whale mitigation management procedure.

7. Survey vessel mounted dual camera-based systems are also considered a viable option to be used to supplement MMO visual detections, especially during poor/night visibility periods. Again, additional MMO personnel may be required for this option to be implemented.

   Of the two systems reviewed, the Seiche Smart Visual Detection System is the more commercially developed system than Thaum's WhalePOD, but both are similar in function and features. The WhalePOD system is an Australian designed and developed unit that, at time of writing, was in the initial stages of its commercialisation phase. Initial field-testing results were positive and industry interest was reported as being high. If the WhalePOD system is a

commercially available system in time for deployment on the Regia 3D MSS it would be a valuable platform for early adoption and feasibility testing for use during marine seismic surveys. Based on initial contact with Thaum's WhalePOD team, early adoption could also result in more beneficial commercial terms, making the cost versus benefit assessment a simple task.

8. The use of DAS fibre optic detection systems as a mitigation tool has been investigated and is considered impractical for use during the Regia 3D MSS. Limitations include the need to connect to existing telecommunications infrastructure, or to deploy dedicated cables on the seafloor and physically interface them to the monitoring equipment. Interfacing to existing commercial fibre optic cables is only feasible when the cable is located within proximity to the survey area and has an uninterrupted light path (no electronic repeater nodes) between the DAS control/record unit and the distributed acoustic sensors setup along the cable's length.

Background

Australian Regulatory Framework for Marine Seismic Surveys

Marine seismic surveys involve the use of sound waves to gather information about the seafloor and subsurface geology. These surveys are often conducted in offshore areas for various purposes, including oil and gas exploration, scientific research, and environmental studies. Given the potential environmental impacts of such activities, regulatory frameworks are in place to ensure that they are conducted responsibly and in compliance with relevant laws.

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA)

In Australia, the regulation of marine seismic surveys falls primarily under the regime of the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA). NOPSEMA is Australia's independent expert regulator for health and safety, structural (well) integrity and environmental management for all offshore energy operations and greenhouse gas storage activities in Commonwealth waters, and in coastal waters where regulatory powers and functions have been conferred. NOPSEMA operates and regulates under the Australian Governments legislation and regulations.

a. **List of legislation**
   i. Public Governance, Performance and Accountability Act 2013
   ii. Offshore Petroleum and Greenhouse Gas Storage Act 2006
   iii. Offshore Petroleum and Greenhouse Gas Storage (Regulatory Levies) Act 2003
   iv. Environment Protection and Biodiversity Conservation Act 1999
b. **List of regulations**
   i. Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011
   ii. Offshore Petroleum and Greenhouse Gas (Safety) Regulations 2009
   iii. Offshore Petroleum and Greenhouse Gas (Environment) Regulations 2023
   iv. Offshore Petroleum and Greenhouse Gas (Regulatory Levies) Regulations 2022

As with any other human activity, marine seismic surveys have the potential for some level of impact on the environment. The type and degree of environmental impact from a seismic survey is influenced by:

- the nature of the biological, social, economic, and cultural features of the marine environment where the survey is proposed to take place,
- the level of spatial and temporal overlap with environmentally sensitive areas and times and
- the individual survey design (e.g. the nature of the sound source and acquisition line spacing).

The Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2023 (OPGGS Environment Regulations) require companies who wish to conduct a marine seismic survey to address these factors through an environmental impact assessment (EIA) for their specific proposed activity circumstances.

The key requirements that apply in Australia are:

- the Environment Protection and Biodiversity Conservation (EPBC) Act Policy Statement 2.1, which sets out procedures for managing interactions with whales
- recovery plans for listed threatened species (particularly where noise is identified as a threat), which define objectives and actions to ensure effective threat mitigation and species recovery
- Australian marine park management plans, which prescribe rules for where seismic surveys can and can't occur, as well as objectives for environmental protection.

There are also a range of international requirements that should be considered, such as:

- the Convention on the Conservation of Migratory Species (CMS) Family Guidelines on Environmental Impact Assessment for Marine Noise-generating Activities (CMS Guidelines)
- various technical guidelines on applying thresholds for the impact of received sound levels, e.g. marine mammal acoustic technical guidance
- various guidelines and codes of conduct for effectively managing environmental impacts from marine seismic surveys, e.g. IUCN guidance on effective planning of geophysical surveys.

NOPSEMA's environmental assessment processes consider all project and activity-specific environmental impacts and risks, including but not limited to those relevant to matters protected under Part 3 of the EPBC Act. Decision-making ensures that environmental impacts and risks, including to matters protected under Part 3 of the EPBC Act, will be of an acceptable level and reduced to as low as reasonably practicable (ALARP).

The object of the Environment Regulations is also to ensure that any petroleum activity or greenhouse gas storage activity is carried out in a manner consistent with the principles of ecologically sustainable development as set out in section 3A of the EPBC Act.

Of direct relevance to the subject of this report is NOPSEMA's. role as compliance regulator of the EPBC Act, with particular a focus on *Policy Statement 2.1 - Interaction between offshore seismic exploration and whales*, as described in the following section.

EPBC Act Policy Statement 2.1 - Interaction between offshore seismic exploration and whales

About the policy statement

The aim of the policy is to:

1. provide practical standards to minimise the risk of acoustic injury to whales in the vicinity of seismic survey operations,
2. provide a framework that minimises the risk of biological consequences from acoustic disturbance from seismic survey sources to whales in biologically important habitat areas or during critical behaviours, and

3. provide guidance to both proponents of seismic surveys and operators conducting seismic surveys about their legal responsibilities under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Scope of the Policy Statement

Under the EPBC Act, a number of whale species are listed as threatened and/or migratory species and are, subsequently, protected under the Act as matters of national environmental significance (NES). Whale species are also part of the Commonwealth marine environment, another matter of NES.

Whales and other cetaceans also have additional protections in the *Australian Whale Sanctuary*. The EPBC Act provides for offences for certain actions that adversely affect whales in the Australian Whale Sanctuary. The Act also provides for permits to be obtained in relation to actions affecting whales in the Australian Whale Sanctuary.

Applicable Species

Not all whales hear the same acoustic frequencies. Seismic survey sound sources are generally focussed at frequencies below 200Hz. Based on the best available scientific information, it is generally understood that baleen whales and some toothed whales are likely to be sensitive to sounds in this lower frequency range.

Due to the difficulties in identifying whales to the species level, particularly at distance, appropriate management procedures (as recommended in Part A Standard Management Procedures and Part B Additional Management Procedures) should be applied whenever **whales** are, or might be, encountered. **'Whales'** includes baleen whales and larger toothed whales, such as, sperm whales, killer whales, false killer whales, pilot whales and beaked whales.

Smaller dolphins and porpoises that have peak sensitivities in the higher frequency ranges are likely to be less disturbed by these lower frequency sounds and less vulnerable to acoustic trauma. Accordingly, this Policy Statement does not apply to encounters with the smaller dolphins and porpoises.

Legislative Responsibilities

If the likelihood of encountering whales is low, the chance of a seismic survey having a significant impact on a whale species should be minimal, provided that the proponent and the operator of the seismic survey adopt the measures outlined in Part A Standard Management Procedures.

While Part A Standard Management Procedures may be sufficient in locations where the likelihood of encounters with whales is low, the proponent may need to consider additional avoidance and mitigation measures for areas and/or seasons where the likelihood of encountering whales is moderate to high. In these circumstances, the proponent should not only apply Part A Standard Management Procedures, but should also consider measures like those outlined in Part B Additional Management Procedures.

Part A Management Procedures

Part A Management Procedures are to be implemented as a minimum requirement for all marine seismic survey activities conducted in Australia where the likelihood of whale interactions is considered low. Part A Management Procedures include: -

1. **Pre-Survey Planning:** to avoid scheduling seismic surveys in areas where and when whales are likely to be breeding, calving, resting or feeding.
2. **Trained Crew:** The survey proponent should ensure that there is sufficient trained crew to fulfil the basic requirements of whale observation, distance estimation and reporting.
3. **During Surveys:** All seismic survey vessels operating in Australian waters must undertake the following basic procedures during surveys irrespective of location and time of year of survey:

    - Pre-start-up visual observation
    - Soft start
    - Start-up delay
    - Operations
    - Power- down and Stop work
4. **Compliance and Sighting Reports:** It is the responsibility of the proponent to maintain a record of procedures employed during operations. Such records should be auditable and account for aspects of the operation that relate to legislative approvals and regulations.

Detailed specifics of the requirements for Part A Standard Management Procedures, such as soft-start durations and mitigation zone distances, can be found in the policy statement document that can be found online at the DCCEEW web site.

Part B Additional Management Procedures

For seismic surveys operating in areas where the likelihood of encountering whales is **moderate to high**, the application of additional measures, to ensure that impacts and interference are avoided and/or minimised, are necessary. The following measures are recommended, however, application of all these measures may not be necessary, applicable or possible for all seismic survey operations.:-

1. **Marine Mammal Observers (MMO):** Whilst listed as an additional management procedure in the policy statement it is now considered standard practice for marine seismic surveys to employ at least one MMO during any seismic survey activity. MMOs should be trained and experienced in whale identification and behaviour, distance estimation, and be capable of making accurate identifications and observations of whales in Australian waters. The MMOs should assist other observers (e.g. trained crew) and be available to provide advice, should whales be encountered.
2. **Night-time/Poor visibility:** For surveys in areas where whales are expected to be encountered, the proponent should include appropriate management measures to detect (or predict) whale presence and apply measures to reduce the likelihood of encounters. Depending on the situation a range of measures may be appropriate, possible measures include:

    - Limiting initiation of soft start procedures to conditions that allow visual inspection of the precaution zone;
    - Daylight spotter vessel or aircraft searches of the night-time survey area to determine if whales are present; and
    - Pre survey research (including surveys) to detect and identify likely whale concentration areas, such as: peak migration paths and times, key feeding sites (e.g. shelf breaks, sea mounts and trenches), or other aggregation areas.
3. **Spotter Vessel(s) and Aircraft:** Where the likelihood of encountering whales is high, spotter vessels/aircraft could be used to assist in detecting the presence of whales. Spotter vessels and aircraft may be usefully employed to determine the presence and likelihood of encountering whales during day and night-time operations; information that can then be used to re-design

the survey or tracks to be run to avoid whales that are in the vicinity. Spotter vessels/aircraft should maintain continuous contact with the seismic survey vessel. An MMO should be employed on board both the survey vessel and the spotter vessel/aircraft.

