# A Report on a PAMGUARD Conference and Workshops held at Heriot Watt University, Edinburgh 28th-29th of March 2007

Compiled by Jonathan Gordon

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**Note:** This document supplements the conference proceedings which were produced as a CD ROM. This includes all of the presentations and the materials for the hands-on workshop. Additional copies of this CD can be obtained from Jonathan Gordon (JG@ecologicuk.co.uk)

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## Objectives

The objectives for this event, agreed by the steering committee, were:

- To introduce passive acoustic monitoring (PAM) and the PAMGUARD project to a broad audience of stakeholders, including marine mammal observers (MMOs), PAM providers, regulators, and developers.
- To provide initial training and an introduction to the PAMGUARD software for users such as PAM operators, MMOs (and others) and for developers. This would also allow the team to receive, collate, and eventually incorporate their feedback.
- To initiate and guide discussion on the strengths and weaknesses of using PAM with different species and in different situations.
- To discuss areas for development and contribution from other PAM software developers within the open source framework of PAMGUARD.

## Organization

### Conference Planning

Planning for the conference and workshops was coordinated by a **steering committee** representing a range of user and interest groups. These were:

Oil and Gas Industry
Dave Hedgeland, Mike Jenkerson, Roger Gentry – Oil and Gas Producers' Joint Industry Programme (OGP JIP), UK

Regulators:
Carol Roden, Minerals Management Service, USA

The PAMGUARD project
Dave Mellinger, Oregon Sate University, USA

PAM providers
Technical – Roy Wyatt, Seiche, UK
Personnel – Mary Jo Barkaszi, GeoCet, USA

Academia
Gianni Pavan, University of Pavia, Italy

The steering committee did its work by email and a series of conference calls.

Jonathan Gordon acted as the secretariat and was responsible for coordination and for most of the practical arrangements for the conference.

## PAMGUARD Development

PAMGUARD was developed by a consortium of research groups-

- Heriot-Watt University, Edinburgh, Scotland, UK
- Oregon State University, Newport, Oregon, USA
- Scripps Institution of Oceanography, San Diego, California, USA
- Sea Mammal Research Unit, University of St Andrews, Scotland, UK
- EcologicUK, Newport on Tay, Scotland UK

## Overview

In order to achieve the ambitious goals and broad spectrum of objectives agreed by the steering committee, the meeting was held over two days. The first day was a small conference consisting of a series of formal presentations on PAMGUARD and other PAM applications while the second day involved hands-on practical training and orientation workshops for both users and developers which ran concurrently with six facilitated workshops providing opportunities for discussion and input from all of the participants.

**Day One** was taken up with as series of lectures from the Pamguard team and other contributors. In all, 18 lectures and short talks were presented along with four posters.
**Day Two** consisted of six facilitated workshops on various aspects of PAM which ran concurrently with two hands-on introductory training sessions with the PAMGUARD software and a workshop for those who might be interested in developing modules in PAMGUARD in the future. These workshops were developed and run by the PAMGUARD team with assistance of trained assistants. The day finished with a meeting to discuss ASA standards for acoustic monitoring for marine mammals being developed by Aaron Thode.

**Attendance** was good with around 90 people participating. As might be expected given the venue, the majority were from the UK but there were also attendees from USA, Canada, France, Italy, Norway, Greenland, Mexico, Denmark, Portugal, Syria and Australia, Attendees also provided a good representation of the different stake holders and interest groups. (A list of attendees is provided in Appendix 1). Feedback received both directly and via questionnaires was very positive.

## Venue

Heriot-Watt University was chosen as the venue for the conference and workshops for a number of reasons. The Heriot-Watt conference centre provided a high quality auditorium and affordable overnight accommodation within easy range of Edinburgh Airport. Heriot-Watt University Department of Electrical, Electronic and Computer Engineering has also been the institution providing the coordination role for the PAMGUARD development project and the Department generously made available fully equipped computer teaching labs and two lecture theatres to accommodate the workshops and training sessions on the second day.