4. **Increased Precaution zones and Buffer zones:** In some locations and circumstances it may be advisable to apply increased distances for the instigation of power-down procedures from those outlined in Part A Standard Management Procedures.
5. **Passive Acoustic Monitoring:** Deployment of PAM with appropriate technologies and programs to detect whales in real time may provide an additional method of detecting and avoiding whales during surveys and may be particularly useful during night-time and low visibility operations.
6. **Adaptive Management:** Where a survey is proposed in an area that is spatially and temporally on the edge of areas considered to provide biologically important habitat, the proponent may consider implementing adaptive management procedures to manage the potential increased likelihood of encountering whales. Adaptive management could include implementation of daytime only operations if there are three consecutive days on which operators experience three or more whale-instigated shut down/power down situations. Adaptive management may also be used in conjunction with other measures described in Part B. For example, if aerial surveys identify whales in the region, increased buffer zones are implemented.

One of the core objectives of this report is to provide details of whale detection and mitigation systems that could be implemented as part of the Additional Management Procedures that will be implemented during the Regia 3D MSS due to the known presence of both Blue and Southern Right Whales in the vicinity of the Survey Planning Area. The most practical and effective additional management procedures/equipment will, where adopted by the survey proponents, be included as mitigation measure commitments within the Regia Seismic Survey Environment Plan.

Detection Technologies Overview

Introduction

The following section provides a broad overview of the technologies and implementation procedures that have been considered for adoption as Additional Management Procedures during the Regia 3DMSS. Advantages and disadvantages have been provided where an assessed technology is regarded as having both.

Passive Acoustic Monitoring

PAM History

Passive Acoustic Monitoring (PAM) for marine mammal detection has a history that spans several decades. The technique relies on the use of underwater microphones, known as hydrophones, to listen to and record the sounds produced by marine mammals. Here's a brief overview of the key milestones in the history of PAM:

1. **Early Observations (1950s-1960s):** The use of hydrophones to study marine life, including marine mammals, dates back to the 1950s and 1960s. Researchers began recording underwater sounds, but the technology was limited and the focus was primarily on general oceanography rather than specific marine mammal studies.
2. **Navy's Interest (1960s-1970s):** The United States Navy became interested in the use of passive acoustic techniques for detecting submarines. While conducting these naval operations, they unintentionally recorded marine mammal sounds, which led to increased awareness of their vocalisations.
3. **Whalesong Discoveries (1960s-1970s):** Researchers studying humpback whales made significant discoveries in the 1960s and 1970s. They found that humpback whales produced complex and repetitive songs, which piqued scientific interest in using passive acoustics for studying marine mammal behaviour.
4. **The Development of PAM Tools (1980s):** During the 1980s, advancements in hydrophone technology and signal processing capabilities made it easier to detect and analyse marine mammal sounds. This led to the development of dedicated PAM tools and software, making the process more efficient and accurate.
5. **International Whaling Commission's Involvement (1980s):** The International Whaling Commission (IWC) recognised the importance of passive acoustics in studying and conserving marine mammals. They initiated efforts to standardise PAM methodologies and data analysis techniques.
6. **Wide Application (1990s-2000s):** In the 1990s and 2000s, PAM gained broader recognition and became an essential tool for marine mammal researchers worldwide. It was used to study various species, including cetaceans (whales, dolphins, and porpoises) and pinnipeds (seals and sea lions), and assess their distribution, abundance, and behaviour.
7. **Integration with Autonomous Systems (2000s-2010s):** With advancements in underwater autonomous systems, such as autonomous underwater vehicles (AUVs) and gliders, PAM techniques were integrated with these platforms to expand coverage and improve data collection.

8. **Industry Applications (2010s):** PAM found applications beyond scientific research. Industries like offshore oil and gas exploration, renewable energy, and shipping began using PAM as part of their environmental monitoring efforts to reduce the impact of their activities on marine mammals.
9. **Real-time PAM (2010s-2020s):** Real-time PAM systems evolved, allowing researchers and operators to monitor marine mammal activity continuously. These systems could detect vocalisations and other sounds, provide alerts for specific species detections, and help mitigate potential risks for marine life.

Overall, passive acoustic monitoring has become an essential tool in marine mammal research and mitigation, offering a non-invasive and effective means of detecting vocalising marine mammals. Ongoing advancements in technology continue to improve the accuracy, efficiency, and scope of PAM use in a broad range of applications.

PAM During Marine Seismic Surveys

PAM is a valuable tool used during marine seismic surveys to monitor and mitigate the impact of seismic operations on marine life, especially marine mammals. Seismic surveys involve the use of airguns to generate powerful acoustic signals, which may be harmful to marine organisms if not properly managed. PAM helps in minimising the potential negative effects by providing real-time monitoring and detection of marine mammal presence within the detectable range of the acoustic energy source.

Here's how PAM is utilised during marine seismic surveys:

1. **Marine Mamal Detection:** PAM systems are installed on seismic survey or energy source vessels and/or in the vicinity of the seismic survey area to continuously monitor for the presence of marine mammals. These systems consist of hydrophones (underwater microphones) or an array of hydrophones that can detect and record the vocalisations and other acoustic signals produced by marine mammals.
2. **Real-time Monitoring:** The hydrophones are connected to onboard or shore-based monitoring stations, where specialised software analyses the recorded acoustic data in real-time. Some PAM software is capable of automatic identification of individual species of marine mammals based on their vocalisation signatures. If marine mammal sounds are detected during survey, operations can be adjusted or halted temporarily to prevent potential harm to the animals.
3. **Mitigation Measures:** PAM allows for the implementation of mitigation measures when marine mammals are detected. These measures can include shutting down the airguns or altering the survey activity to minimise potential impacts on marine life. The mitigation measures are often guided by the likely species present and environmental regulations and guidelines specific to the area of operation.
4. **Data Collection and Analysis:** The data collected through PAM systems during seismic surveys are also essential for assessing the effectiveness of mitigation measures and studying the behaviour of marine mammals in response to seismic activities. This information helps researchers and regulatory authorities make informed decisions about future seismic operations.
5. **Compliance with Regulations:** Many countries and international organisations have strict regulations and guidelines to protect marine life during seismic surveys. In some countries PAM has been mandated as a required mitigation tool during all seismic survey activities. In Australia PAM use is not yet mandated. However, it is considered best practice as an "Additional

Management Procedure" beyond the "Standard Management Procedure" requirements of the EPBC Act, Policy Statement 2.1.

It's important to note that the use of PAM is just one aspect of a comprehensive environmental monitoring and management plan that operators implement during seismic surveys. Other measures, such as visual monitoring, pre-survey assessments, and adherence to mitigation zones, also play significant roles in safeguarding marine life during seismic operations.

Regardless of the platform on which a PAM system is deployed during a seismic survey activity there is one common disadvantage, or limitation, being the ability to detect marine life acoustic signals in amongst the large impulse noise of seismic airgun arrays being discharged, as well as the engine and propellor noises generated by the survey vessel(s) themselves. During survey data acquisition a typical airgun array discharge repetition rate is between 7 to 10 seconds. This high amplitude noise is received directly by PAM hydrophones through the water column, overpowering lower amplitude sounds.

Dependent on the water depth and subsurface geology, the subsurface acoustic reflections from each seismic source impulse can still be returning to the sea surface whilst the next airgun array impulse is generated. This means that the actual "quiet" period where lower amplitude marine fauna noise source levels can be monitored, without background seismic signal data present, is either minimal or non-existent during active survey periods. Therefore, PAM systems need to be able to filter out, or differentiate between seismic energy returns. The best times for detection of marine mammal vocalisations are the short periods of lower noise levels between seismic airgun pulses and during transits between seismic survey transect lines (line changes).

Towed Streamer PAM

Towed streamer PAM has been utilised for many years and is the most common form of passive acoustic monitoring used during seismic surveys to date. This detection method involves using a dedicated array of underwater microphones, or "hydrophones", which are incorporated in a long cable or "streamer" that is towed behind a seismic survey or associated support vessel.

The hydrophones pick up sounds in the underwater environment, including the vocalisations and other noises made by marine animals, such as whales. The PAM hydrophone arrays are interfaced to bespoke electronic equipment that can filter, digitise, and condition the acoustic signals for analysis by specialist software, such as the Open Source "PamGuard" system.

More recently manufacturers of in-water seismic survey equipment, such as Sercel's "QuietSea", system has incorporated cetacean detection hydrophones within the same streamers used to receive subsurface acoustic reflection data from the seismic energy source. The PAM hydrophone data is fed back to the survey vessel independently of the seismic data and is interfaced to equipment designed to analyse received acoustic signatures and automatically detect and identify cetaceans, alerting survey operators of their presence within the vicinity so that suitable mitigation measures can be instigated.

By incorporating PAM sensors in the seismic streamers, the need for additional dedicated PAM hydrophone arrays is eliminated, removing the risk of entanglement of the PAM streamer with the seismic vessel's towed equipment. It also reduces exposure of personnel to risks associated with the deployment and recovery of third-party PAM streamers from the stern of seismic survey vessels.

The integration of PAM data within the seismic streamers also provides for far greater numbers of hydrophones listening for cetacean vocalisations over a much broader area of the ocean. Dependent on the geophysical objectives, a typical modern seismic streamer deployment configuration during a marine 3D survey is between ten and fourteen individual seismic streamers of up to ten or twelve kilometres in length, spaced between fifty and one hundred and fifty metres apart. This provides a PAM hydrophone array of up to two square kilometres or more. Such large, two-dimensional arrays provide the ability to better compute geographic locations of received vocalisations by comparing the arrival times of individual acoustic signatures across the array to determine bearing and distances to the sound source.

Supplementary Vessel Towed PAM

The use of one or more vessels, in addition to the seismic survey vessel, to deploy towed PAM systems during a seismic survey can add considerably to cetacean mitigation efforts by enabling marine mammal detections at greater distances from the seismic energy source.

Dependent on the species of concern and the regulatory requirements for mitigation buffer zone distances from the active energy source(s) it may be impossible for seismic vessel-based towed PAM to detect cetacean vocalisations out to the required mitigation zone radius. Survey vessel towed PAM receivers are positioned astern of the vessel and therefore offset from the centre of the acoustic energy source. Positioning another vessel with its own towed PAM system ahead of the survey vessel could increase the potential to detect cetaceans ahead of the survey vessel, in the direction of travel along pre-plotted seismic lines.

Advantages of one or more supplementary vessels equipped with towed PAM are:-

- Increased range for detection of cetacean vocalisations from the seismic vessel, potentially providing more advanced warning of whale presence ahead of the energy source.
- Additional platform(s) for visual detections, including using more MMOs and possibly extra automated camera-based detection systems.
- Increased distance from the energy source means a lower level of direct arrival impulse noise as the amplitude decays with distance.
- A secondary vessel can potentially offer verification of received vocalisations and may assist in determining the location of the sound source.

Some disadvantages include: -

- The need for additional people to install, deploy, recover, and operate the PAM equipment, leading to additional safety risks for personnel at sea.
- The costs of an additional vessel and its crew capable of accommodating the extra PAM/MMO personnel and being able to work alongside the survey vessel in all weather conditions is not insignificant.

Tethered Buoy PAM

A tethered buoy PAM system is a tool used in marine research and mitigation efforts to monitor and protect marine animals, particularly cetaceans like whales and dolphins.

Here's how a tethered buoy PAM system works:

1. **Buoy**: The system typically consists of a buoy that floats on the water surface. The buoy is designed to stay afloat and stable in various sea conditions.
2. **Tethered Design**: The buoy is tethered to an anchor or weight on the seafloor. The tether keeps the buoy in place, preventing it from drifting away with ocean currents.
3. **Underwater Hydrophones:** The buoy is equipped with underwater hydrophones. These hydrophones are sensitive to underwater sounds and can pick up a wide range of frequencies.
4. **Data Recorder:** The buoy is connected to a data recorder or logger, which stores the acoustic data captured by the hydrophones. Depending on the system, the data can be stored locally on the buoy or transmitted in real-time, via either radio frequency (including Wifi)or satellite-based data telemetry, to a shore-based monitoring station or onboard the seismic survey vessel.
5. **Acoustic Monitoring:** The tethered buoy PAM system operates continuously, listening for underwater sounds in the surrounding environment. It can detect various marine animal sounds, such as whale calls, dolphin clicks, and other vocalisations.
6. **Research:** Tethered buoy PAM systems are particularly useful for long-term monitoring in specific areas, such as migration routes or important feeding grounds.
7. **Non-Intrusive:** Since the PAM system does not emit any sounds, it is considered non-intrusive and does not disturb marine life during the monitoring process.

Tethered buoy PAM systems have been deployed in the field during marine seismic surveys to supplement the towed array PAM systems typically deployed from the seismic survey vessel and/or the energy source vessel. Buoys can be placed around the perimeter of the active seismic operations area in order to alert survey operations of the arrival of cetaceans within the area.

Dependent on the size of specified mitigation zones, when compared to the distances between the detected animals and the seismic energy source, actions can be taken to either heighten the level of alertness, such as increasing visual or acoustic monitoring efforts, or suspend survey operations until no further detections have been received within a pre-defined period, equivalent to the likely movement of detected whales outside the mitigation zone.

Tethered buoy PAM has the following advantages: -

- Buoys can be deployed around the perimeter of the seismic survey operations area to virtually ringfence the active source area, enabling detections of vocalising cetaceans prior to them entering the mitigation zone.
- Monitoring of real-time buoy PAM can be performed remotely at any location, either onshore or offshore, using satellite-based acoustic data telemetry. No additional personnel need to be assigned to a survey vessel, reducing risk and costs of travel as well as reducing pressure on survey vessel bunk space. Onshore monitoring provides more flexibility in shift timing and manning levels.
- Buoys can be used to compare received energy source sound levels at distances from the centres of sources with the modelled levels used to define the mitigation zones. Mitigation zone distances could be amended based on real-world sound level measurements.

Tethered buoy PAM disadvantages include: -

- Cost of buoy deployment and recovery is not insignificant.

- Corrective maintenance in the event of equipment failure is logistically difficult and costly due to the potential need for third party vessel charter to repair or replace buoys.
- Poor weather can affect buoy operational effectiveness. Buoy surface movement can affect hydrophone data quality through additional noise. Constant cloud cover can reduce solar panel effectiveness to charge system onboard batteries.
- Tethered buoys can become a navigation risk to other vessels. Buoy locations are required to be registered with government and military authorities and released in official Notices to Mariners.

Unmanned Surface Vessel PAM

USVs (Unmanned/Uncrewed Surface Vehicles) can be utilised for various purposes, including Passive Acoustic Monitoring (PAM). USVs can enhance PAM operations by serving as a platform to deploy and maintain the acoustic sensors, collect data, and transmit it to the operators or data centres. Here's how USVs can be beneficial for PAM:

1. **Autonomous operations:** USVs can be programmed to follow specific paths or patrol areas or keep station autonomously, reducing the need for constant human intervention. This autonomy enables extended monitoring periods and increased coverage of marine environments.
2. **Reduced cost and risk:** Using USVs for PAM reduces the need for manned vessels, thereby cutting down operational costs and minimizing risks to human personnel in challenging or dangerous marine conditions.
3. **Extended endurance:** Many USVs can operate for extended periods, even in remote locations, allowing for continuous monitoring of underwater sounds over long durations.
4. **Precise positioning:** USVs equipped with GPS technology can maintain accurate positions, ensuring that acoustic sensors are deployed at specific locations for precise data collection.
5. **Low acoustic interference:** USVs are generally quieter than traditional manned vessels, reducing the potential for acoustic interference with marine life and improving the quality of PAM data.
6. **Remote control and data transmission:** Operators can remotely control USVs and receive real-time data from the acoustic sensors, enabling quick analysis and decision-making.
7. **Flexibility:** USVs can be equipped with different types of sensors, allowing them to perform a variety of tasks beyond PAM, such as meteorological or oceanographic data collection.

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- Configurable payloads and sensors
- Real-time data transfer via satellite telemetry.
- Potential alternatives to tethered buoys, especially in very deep water.

Some USV PAM disadvantages are: -

- Potential navigation risk to other marine users.
- Potential for entanglement of the towed hydrophone array with in-sea debris or fishing gear.
- Unmanned, so potential targets for theft or vandalism in certain deployment scenarios.

Unmanned Underwater Vessel PAM

Unmanned underwater vessels, often referred to as underwater drones or autonomous underwater vehicles (AUVs), can play a crucial role in conducting PAM efficiently. Here's how they could be used for this purpose:

1. **Data Collection:** Unmanned underwater vehicles equipped with hydrophones (underwater microphones) can collect audio data from different depths and locations in the ocean. These vehicles can travel to specific areas of interest and record underwater sounds without disturbing marine life.
2. **Extended Operation:** AUVs can operate for extended periods, covering large areas of the ocean. This allows for continuous or scheduled monitoring, which is especially useful for tracking the migration patterns and behaviours of marine species.
3. **Precise Localisation:** AUVs can be programmed to move to specific coordinates, enabling targeted acoustic data collection near underwater sources of interest, such as breeding or feeding grounds of marine animals.
4. **Real-time Data Transmission:** Some AUVs can transmit data in real-time to a monitoring station on the surface. This feature is advantageous for immediate analysis and decision-making based on the collected acoustic data.
5. **Adaptability:** AUVs can be programmed to follow predefined paths, adapt to changing environmental conditions, and navigate complex underwater terrain, ensuring optimal coverage of the monitored area.
6. **Reduced Human Interaction:** Using AUVs for PAM reduces the need for constant human presence at sea, minimizing the associated risks and costs.
7. **Integration with Other Sensors:** AUVs can carry additional sensors, such as environmental sensors or cameras, to gather more comprehensive data about the underwater environment and the marine life within it.
8. **Data Processing and Analysis:** The collected acoustic data can be processed to identify specific species based on their characteristic sounds. Machine learning algorithms can be employed to automate the analysis process and identify patterns in the recorded sounds.
9. **Reduced Environmental Impact:** Compared to traditional survey methods that involve larger vessels and potentially disruptive activities, AUVs produce minimal noise pollution and disturbance to marine life.

The advantages of autonomous underwater vessel use for PAM are similar to those of autonomous surface vessels, with the addition of the ability to submerge the hydrophone arrays to water depths where sea surface noise in greatly lessened. This provides a quieter environment for detecting distant whale vocalisations. However, this advantage comes at the cost of real-time data telemetry to the PAM monitoring station during periods of submersion, making it impractical as a mitigation option.