## Program for Day 1. 28th of March 2007

**Venue: Lecture Theatre 1, Herriot Watt Conference Centre**

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| 08:30-09:15 | **Registration. Lecture Theatre 1** |
| **Session One. Chair Ron Mc Hugh, Heriot-Watt University.** | |
| 09:15 - 09:20 | Welcome, Introduction<br>***Ron McHugh, Heriot-Watt University, UK*** |
| 09:20 - 9:45 | Why PAM? An introduction to marine mammal acoustics and passive acoustic monitoring for mitigation and research.<br>**Jonathan Gordon, EcologicUK, UK** |
| 9:45 - 10:15 | Principles and approaches to automatic detection and classification: a non-technical overview.<br>**David K. Mellinger, Oregon State University, USA**<br><br>Principles and approaches to localisation: a non-technical overview.<br>**Aaron Thode, Scripps Institution of Oceanography , USA** |
| 10:15 - 10:30 | Discussion |
| 10:30 – 11:00 | The PAMGUARD Concept. Why it is necessary, goals, organisation, structure, future plans<br>**Mike Jenkerson, International Association of Oil and Gas Producers, E&P Sound and Marine Life** |
| 11:00-11:15 | Coffee and posters |
| **Session 2 Chair David Mellinger, Oregon State University** | |
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| 11:15 - 13:00 | To provide an overview from a range of perspectives of people's experiences of using PAM and how PAMGUARD should contribute nine short (~10 mins) presentations were invited. |
| 1 | Uses of passive acoustics in research: the "Song of the Whale" story**.** **Oliver Boisseau, International Fund for Animals Welfare, UK** |
| 2 | Seismic Operations perspective **David Hedgeland, PGS** |
| 3 | Bioacoustic applications and analysis requirements for biological research. **Harold Figueroa, Bioacoustic Research Program, Cornell University, USA** |
| 4 | Passive Acoustic Monitoring Using DASARs to Assess Impacts of Offshore Oil Production on Bowhead Whales at BP's Northstar Facility, Alaskan Beaufort Sea **Bill Streever, BP, USA** |
| 5 | Construction/other Energy related activities, (piling, decommissioning.) **Roy Wyatt, Seiche, UK.** |
| 6 | Military perspective **Ed Harland, Chickerell Bioacoustics, UK** |
| 7 | Regulatory perspective **Zoe Crutchfield, JNCC, UK?** |
| 8 | MMO perspective. **Alison Gill, Marine Team** |
| 9 | PAM equipment and service providers perspective**.** **Scott Carr, JASCO, Canada** |
| | Discussion |
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| 13:00-13:45 | Lunch. and posters |
| **Session 3. Chair Mary Jo Barkaszi, GeoCet, USA** | |
| 13:45-14:30 | A non-technical introduction to the PAMGUARD software environment.<br>***Douglas Gillespie, University of St. Andrews, UK*** |
| 14:30-14:40 | Discussion |
| 14:40-15:00 | Pamguard in the seismic arena: challenges and possibilities.<br>***Jonathan Gordon and Douglas Gillespie, Sea Mammal Research Unit, University of St. Andrews, UK*** |
| | Discussion |
| 15:00–15:30 | Tea and posters. |
| **Session 4. Chair Roy Wyatt, Seiche, UK** | |
| 15:30-15:50 | Broader Consideration of future development of PAMGUARD.<br>***David K. Mellinger, Oregon State University, USA and Aaron Thode, Scripps Institution of Oceanography, USA*** |
| 15:50–16:00 | Discussion |
| 16:00-16:30 | Strategies for long term sustainability of PAMGUARD<br>**Phil Trinder, Heriot-Watt University, UK** |
| 16:30–16:45 | Discussion |
| 16:45-17:00 | Wrap up. Overview of next day's activities |

## Abstracts of Presentations on Day 1

(Note: These abstracts as well as flash and pdf versions of the Powerpoint presentations are provided on a CD which was produced as a proceedings for the conference and distributed to all participants.)

### Why PAM? Introduction to marine mammal acoustics and passive acoustic monitoring for mitigation and research.

*Jonathan Gordon, Ecologic UK,*

The development of PAMGUARD is testament to a growing interest in and acceptance of the use of passive acoustic monitoring to detect marine mammals at sea for both for research and mitigation. There are essentially two reasons why PAM contributes so much to the problem of detecting so many marine mammals. On the one the one hand, these animals, even the large whales, are very difficult to spot at sea. They spend only a small proportion of their time at the surface and may only produce visible cues intermittently. Detection of these is greatly affected by weather conditions, falling off rapidly as sea state increases above two or three, and of course during poor visibility, (such as fog) or when its dark (approximately half the time) they are effectively invisible. By contrast, on the other hand, many marine mammals produce loud distinctive calls when they are underwater, and some do this frequently and consistently. Sound propagates extremely well through the sea, making it the medium of choice for long term sensing and communication underwater for both humans and marine mammals and many marine mammals can be detected at substantial ranges, often further than they can be seen. In addition, acoustic monitoring is less onerous than visual searching and can often be conducted with smaller teams operating from smaller less expensive vessels. There is also a substantial potential for automation of the detection and localisation process.