Fibre Optic Distributed Acoustic Sensors

Fibre optic distributed acoustic sensors (DAS) are a type of technology that utilises optical fibres to detect acoustic signals along the length of the fibre. These sensors are capable of converting the fibre optic cable into an array of virtual microphones, making them ideal for various applications in monitoring and surveillance.

Here's how fibre optic DAS generally works:

1. **Principle**: The basic principle behind fibre optic DAS is the interaction between light and sound. When an acoustic wave (sound) interacts with the fibre optic cable, it causes minute changes in the properties of the light traveling through the fibre.
2. **Optical Fibre:** The fibre optic cable used in DAS is typically a single-mode optical fibre, which allows only one mode of light to propagate along the fibre core. This is crucial for maintaining the integrity of the signal.
3. **Laser Interrogation:** A laser source is used to generate a continuous wave of light that travels through the optical fibre.
4. **Scattering:** When an acoustic wave interacts with the fibre, it causes minute changes in the refractive index of the fibre due to phenomena like Brillouin scattering or Rayleigh scattering. These changes result in the scattering of light along the fibre.
5. **Interference Measurement:** The backscattered light returns to the DAS unit, where it is analysed to detect changes in the phase and intensity of the light. By analysing these changes, the DAS system can pinpoint the location and characteristics of the acoustic disturbance.
6. **Data Processing:** The collected data from the DAS system is then processed using advanced signal processing algorithms to interpret the acoustic information accurately. This allows the system to distinguish between different types of acoustic events.

Fibre optic DAS has several advantages over traditional point sensors:

- **Continuous Monitoring:** Since the fibre optic cable acts as an array of virtual microphones, DAS provides continuous monitoring along its entire length, enabling the detection of acoustic events over long distances.
- **Sensitivity and Resolution:** DAS systems have excellent sensitivity and high spatial resolution, allowing for precise localization of acoustic events.
- **Versatility:** Fibre optic DAS can be used in various applications, such as pipeline monitoring, perimeter security, seismic monitoring, and structural health monitoring.
- **Immune to Electromagnetic Interference**: Fibre optic cables are not affected by electromagnetic interference, making DAS systems suitable for harsh environments.

Due to these advantages, fibre optic distributed acoustic sensors have gained popularity and are being employed in diverse industries for efficient and reliable acoustic monitoring applications.

An article published in Frontiers in Marine Science in July 2022 titled "Eavesdropping at the Speed of Light: Distributed Acoustic Sensing of Baleen Whales in the Arctic" *(Bouffaut et al)* detailed the successful use of a 120km long sub-sea telecommunications fibre optic cable, with sensing points every 4 metres, to identify and estimate the 3D positions of vocalising baleen whales. It also demonstrated the use of frequency modulated whale vocalisations recorded on the DAS to generate correlated subsurface seismic profiles down to a depth of around 2 seconds.

Disadvantages of DAS include:

- DAS can only operate over uninterrupted lengths of fibre optic cable. It cannot pass through repeater modules or other electronic nodes.
- Use of DAS with existing cables requires the assistance and cooperation of the telecommunications company that owns and/or operates the cables.
- DAS can only be used on dedicated fibres and therefore needs to utilise spare or unused fibres within any existing cable infrastructure.

- Deployment of dedicated DAS fibre optic cables on the seafloor may need some forms of regulatory approval prior to deployment.
- Deployed seafloor cables may be at risk of damage through external sources, such as trawling operations.
- Dedicated DAS cables needs to be physically connected to the recording equipment. In most cases this means the need to run the cable to a shore-based facility or possibly an offshore installation, such as an oil rig/platform. The logistics of this requirement are prohibitive.
- As at 2021, there is only one submarine telecommunications cable, Indigo Central, that passes through the Regia 3D survey area. This cable runs between Sydney and Perth, making the likelihood of potential utilisation due to the distances involved extremely slim.

Satellite Imagery

Satellite imagery has been utilised for various purposes, including environmental monitoring and wildlife conservation. However, using satellite imagery specifically for whale detection presents some challenges.

Whales are massive marine creatures that typically spend most of their time submerged underwater. While some whale species exhibit behaviours such as breaching (jumping out of the water) or spouting (blowing air and water from their blowholes), these activities can be relatively infrequent and challenging to capture from space.

Nevertheless, advancements in satellite technology and image processing algorithms have made it possible to detect large marine mammals, including whales, under certain circumstances. Here are some ways satellite imagery can be used for whale detection:

1. **Large Whale Detection:** Satellites equipped with very high resolution (VHR) optical sensors can detect large whales when they surface for air. These sensors can capture images of large whales like humpback whales, blue whales, and Southern Right whales when they breach or spout. While not continuous monitoring, these images can provide valuable data on whale distribution and migration patterns.
2. **Whale Migration Tracking:** Satellite-tagged whales can transmit signals when they surface, allowing researchers to track their movements and migration routes. This information can be used to understand whale behaviour and identify critical habitats.
3. **Whale Population Estimation:** Researchers can analyse satellite images to estimate whale populations in specific regions, such as areas where seismic survey activities are planned. This approach involves identifying and counting whales in the images, which can provide valuable insights into population trends and mitigation efforts.
4. **Detection of Human Activities Impacting Whales:** Satellite imagery can also be used to monitor human activities that may negatively impact whales, such as ship traffic, coastal development, and oil spills. By identifying potential threats, regulators can take appropriate measures to protect whale habitats.

However, it's important to note that satellite-based whale detection has its limitations. Cloud cover and weather conditions can obstruct the view from satellites, making consistent monitoring challenging. Moreover, smaller marine mammal species, or those that spend more time underwater, might be difficult to detect using current satellite technology.

The field of satellite imagery and marine mammal monitoring is continuously evolving, and there may be more advanced techniques and systems developed in the future. A German company, Space Whale, has developed a cetacean survey method, employing a convolutional neural network (CNN) to automate much of the VHR satellite imagery interpretation. Space Whale offers VHR satellite-based whale detection and monitoring as a service, with end users merely needing to provide corner coordinates for a rectangular area of interest, start and end dates for monitoring and the whale species of interest in order to obtain a quote for services.

At present though, real-time satellite imagery for use in whale detection as a real-time mitigation measure is not considered a practical option. It can certainly be considered as a means to establish whale population presence in a survey operational area over time in order to determine the best time to conduct a seismic survey.

Camera-Based Detection

Infrared Cameras

Infrared, or Night Vision cameras can be used for various purposes, including whale detection. Infrared cameras have been used to monitor and study marine mammal populations, including whales, in both research and mitigation efforts. Here's how infrared cameras are employed for whale detection:

1. **Thermal Imaging:** Infrared cameras are also known as thermal imaging cameras because they detect and capture infrared radiation (heat) emitted by objects, including living beings. Whales, like all warm-blooded animals, generate heat, and this thermal signature can be detected by infrared cameras even when the whales are underwater.
2. **Day and Night Vision:** Infrared cameras can operate in low-light conditions and even in complete darkness, making them valuable tools for marine research, especially in remote locations or during nighttime studies.
3. **Identification and Monitoring:** By using infrared cameras, researchers can identify and track whales without disturbing them or altering their natural behaviour. This helps in studying their movement patterns, behaviour, and population dynamics.
4. **Aerial Surveys:** Infrared cameras mounted on drones or aircraft can conduct aerial surveys of whale populations over large areas, making it easier to assess their numbers and distribution.
5. **Remote Monitoring:** Infrared cameras can be set up at specific locations, such as coastal areas or key migration routes, to continuously monitor whale activity. This allows researchers to collect data over extended periods without the need for direct human presence.
6. **Mitigation Applications:** Infrared cameras can play a role in marine mitigation efforts by providing valuable data on whale populations, migration patterns, and interactions with their environment. This information can be used to develop better mitigation strategies to protect these species.

It's important to note that while infrared cameras are a useful tool for whale detection, they are often used in conjunction with other monitoring techniques, such as acoustic monitoring (PAM) and visual observations (MMOs), for additional mitigation measures during marine seismic surveys.

Advantages of infrared cameras include: -

- Ability to identify whales in low light or dark conditions.

- Up to 360-degree, 24-hour remote scanning of the ocean around the monitoring platform out to the horizon.
- Systems are relatively inexpensive and are lightweight, easily transported, and relatively simple to install.
- Some camera systems incorporate Artificial Intelligence (AI) software to automatically identify whales through thermal imaging and blow detections.

Some disadvantages of infrared camera systems are: -

- Reduced effectiveness during periods of poor weather, including sea state and precipitation and during high sun glare situations. Fog and humidity can also adversely affect camera performance.
- If being used as an additional night time visual mitigation procedure, alongside the use of PAM detection systems, it may be necessary to engage additional MMO personnel to provide full 24 hour visual monitoring coverage onboard the survey or support vessel(s).

Dual Camera Systems

A Dual HD Image and Infrared Whale Detection Camera System is a specialised technology designed to monitor and detect the presence of whales using both high-definition visual imagery and infrared (IR) technology. This type of system is commonly used in marine research, conservation efforts, and environmental monitoring.

Here's how dual camera systems work:

1. **Dual Camera Setup:** The system consists of two types of cameras: high-definition (HD) visual cameras and infrared (IR) cameras. These cameras are typically positioned on a platform, such as a survey vessel or a fixed installation like an oil rig or platform.
2. **HD Image Cameras:** The HD cameras capture visible light imagery of the surrounding ocean. These images provide clear visual information about the appearance, behaviour, and location of whales. HD cameras are particularly useful for identifying specific species, observing behaviour patterns (breaching, swimming, etc.
3. **Distance Measurement:** Some dual camera systems can integrate automatic distance estimation analysis software, such as the Seisch Real Time Automated Distance Estimate at Sea (RADES) software.
4. **Infrared (IR) Cameras:** As detailed previously, IR cameras capture heat signatures emitted by living organisms, including whales, in the form of thermal radiation. Whales generate heat due to their metabolism, and this heat signature can be detected by IR cameras even when visibility is poor, such as in low light or adverse weather conditions. IR cameras are advantageous for night-time observations and in areas with reduced visibility.
5. **Image Processing and Analysis:** The system typically includes image processing software that can analyse the captured images and videos in real-time or post-capture. Machine learning algorithms can be employed to identify and classify whale species based on their visual features and heat signatures.
6. **Whale Detection Algorithms:** The core functionality of these systems lies in their ability to automatically detect the presence of whales within the captured images and videos. Detection algorithms are trained to recognise specific shapes, patterns, and characteristics of whales, both in visible light and in IR images. When a potential whale is detected, or an anomaly in the incoming images flagged, the system can trigger alerts for further observation or examination.

7. **Data Storage and Transmission:** The systems can store the captured images and videos for further analysis and research. Additionally, if a system is connected to a network, it can transmit real-time data to MMOs or a central database for instant analysis and response.
8. **Research and Conservation Applications**: A Dual HD Image and Infrared Whale Detection Camera System has numerous applications. It can aid in understanding whale migration patterns, assessing population sizes, monitoring the health of individual whales, and studying their behaviour. Furthermore, it can be used to support additional mitigation procedures, such as during marine seismic surveys, where they can be used as an additional source of real-time whale monitoring and detection to trigger required mitigation control measures.

This technology combines the advantages of high-definition visual imagery and infrared technology to provide a comprehensive and accurate method for monitoring and detecting whales. The advantages of a dual camera system include all of those previously listed for infrared cameras, plus the ability to better identify whale species and distances during daytime operations. The inclusion of automated distance estimation software further adds to the list of advantages.

The disadvantages of dual camera system use are also similar to those of a straight infrared camera option, being the limited effectiveness during poor sea state and weather conditions. Both systems are also limited by the location of the platform on which they are mounted, with a 360 degree uninterrupted view being almost impossible to achieve on most vessels due to the presence of the ship's mast(s) and any other upper deck superstructures, such as cranes, stacks and the like. Mast-top mounting, where the view is less obstructed, is impractical in most situations due to the height and the increased motion experienced at that height.

Aerial Surveys

Manned Aircraft

Manned aircraft aerial surveys for whale detections are a valuable method used by researchers to study and monitor whale populations in their natural habitats. These surveys involve using aircraft, such as airplanes or helicopters, equipped with specialised equipment and cameras to observe and document the presence of whales in a given area. Here's an overview of how aerial surveys for whale detections typically work:

1. **Survey Planning:** Researchers plan the aerial survey by defining the study area and identifying the target species of whales they want to observe. The study area can be a specific region, a migration route, or a known feeding or calving ground for the whales. For seismic survey planning purposes this would be the survey's Operational Area plus any prescribed mitigation zone buffers.
2. **Aircraft and Equipment:** A suitable aircraft is selected for the survey, considering factors such as range, speed, and altitude capabilities. The aircraft is often equipped with high-quality cameras and, in some cases, specialised sensors like infrared or thermal cameras that can aid in detecting whales more effectively.
3. **Flight Patterns:** Project planners determine the flight patterns based on the study objectives and the characteristics of the whales they are monitoring. The aircraft may fly along predetermined transects, circular patterns, or adaptive flight paths to cover the designated study area systematically.

4. **Detection and Documentation:** During the flight, trained observers/spotters scan the ocean surface for signs of whales, such as blows (exhalations), breaches, or fluke dives. When a whale is sighted, its location, behaviour, and species are recorded. Photographs and videos may also be taken for later analysis and identification.
5. **Data Analysis:** After the aerial survey, observers analyse the collected data to estimate whale abundance, distribution, and behaviour. They use statistical methods to extrapolate the observations to estimate the total whale population in the study area.
6. **Mitigation and Management:** The data gathered from aerial surveys help inform mitigation measures and management decisions related to whale populations. It aids in understanding population trends, identifying critical habitats, and assessing the impact of human activities on whale populations.

Advantages of Aerial Surveys:

- Aerial surveys allow spotters to cover large areas efficiently and rapidly.
- They provide a non-invasive method to study whales without disturbing their natural behaviours.
- Aerial observations can be used to complement data obtained from other survey methods, such as shipboard surveys, shore-based observations, or acoustic monitoring.
- Pre-activity aerial surveys can be used to help plan seismic survey timing to minimise exposure to periods of peak presence of whale species of concern.

Limitations of Manned Aerial Surveys:

- Weather conditions and sea state can affect survey flight operations and the ability to detect whales accurately.
- The altitude of the aircraft may limit the ability to identify smaller whale species or individuals.
- Aerial surveys can be expensive, especially if frequent or ongoing coverage is required.
- Aerial surveys are limited in duration and highly dependent on aircraft fuel endurance and distances from suitable air strips based within practical range of survey locations.

Overall, aerial surveys for whale detections can be a useful addition to marine seismic survey mitigation methods. However, the additional risks associated with personnel spending significant periods of time in low flying aircraft, plus the significant additional costs of this method, combined with the restrictions to flights in poor weather conditions, makes this option less desirable as a real-time mitigation method for a seismic survey, especially when located in areas of frequent bad weather.

Drones

Using drones for whale research and detection has become an increasingly popular and effective method in recent years. Drones offer numerous advantages for studying and monitoring whales in their natural habitats. Here are some ways in which drones are utilised for whale monitoring:

1. **Aerial Surveys:** Drones equipped with high-resolution cameras can conduct aerial surveys over large ocean areas, making it easier to spot whales and other marine mammals from above. This approach is especially valuable for species that spend a lot of time at the surface, like humpback whales and southern right whales.

2. **Behaviour Observation:** Drones allow researchers to observe the behaviour of whales without disturbing them. They can document social interactions, feeding behaviours, breaching, and other activities, providing valuable insights into the lives of these animals.
3. **Population Monitoring:** By flying over known habitats or migration routes, drones can help researchers estimate whale populations more accurately. Traditional survey methods may miss some individuals, but drones can cover larger areas and improve counting accuracy.
4. **Identification:** Drones equipped with specialised cameras, such as thermal or multispectral sensors, can aid in identifying whale species based on unique markings, colour patterns, or heat signatures.
5. **Tagging and Tracking:** Some drones are equipped with specialised dart guns or tagging devices that can safely attach tracking tags to individual whales. These tags allow researchers to monitor the movements and behaviours of specific whales over time.
6. **Acoustic Monitoring:** Drones can also carry hydrophones or other acoustic sensors to record whale vocalisations, helping scientists study their communication patterns and track their presence in areas with low visibility.
7. **Environmental Research:** Drones can be utilised to collect water samples, measure sea surface temperatures, and study other environmental factors that may influence whale behaviour and distribution.

When using drones for whale detections, it is essential to follow ethical guidelines and regulations to minimise disturbance to the animals and their environment. Observers must maintain a safe distance from the whales and ensure that the drone's presence does not cause stress or disruption to the animals. Additionally, adherence to local laws and permits related to drone operations and wildlife observation is crucial.

Advantages of drones:

- Drones are a cost effective and safe means of visual detection of whales. One or more drones can be deployed from either the survey or a support vessel at any time to scan a large area of ocean from heights capable of spotting whales at considerable distances.
- Modern consumer drones have flight times in excess 40 minutes and ranges up to 20km, with real-time, high-definition video streamed back to the drone pilot's video monitor or First Person View (FPV) goggles. Individual drones can be rotated as batteries are recharged, providing almost continual aerial monitoring, as long as flight conditions are suitable.
- Drones can be fitted with an additional infrared camera for use on low light or night detection flights. Some drones also include a laser range finder for accurate measurement of the geographic coordinates of a visual target.
- Drones can be quickly launched in response to acoustic whale detections to provide visual confirmation of presence and location of detected whales.
- Some drones can use dual controllers, with one controlling the flight while the other controls the cameras, allowing for MMOs to concentrate on species location and identification while the drone pilot focusses on the flight controls.
- Drones can be programmed to autonomously fly preset patterns around moving seismic vessels, such as circular flight paths at fixed offsets, or by using fixed routes around programmed geographic waypoints. They can also be used to scout well ahead of a seismic vessel along survey line transects, providing significant advanced notice of the presence of whales beyond the immediate mitigation zone.

- Drones can be used to electronically tag whales using drop tags to potentially add a valuable whale research data source during a seismic survey activity, in association with a third-party research organisation. This could result in improved PR for the survey operator.

Disadvantages of drones:

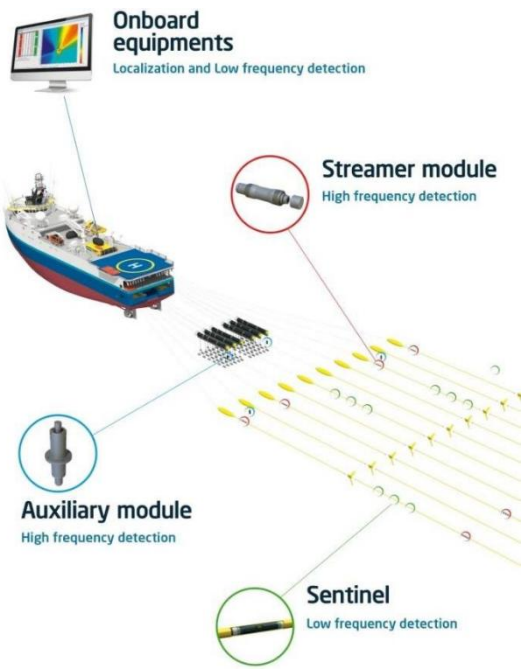
- Most drones cannot operate during periods of very poor weather, such as in strong winds or heavy rain although some high-end commercial drones, such as the DJI Matrice 30 and Autel Robotics EVO II Dual 640T Thermal drones, are weather resistant, including the controllers.
- Drones require trained pilots to get the best operational and safety performance from the aircraft. Pilots may also need to be trained as Marine Mammal Observers (MMOs) to aid in species identification and regulatory regimes. Alternately, MMOs may need to be trained as competent drone pilots.
- Drones can be subjected to attacks from bird species, causing loss of flight control and possible crash landings at sea.
- Drone flight limes are limited by battery life and regular landings are needed to replace batteries.