Marine mammals exhibit a huge diversity and range of acoustic behaviours and vocalisation types. For example, thinking simply in terms of frequency, vocalisations range from the infrasonic (15Hz) moans of blue whales that can be detected at ranges of tens to 100s of kms to the high ultrasonic narrow band pulses of harbour porpoises (130kHz) which can only be detected at distances of several hundreds of metres. This diversity is also reflected in wide differences in the opportunities and constraints in monitoring different marine mammals species acoustically, in the techniques, equipment and approaches required for PAM and in the extent to which PAM enhances our ability to detect these animals.

There can be a tendency to portray acoustic and visual techniques as being in competition, which of course is not helpful. They are simply two of the most promising techniques for detecting marine mammals in the field, and in many cases they are complimentary with the strengths of one approach compensating for shortcoming in the other. During mitigation exercises, the objective is often to maximise the probability of detection and monitoring teams should use intelligent combinations of approaches to achieve this.

One of the great advantages in using PAM is the impressive and growing extent to which computer programs can be used to make detections and calculate locations. Automated acoustic monitoring has several potential advantages. It can make PAM easier to perform, and reduce the size of field teams required, it can result in a more consistent and predictable performance and efficiency, it can allow detections outside the human auditory range and it can allow the spatial localisation of vocalisations in near real time. Indeed, some of the most impressive capabilities of

PAM can only be achieved with the help of dedicated analysis programs. PAMGUARD is being developed to the address the needs of PAM for mitigation and monitoring with an emphasis on real time detection and localisation using affordable and equipment and a straight forward interface for non-specialist operators working at sea in challenging conditions.

## Principles and approaches to automatic detection and classification: an overview for non-specialists

*David K. Mellinger, Oregon State University, USA*

Passive acoustic monitoring is becoming widely used for detecting marine mammals at sea. Passive acoustic detection can be done manually, by having an expert detect sounds as they are received by the hydrophones. It can also be done automatically, using a computerized detection method that detects sounds of some species.

Automatic methods have been devised for click sounds made by dolphins and toothed whales, for whistles made by dolphins, for the stereotyped moans made by some baleen whales, and for highly variable sounds made by other baleen whales such as humpback whales. For using any automatic detection method, a key issue is the level of specificity desired: Do you need to detect all marine mammals? Some sub-group, such as beaked whales or baleen whales? A certain species, such as blue whales? Or a certain call type, such as the "creak" vocalization of sperm whales? Different methods are useful for detecting each of these. Another important issue is the tradeoff between detecting as many calls as possible and the number of false detections. Generally as a detection method is asked to detect fainter and fainter calls, it becomes more and more likely to make mistakes in which it "detects" things that are not really calls. Understanding these issues is essential to using automatic detection effectively.

## Principles of passive acoustic localization

*Aaron Thode, Scripps Institution of Oceanography , USA*

The localization of an underwater sound is a key component of passive acoustic monitoring. Besides determining whether a particular sound lies within a mitigation zone of interest, localization methods can also enhance detection and classification efforts, provide information on the source levels of sounds of interest, and provide information about oceanic propagation conditions. Localization will also be a key component in efforts to monitor ocean populations via acoustic "censusing".

All localization methods consist of measurements of an acoustic field, an a model that is used to translate the measurements into an estimate of animal position. The most common measurements used for marine mammal localization are the relative arrival times of a sound at a set of hydrophones at different locations. If the sound also arrives via different propagation paths, such as from a surface or bottom reflection, then the relative arrival times of this "multipath" can also be used for localization. Given a model that assumes how fast sound travels underwater, a 1, 2, or 3-D localization can be obtained. The simplest localization procedure, estimating the bearing of a sound using two closely-spaced hydrophones, uses this type of localization procedure. Although the basic method has been used on marine mammals for almost 40 years in the open literature, refinements in the method continuously appear, such as the use of more sophisticated propagation models that explicitly account for depth-dependent sound speed profiles and multipath arrivals.