Vendor Equipment Reviews

Towed PAM

Sercel QuietSea

Conventional PAM (Passive Acoustic Monitoring) systems are composed of a separate PAM antenna at sea with a limited number of sensors. The Sercel system is an innovative PAM system integrated in the seismic acquisition system: for low-frequency detection, it is using up to 384 seismic hydrophones of the streamer sections and for high-frequency detection, up to 120 dedicated broadband hydrophones also integrated in the streamers (QuietSea Streamer Modules) and below impulsive source array (QuietSea Auxiliary Modules, intended to improve detection in the vicinity of the source).



This integrated system offers numerous advantages: good coverage of the exclusion zone (centered on the source) by many sensors, high precision of the marine mammal localization (by the mean of sensors positioning in real-time), reduction of the risk of accidents during deployment, easy retrieval and operation (no separate antenna at sea) and thus, significant reduction of operational downtime and possible equipment replacement costs.

Assessment Criteria	Comment
Availability	Immediate. Will be pre-installed on the survey vessel prior to mobilisation for the survey
Prior deployment histories and reported effectiveness.	Has been used worldwide since 2016 with demonstrated success.
Practicality of implementation	Easily implemented based on historical use
Safety & environmental concerns	No concerns raised
Cost versus benefit	Will be incorporated in survey activity budget. Benefits outweigh costs.

References

- https://www.sercel.com/products/pages/quietsea.aspx
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Seiche Towed PAM

The base system comprises a towed array cable, deck cable, electronic processing unit including data acquisition devices, computer and headphones. The physical spacing of hydrophones and the frequency response of the system provides optimal performance and the acoustic detection of species of interest. PAMGuard software is integrated as standard. Equipment is provided with 100% back-up.



The system can be readily configured to suit the project requirements. The array section includes either four or six hydrophones arranged in pairs of calibrated hydrophone channels with low noise preamplifiers, identical sensitivity and frequency response. An array depth sensor is integrated at the rear of the array. A 230 m heavy tow cable with a detachable 20-25 m array section may be preferred for harsh environments. A networked PAM station is available to enable the PAM system to be monitored and controlled from the most convenient location onboard.

Assessment Criteria	Comment
Availability	Systems available with advanced shipping notice ex-UK and USA
Prior deployment histories and reported effectiveness.	Many years of prior use on seismic surveys worldwide
Practicality of implementation	Practical for use on support or supplementary PAM vessels. Survey vessel will have Sercel QuietSea fitted.
Safety & environmental concerns	No significant concerns other than the need for additional in-water equipment deployment and recovery, with the potential for entanglement and personnel exposure to deck equipment.
Cost versus benefit	Cost of equipment and additional PAM operator personnel is not prohibitive

References

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- https://www.seiche.com/wp-content/uploads/2022/10/Seiche-Data-Sheet-Towed-PAM.pdf

Tethered PAM

Sercel Buoy Solution

Automated & Real-time detections via QuietSea algorithms

- Connected via IRIDIUM or 4G
- Harbour porpoise detector available
- Other species under development
- Raw data available for post-processing 〉 High level integration
- Detections are visible on the seismic vessel



Specifications

- Diameter: 1200mm
- Height: 2182 mm
- Weight: 210 kg (without the anchoring)
- Navigational Aid: LED Lantern, AIS Transponder, Real Time GPS tracker
- Telemetry: AIS, Iridium, 4G and Wi-Fi as needed and relevant.

Assessment Criteria	Comment
Availability	Sercel are currently building 4 x buoys for potential deployment as a trail in the Regia 3D survey area.
Prior deployment histories and reported effectiveness.	No history of use during seismic surveys. One prototype buoy in use in the UK for Harbour Porpoise detection trials.
Practicality of implementation	Potentially expensive to ship from Europe and deploy/recover in Victorian waters due to size and weights..
Safety & environmental concerns	None
Cost versus benefit	Unknown cost element but potentially advantageous pricing due to the CGG/Sercel business association and beta test status of the units.

Seiche Modular Buoy Systems

The Modular Buoy Detection System uses Passive Acoustic Monitoring (PAM) to provide a flexible approach to monitoring vocalising marine mammals and underwater noise.

The system consists of a remote moored buoy with a multi-element detachable hydrophone array suitable for mitigation and anthropological noise capture. Signals can be captured up to a sampling rate of 500 ks/s at 16 bit depth. The system can be configured to record the data locally within the buoy or remotely at the receiving station, whichever is required.

Further options include:

- Remote on/off via Radio Frequency (RF) link (868 Mhz)
- Real-time remote monitoring of audio via RF link (2.4 Ghz)
- Truly global remote control via Iridium
- Truly global GPS via Iridium



Telemetry

The buoy has the necessary components to transmit signals received at the hydrophone (PAM data) to the survey vessel, as well as transmitting position information (from an Iridium GPS receiver on board the buoy).

- The telemetry system for the PAM data operates in the 2.4 GHz band
- The position telemetry system operates in the 1–2 GHz band
- The remote power control system operates in the 868 MHz band

Hydrophone

Due to the modularity of the array sections, Seiche can provide custom-made array sections to suit specific needs. However, we also offer an off-the-shelf option with the following specification:

- • Hydrophone element H1
- • Super Broadband 10 Hz to 200 kHz (3 dB points)

Assessment Criteria	Comment
Availability	Unknown availability. No response received from Seiche at time of writing.
Prior deployment histories and reported effectiveness.	Unknown for seismic surveys but many commercial deployments quoted.
Practicality of implementation	Use of RF audio data telemetry, rather than satellite-based, may prove problematic due to distances involved between deployed locations and survey line lengths. However, if the effective operating range is beyond the required detection range it may be possible to deploy an array of buoys to provide continuous coverage around the survey area.
Safety & environmental concerns	None
Cost versus benefit	Unknown cost but likely not prohibitive for the project.

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JASCO Ocean Observer Buoy



A compact and powerful system for real-time passive acoustic monitoring (PAM), acoustic data collection, and non-acoustic measurements. Based on JASCO's OceanObserver electronics suite, it records data to removable memory with two classes of real-time telemetry options:

- Stream full bandwidth data via Wi-Fi, cellular, or VHF (short range, lifetime of days or weeks)
- Transmit processed information products via Iridium (long range, lifetime of weeks or months)

Collects data from acoustic and non-acoustic sensors and supports a variety of sensor and array options. Transmits full bandwidth data to nearby vessels or shore stations or performs in situ processing to transmit results via satellite, including marine mammal calls and clicks, pitch tracks for validation, vessel noise quantification, and ambient noise statistics. Typically fitted with up to three hydrophones, GPS, AIS, and Wi-Fi. Can be moored or free drifting.

Specifications

Mass:	45 kg , 99.3 lbs
Dimensions:	(D × H*)24 × 77 in [610 × 1956 mm]
Main platform:	JASCO Ocean Observer electronics suite
Local telemetry:	Wi-Fi, cellular, VHF
Global telemetry:	Iridium
Acoustic sensors:	Omnidirectional hydrophones
	Directional sensors
	Small linear or spatial arrays

Hydrophone suspension:	Straight cable or inverse catenary
Battery pack:	96 alkaline D-cells (internal)

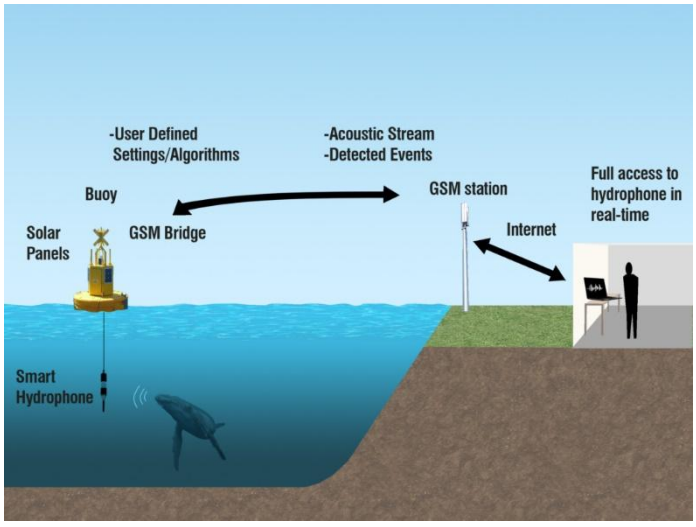
Assessment Criteria	Comment
Availability	Unknown
Prior deployment histories and reported effectiveness.	Unknown
Practicality of implementation	Similar in size and functionality to the Seiche buoys, the Jasco units would be no less practical to deploy and operate. The use of satellite telemetry to transmit "in-situ processing" needs to be clarified as far as time lag between detection and receipt of notification at the monitoring station. Otherwise the use of VHF telemetry to the survey (or ancillary) vessel limits the real-time detection range to around 30km.
Safety & environmental concerns	None
Cost versus benefit	Costing has yet to be confirmed but it is unlikely to be prohibitive for the project.

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PAM Smart Buoy

A Passive Acoustic Monitoring (PAM) Buoy offers real-time acoustic monitoring with a smart hydrophone, environmental data buoy and global system for mobile (GSM) communications bridge. When deployed in the ocean, the PAM Smart Buoy captures sounds from the surrounding environment and facilitates real-time acoustic data transmission.