One of the greatest challenges of implementing the method are identifying the relative arrivals on different hydrophone systems, particularly in cases where multiple animals are present, and when a given animal is repeating a stereotyped call at an interval that is less than the travel time between receivers. Other challenges include accurate modelling of sensor positions (particularly sensors that shift position with time) and detection range limitations from a single hydrophone.

Two other measurements that are currently being used to track marine mammals are direct measurements of sound particle velocity (e.g. DIFAR sensors) and measurements of the interference pattern a low-frequency sound produces as it propagates in a shallow ocean or near the ocean surface. The talk concludes with a list of localization methods that are currently implemented in popular bioacoustic software, including PAMGUARD

### Use of Towed Passive Acoustic Monitoring (PAM) systems during seismic operations

*D. Hedgeland, International Association of Geophysical Contractors (IAGC), UK*

In recent years, recognising the potential benefits offered by PAM technology, the use of PAM systems during seismic operations has been investigated in various areas; for example offshore UK, Australia, Brazil, Canada, USA and West Africa. These activities have further highlighted a number of issues related to the operational use of acoustic monitoring methods with seismic surveys.

While initial results from early research studies showed promise, it is clear that further development is required to overcome some of the shortcomings now commonly associated with towed PAM systems, which include limited range and bearing estimation capabilities inherent in using a two element hydrophone array, limited automated species recognition and a need for an experienced operator to interpret detection data in real-time.

The number of experienced PAM operators is limited due to the broad combination of skills required in the fields of marine mammal biology, hardware/software engineering and seismic operations (particularly with regard to safety) in order to optimize the use of PAM during offshore operations.

### Passive Acoustic Monitoring Using DASARs to Assess Impacts of Offshore Oil Production on Bowhead Whales at BP's Northstar Facility, Alaskan Beaufort Sea

*Bill Streever, Environmental Studies Leader, BP, PO Box 196612, Anchorage, Alaska, 99519-6612, USA.*
*Susanna B. Blackwell and Charles R. Greene Jr., Greeneridge Sciences Inc., 1411 Firestone Rd., Goleta, Calif., 93117, USA.*
*Trent L. McDonald, WEST Inc., 2003 Central Ave., Cheyenne, Wyoming, 82001, USA.*
*W. John Richardson, LGL Ltd., environmental research associates, 22 Fisher St., POB 280, King City, Ont., L7B 1A6, Canada.*

Industrial activities that change the behavior of the bowhead whale (*Balaena mysticetus*) are regulated in the U.S.A. In addition, the subsistence harvest—a culturally defining activity of the Inupiat people—is protected by local and federal

laws. Both scientists and Inupiat hunters were concerned that the Northstar production facility 6 km offshore in the Beaufort Sea would deflect whales away from their normal fall migration corridor. Every September since Northstar construction in 2000, stationary passive acoustic monitoring devices have been used to localize whale calls and to assess the effect of Northstar sounds, which varied from about 80 to 125 dB RE 1µPa (10-450 Hz), as recorded ~450 m seaward of the island. These devices, called DASARs (Directional Autonomous Seafloor Acoustic Recorders), are deployed in an array so that whale calls heard at two or more stations can be localized through triangulation. As many as 49,000 localizations have been collected in a single study season. Application of quantile regression analyses suggests statistically significant changes in the locations of the closest calling whales during periods when Northstar activities result in sound levels above ~110 dB RE 1µPa at the monitoring location ~450 m offshore. Boat operations appear to be responsible for the majority of sounds greater than 110 dB RE 1µPa. Following these findings, Northstar replaced its crewboat with a hovercraft producing less in-water sound and attempted to minimize other boat traffic. Data from the DASARs are also being used to better describe bowhead whale calling behavior and to assess changes in calling behavior in response to industry sounds. As a mitigation tool, Passive Acoustic Monitoring is now most often employed during seismic and naval operations. However, Northstar and similar studies show that it can also be important for research, monitoring and mitigation associated with other industrial activities.

**Passive Acoustic Monitoring. Applications in Construction and Demolition**
*Roy Wyatt, Seiche Measurements Ltd*

The presentation considers the use of Passive Acoustic Monitoring in the applications of shallow water pile driving (construction) and oil rig de-commissioning (demolition).

The shallow water pile driving section of the presentation is based on work carried out in Milford Haven which is within the Pembrokeshire Marine Special Area of Conservation. In this area both the harbour porpoise and grey seal are common. The methods used to determine the sound pressure level generated by the piling operation and the mitigation methods put in place are discussed.