Ocean Sonics' icListen Kayak new architecture is compact, energy efficient and scalable. This Smart Hydrophone has a wide dynamic range for high quality data & long term stability. This all-in-one instrument processes data while streaming HD acoustic data in real time. It is configured to keep all raw data or keep only data of specific frequency set by the user.

Key Features of Ocean Sonics icListen Kayak Hydrophone

- Passive Acoustic Monitoring (PAM)

- Bandwidth 10 Hz to 200 kHz
- 24-bit Resolution
- Very High Sensitivity
- Ultra Low Noise Sensing Element
- Extra Low Power, 0.2W
- Scalable – can be used in arrays of up to 100 hydrophones

Assessment Criteria	Comment
Availability	Unknown. No response received from vendor enquiry. Vendor based in Cyprus, so potentially an issue.
Prior deployment histories and reported effectiveness.	As above, no response received.
Practicality of implementation	This system utilises GSM data telemetry, so not practical outside GSM coverage areas.
Safety & environmental concerns	None
Cost versus benefit	Unknown cost of equipment of shipping.

Unmanned Vessel PAM

Autonaut USV



The AutoNaut is an uncrewed surface vessel (USV) propelled forward by the motion of the waves. Patented Wave Foil Technology enables long-term mission duration. Powered entirely by renewable energy and with no requirement for offshore personnel the AutoNaut significantly reduces costs and safety risks at sea. Solar energy powers an extensive range of sensors and equipment for 24/7 operation.

- Uncrewed operation: no offshore personnel at risk
- Powered by renewable energy: no fuel costs, no emissions
- Mission duration of several months
- Station keeping within 25 metres
- Storm-proven robustness
- Simple deployment/recovery from vessel or slipway
- Flexible payload and sensor capacity
- Data transfer

SENSORS

Seiche analogue array

The Seiche analogue array incorporates two hydrophone sensors and a depth gauge. It is 30m in length and has been designed for minimal flow noise and simple deployment.

Seiche digital thin line array

This high-sensitivity acoustic array is fully configurable in real-time. Eight digital hydrophone sensors are incorporated within the 25metre array.

Additional sensors

Additional sensors can also be incorporated for supplementary meteorological and oceanographic data as well as visual imaging.

Assessment Criteria	Comment
Availability	Unknown
Prior deployment histories and reported effectiveness.	Unknown
Practicality of implementation	Unknown

Safety & environmental concerns	None
Cost versus benefit	Unknown

OceanObserver on the Slocum Autonomous Underwater Glider

JASCO Applied Sciences has teamed with Teledyne Webb Research to integrate JASCO's OceanObserver™ intelligent acoustic monitoring system into the Slocum underwater glider. The buoyancy driven Slocum glider gathers data as it rises and dives in the water to propel itself forward. The Ocean- Observer system onboard records the underwater sounds while running automated cetacean detectors that flag possible marine mammal calls or other events of interest. The glider surfaces at specified intervals to send the flagged events to shore, where analysts can review and confirm the detections. All data are recorded on 6 TB of removable SD memory cards for full analysis upon retrieval.



Customized Detections and Processing

JASCO's experienced bioacousticians tailor the detection algorithms to the species and call types of your choice. Concurrent detections are associated to provide con-textual information for onshore analysts. During times of high glider self noise, the processing algorithms can be disabled to minimize false alarms, reducing personnel workload and maximizing satellite bandwidth use.

Intelligent Communications

The processed events are prioritized so that important events, like detections of species at risk, are sent first, making best use of the communication window. The event information is then distributed by email. The durations of the event time windows vary, and events are aggregated as ensembles, to maximize the contextual information available to analysts.

Detailed Detection Contours

The acoustic data, and even spectrogram images, are too large to be sent by satellite. So the Observer converts the detection spectrograms into frequency contours that are small enough to be relayed via satellite. Superior to pitch tracks, the contours give a richer representation of the data for easier, more accurate species detection and identification.

Customized Onboard Processing

- Marine mammal call detectors for baleen whales, toothed whales, and pinnipeds
- Various call types, including moans, whistles, and clicks
- Seismic pulse detection and quantification
- Ambient sound level calculations

Communication

- Telemetry via Iridium (RUDICS) satellite
- Detection information distributed via email to end users

Technical Specifications

Acoustics
Sample rate: 8–512 ksps
Resolution: 24 bits
Hydrophone: Customizable options from various manufacturers.
Sensitivities and frequencies tailored to your needs.

Physical
Mass: 55–70 kg 122–155 lbs
Length: 1.5 m 59.1 in
Hull diameter: 220 mm 8.7 in
Maximum depth: 1000 m
Horizontal speed: 0.35 m/s (0.68 knots) average
Up to 0.5 m/s (1 knots) with full drive

Assessment Criteria	Comment
Availability	Slocum Gliders are in use worldwide for various applications and availability is not expected to be an issue.
Prior deployment histories and reported effectiveness.	Has been used for whale detections previously. Unknown for use during a seismic survey.
Practicality of implementation	System can be deployed from the survey or a support vessel by one or two persons.
Safety & environmental concerns	None
Cost versus benefit	Unknown cost of implementation.

Camera-Based Systems

Seiche Smart Visual Detection System (SVDS)

The SVDS camera system consists of: High-Definition Video (HDV) and Long-Wave Infrared (LWIR) & thermal imaging camera pair, with on-board processing and storage. Each unit is housed robustly for maritime use. Various configuration options are available to ensure optimal visual coverage and ranges up to 360 degrees.



The new generation camera system builds on decades of experience of visual and underwater acoustic maritime monitoring combined with technologies originally found in self-driving vehicles. The cameras are more robust, compact, and lighter, making them easier to ship, and install, thereby reducing operational costs. Boasting lower power consumption and 1000x more powerful computing than the previous generation systems, the new cameras are capable of real-time on-board automated detection. For improved data security our cameras have built-in encrypted SSD storage to allow continuous data capture even during network interruption or observer workstation down time. The improved pan and tilt system allows for user configurable automatic scanning of an area up to 360 degrees.

General

- Modular customisable configurations
- Optional mounting systems
- Portable system deployed in hard case
- Fully marinised waterproof housing IP68 (pending certification)
- Hydrophobic glass
- Operating Temperature Range: -30°C to 70°C (pending certification)
- Shock: 1,500 g @ 0.4 msec (pending certification)
- Operating Voltage 19-30 VDC / supply voltage AC 110-240V
- Power consumption: Low power mode 20W Nominal 35W, Max Peak 135W
- On board GPU image processing 32GB on system storage
- On board Dual 4TB storage, main and encryption backup
- Networked removable storage up to 100TB
- Wi-Fi & satellite connectivity available on request
- GigE connectivity

- External triggers available 3.3V, 5V, 12V, serial optional protocol upon request
- Optional Workstations
- Built in 48 Channel GPS
- IMU orientation +/- 0.1°
- 360-visual scan with PTU

Software

- Mysticetus software compatibility
- Fast logging
- Auto detection (customised training dependant)
- Radar map visualisation with built in antenna for target location
- Automatic ranging – accurate target range estimation

RGB Camera: Standard RGB camera

(Optional upgrades):

- Sensor: 1/2.3 CMOS SONY IMX392
- Resolution: 2.4MP
- Array Size: 1920x1080
- Pixel Size: 3.45µm x 3.45µm
- Dynamic Range: 48dB
- Shutter Type: Global Shutter

Thermal camera:

- Thermal sensitivity: <40mK
- Pixel Pitch: 12 µm
- Full Frame Rate: 60 Hz
- Array size: 640 x 512
- f-number: 1.0
- Continuous Electronic Zoom: 1X to 8X zoom
- Spectral Range: Long-wave Infrared; 7.5 µm – 13.5 µm
- Scene Dynamic Range: to 140 °C (high) to 500 °C (low)

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Assessment Criteria	Comment
Availability	TBA

Prior deployment histories and reported effectiveness.	TBA
Practicality of implementation	The only limitation could be the ability to mount the camera in a position of unobstructed 360 degree visibility due to ship or USV masts.
Safety & environmental concerns	None
Cost versus benefit	TBA

WhalePOD

Introduction



WhalePOD is a bespoke thermal and colour camera system integrated with artificial intelligence, designed for automatic detections, ranging, and an intuitive software interface tailored for marine mammal detection and compliance reporting. What sets WhalePOD apart from other visual detection systems is our distinct camera platform design and approach. As we developed WhalePOD's camera platform to be deployed on vessels, our emphasis has been on achieving both long-range and high-speed panoramic coverage, day and night.24/7 automated detection of whale surfacing at sea.

Last month, we concluded a shore field trial of WhalePOD during the northern migration at North Stradbroke Island. The preliminary results are outstanding. To illustrate, during a night shift on 11 July, between 1 am and 4 am, I observed 40 whale surfacing events using our thermal camera, at distances ranging from 2 km to 4 km. In daylight, whale blows were visible from well over 10 km away. The system's ability to comprehensively cover an area without compromising detail was crucial in capturing these brief surfacing events. (*pers comms - Aqeel Akbar, Founder & Director, Thaum*)

Description

WhalePOD is an AI-centric product co-designed with regulators, industry, and researchers.

WhalePOD seeks to define a new gold-standard for ESG monitoring. We are aligning business outcomes with responsible stewardship and sustainability.

Feasibility Study: Awarded AUD $100k grant from NOPSEMA and AAD via BRII Priority Sectors, January 2020

ON Accelerate 7: WhalePOD completes Australia's premier deep-tech accelerator run by CSIRO, Feb-May 2023

Thaum, a startup team from the ANU Research School of Physics deep-tech incubator Momentum, is commercialising WhalePOD – a technology to enable a new age of industrialisation where environmental conservation and scientific contribution is an outcome of business, not a burden.

WhalePOD's disruptive vision capabilities help offshore industries implement harm mitigation strategies to protect marine mammals.

The core platform technology is a high-performance, panoramic, thermal and colour camera that uses artificial intelligence for 24/7, all-weather, and long-range detection of objects of interest in harsh marine environments.

Assessment Criteria	Comment
Availability	Thaum has indicated likely commercial availability in early 2024
Prior deployment histories and reported effectiveness.	Currently under testing for commercial deployment
Practicality of implementation	Unknown due to early stages of commercialisation
Safety & environmental concerns	None
Cost versus benefit	Unknown but unlikely to be cost prohibitive for the potential benefits of system deployment.

Aerial Drones

DJI Matrice 30T (thermal)

The new DJI Matrice 30 Series is DJI Enterprise's flagship drone that fits in a backpack. It integrates multiple high-performance sensors into one single camera payload, controlled with an ingenious redesigned remote control and runs on upgraded Pilot 2 software, which significantly improves the flight experience.

The M30 model offers much more power, endurance and capability for rugged professional uses, while its size makes it ideal for easy transportation and fast setup.



The DJI Matrice 30 series enterprise drone is a weather-proof, relatively portable UAV that offers a 48 MP stabilized camera with up to 200x hybrid zoom, thermal imaging camera, laser rangefinder, and a low-light optimized FPV camera. It comes with a new rugged DJI RC Plus controller. On top of that, an optional DJI Dock is able to automatically operate up to 7km away and charge the drone quickly when needed.

The M30 series comes in two versions, the M30 and the M30T. (Both versions are using a fixed payload system) The only difference is that the M30T also includes a thermal imaging camera. The use cases for this drone range from equipment inspection to seek-and-rescue types of missions.

The M30 model integrates a 48 megapixel 1/2" CMOS sensor zoom camera with 5×~16× optical and 200× digital zoom, a 12-megapixel wide-angle camera, 8k photo 4K/30 fps video resolution, and a laser rangefinder that can give the precise coordinates of objects up to 1,200 meters away.

Despite having integrated payloads, the Matrice 30 Series will continue to support PSDK integration for third-party payload development, including spotlights, loudspeakers, gas detectors, parachutes, and more.

It's clear DJI wants to revolutionize drone operations by extending flight time and use, regardless of the environment. When equipped with two TB30 intelligent batteries the new Matrice 30 Series drones offers up to 41 minutes of flight time. The self-heating feature of the TB30 batteries helps the M30 stay functional in extremely cold environments.

As part of the M30 Series kit, DJI launched the BS30 intelligent battery station, which can charge 4 pairs of the TB30, at three different levels: standard, storage, and ready to fly. Each level maintains differing charge capacities:

- **Standard:** Charges batteries to 90% in 30 minutes.
- **Storage:** Maintains batteries at 50% for a longer lifespan and overall health.
- **Ready to Fly:** Maintains full charge for immediate hot-swap during operation.

Key Features:

Wide Camera

- Equivalent Focal Length: 24 mm, DFOV: 84°
- 12 MP 1/2" CMOS Sensor
- Video Resolution: 4K/30fps
- Zoom Camera
- 48 MP 1/2" CMOS Sensor
- 5×-16× Optical Zoom
- 200× Max. Hybrid Zoom
- Photo Resolution: 8K
- Video Resolution: 4K/30fps

Thermal Imaging Camera

- Equivalent Focal Length: 40 mm
- Resolution: 640×512
- Frame Rate: 30fps
- Measurement Accuracy: ±2°C or ±2%
-
- Laser Rangefinder
- Range: 3 m - 1200 m
- Accuracy: ±(0.2m+D×0.15%)

Powerful Flight Performance

- A balance of power and portability delivers higher operational efficiency. Max Flight Time: 41-min
- Wind Resistance: 15 m/s
- Service Ceiling: 7000 m
- Max Speed: 23 m/s

Environmental Adaptability

- With IP55 protection, the M30 can easily handle adverse weather and temperatures ranging from -20° C～50° C.

FLAGSHIP PERFORMANCE

HYBRID VISUAL, THERMAL, LRF PAYLOAD CAMERA



Assessment Criteria	Comment
Availability	Available from several Australian vendors or direct from DJI
Prior deployment histories and reported effectiveness.	No available data on use for whale sighting missions but demonstration video footage of night search and rescue of people in the ocean would suggest whales would also be sighted using the thermal image camera when at the sea surface.
Practicality of implementation	Should be easily implemented with flights based to and from the survey vessel helideck. Need to check the potential for registering moving platform automated Return To Base (RTB) in the event of communications failure.
Safety & environmental concerns	None identified
Cost versus benefit	Relatively inexpensive drone purchase price at ~AUD18K. Cost of an additional contract drone pilot, if required, including bunk space & meals, may prove more costly and logistically restrictive.

Autel EVO II Dual 640T Enterprise

The Autel Robotics EVO 2 Dual 640T V3 is one of the most compact and advanced thermal drones on the market. Featuring a 640x512 radiometric thermal sensor and 50MP RGB lens with 16x digital zoom - it is easy to observe distant targets in amazing detail. The system uses a new image processing algorithm making thermal imaging details clearer and more discernible than competition with the similar resolution and hardware. With a 38-minute flight time and 9.3-mile transmission range - the EVO 2 Dual 640T V3 is a powerful tool professionals can use to get the job done right!

Thermal Camera

The thermal camera is equipped with a 13mm focal length lens and the ability to record at 640 x 512 resolution at 30 Hz. In dangerous situations, you can keep the drone back as you use 16x digital zoom with 4x lossless zoom to find what you're looking for. The V3 thermal image is designed to better display discernible differences and detail. Keep reading to view the array of thermal modes and features the EVO II Dual 640T offers, in addition to its thermal detection, recognition, and identification ranges:



- Central temperature measurement: View real-time temperatures in the center of the remote's display.
- Spot temperature measurement: Tap the remote's display and view an object's temperature in real time.
- Regional temperature measurement: A dynamic view of average, minimum, and maximum temperatures.
- Ten thermal color palettes: White Hot, Cold and Hot, Rainbow, Enhanced Rainbow, Ironbow, Lava, Arctic, Searing, Gradation, and Heat Detection.

- Picture-in-picture display mode: View visual and thermal imaging at the same time.
- Temperature alarm: This will monitor a set temperature in real time and set off an alarm if reached.
- Isotherm: Set a temperature range and the system will detect any object in view that's within that range.
- Image enhancement: Real-time adjustment of the thermal image brightness, contrast, and details; the system will highlight any object within the target temperature.
- Infrared thermal analysis tool: The IRPC tool quickly imports images, edits and analyzes temperature measurements, and generates detailed reports for sharing and collaboration.
- Detection range: Detects a person up to 0.34 miles away, an SUV from up to 1.03 miles away, and a truck from up to 1.8 miles away.
- Recognition range: Recognize if an object is a person from up to 443' away, an SUV from 0.26 miles away, and a truck from up to 0.45 miles away.
- Identification: Identify a person from up to 223' away, an SUV from up to 682' away, and a truck from up to 0.22 miles away.

Visual Camera

Inspections and rescues are not the only things you can do with your EVO II Dual 640T. The 50MP visual camera is capable of capturing stunning professional footage at 4K HDR resolution. With its 0.8" RYYB CMOS sensor instead of a traditional RGB sensor, the larger surface area delivers a high level of detail in high-contrast lighting conditions. Dynamic tracking shots are possible with the quick focusing of the PDAF+CDAF system, and low-light scenes will be clearer thanks to the moonlight algorithm 2.0's increased noise suppression.

Smart Controller V3 with SkyLink 2.0

Utilizing SkyLink 2.0, the Smart Controller V3's built-in 7.9" display can receive HD video transmission in flight from up to 9.32 miles away (or QHD quality from up to 0.62 miles away). Reception is engineered to be stable and interference-free, thanks to triple-band (900 MHz, 2.4 GHz, and 5.8 GHz) frequency hopping. Thanks to the display's 2000 cd/m² brightness, you can easily view the drone's footage, even in direct sunlight. You're not restricted to flying on sunny days, though. The Smart Controller V3 can withstand -4 to 104°F temperatures and is IP43-rated for all-weather performance.

360-Degree Obstacle Avoidance

While in flight, an array of 19 sensors, including 12 visual sensors, the main camera, ultrasound IMUs, and more, can build a 3D map of the drone's surroundings and plan a clear path to its destination in real time.

Additional Features

- Foldable design
- Can deploy and take off in under a minute
- Up to 38 minutes of flight time
- Up to 39 mph of maximum wind resistance
- Maximum flight speed up to 45 mph

- Maximum payload up to 2 lb
- Can be flown even if the firmware and app are not fully updated
- Without built-in fly zones, nothing prevents you from taking off when needed
- The EVO II Dual 640T is not under the United States ITAR (International Traffic in Arms Regulations)
- Compatible with optional Live Deck 2 for broadcasting live mission intel

Assessment Criteria	Comment
Availability	Available from at least one Australian vendor or from Autel based in Honk Kong or Shenzen.
Prior deployment histories and reported effectiveness.	No available data on use for whale sighting missions but demonstration video footage of night search and rescue of people in the ocean would suggest whales would also be sighted using the thermal image camera when at the sea surface.
Practicality of implementation	Should be easily implemented with flights based to and from the survey vessel helideck. Need to check the potential for registering moving platform automated Return To Base (RTB) in the event of communications failure.
Safety & environmental concerns	None identified
Cost versus benefit	At ~ AUD$10K the Autel 640T is less costly than the DJI M30T but lacks some of the DJI technology, like laser ranging and 200X image zoom. Cost of an additional contract drone pilot, if required, including bunk space & meals, may prove more costly and logistically restrictive.

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