The rig de-commissioning section of the presentation discusses the method used to mitigate for the noise of explosives used to remove steel structures from the sea bed. A remote Passive Acoustic Monitoring system has been developed to enable acoustic monitoring of the mitigation area whilst the operating vessel is at a safe distance from the explosive charges

**PAMGAURD Workshop – Regulatory Perspective**
*Zoe Crutchfield, JNCC, UK*

The Joint Nature Conservation Committee (JNCC) provides advice to the UK Government including Department of Trade (DTI) and Industry and Department for Food and Rural Affairs (Defra) on the noise impacts of marine industry activities occurring in UK waters. Zoe Crutchfield, Senior Offshore Advisor at JNCC, will provide a brief overview of the consenting regime within UK waters and how Passive Acoustic Monitoring can be used as an effective mitigation tool for industrial activities. This talk will discuss what an 'ideal' PAM system would be like for mitigation purposes in relation to piling operations associated with windfarms and the use of explosives or seismic surveys during oil and gas industry activities.

## Marine Mammal Observer's Perspective on PAM

*Alison Gil,l Marine Team Offshore, UK.*

In recent years there has been increased concern for the effect of man-made noise pollution in the ocean, particularly upon cetaceans - which are known to be sensitive to sound. As a result, environmental regulations have been introduced in an attempt to minimise negative impacts on marine wildlife in some areas of the world. These guidelines have focused on the oil industry's seismic exploration for offshore oil. They centre on the practice of delaying or shutting down the use of air-guns if a whale or dolphin is sighted nearby.

Marine Mammal Observers (MMOs) are employed to implement these regulations in the field and to date, most of the effort involved in detecting marine mammals has been carried out by visual methods. However, several offshore projects have involved the use of Passive Acoustic Monitoring (PAM). While mitigation guidelines are clear on how visual monitoring should be conducted, guidelines for using PAM are more open to interpretation. For some offshore projects PAM is used as an aid to visual monitoring whereas for other projects PAM is an essential requirement for mitigation. MMOs have, over the last few years, faced a number of scenarios when using PAM offshore which influence its effectiveness as a mitigating tool. The ability to determine the range and bearing of species is often compromised by the method of deployment of the PAM equipment i.e. whether it is deployed from the guard vessel or from the source vessel. Ambient noise from the source vessel can sometimes make any detection unlikely, however choosing to deploy from the guard vessel compromises the ability to pinpoint the location of the animal in relation to the exclusion zone around the airguns.

The standardisation and development of PAM software into the PAMGUARD framework will improve the ability to locate marine mammal species and consequently allow more accurate mitigation decisions. The range in experience of MMOs being employed as PAM operators should be considered in the development of this software and it is recommended that the software is designed appropriately. When developing PAMGUARD the involvement of working MMOs should be encouraged to provide feedback during its development to ensure a workable system for future mitigation.

## A non-technical introduction to the PAMGUARD software environment.

*Douglas Gillespie, Sea Mammal Research Unit, University of St Andrews, Scotland, UK.*

The applications of Passive Acoustic Monitoring (PAM) are many and varied, driven both by the species (and therefore types of sounds) likely to be encountered in a given area and also be the type of information required. For instance, if one were developing mitigation for the deep waters of the Gulf of Mexico, detectors for sperm whales would be required. In the southern North Sea, sperm whales are unlikely to be encountered and the detection system would need to be optimised for harbour porpoise and other small odontocetes. Even within one sea area, different studies might require different types of information. For instance, during a mitigation survey, measurement of range may be of primary importance, while species id is less critical. For an abundance survey, species id may hold a much higher importance.

The PAMGUARD software has been developed to provide flexibility for both users and developers. Users may configure any number of detectors for different types of sound, the only limitation being the available processor power and memory of the computer in use. Multiple instances of the same basic detector can run simultaneously if desired. For example, the same basic click detector can be configured for both sperm whales and for harbour porpoises, spectrogram cross correlation detectors could be configured for both blue and fin whale calls. The user interface clearly shows the relationships between the various detection modules and the data flow between them. Wherever possible, data are shared between detectors. For instance, the same FFT data can be used for display on a spectrogram display and or for further analysis e.g in an odontocete whistle detector.

For the developer, built in modules for sound acquisition, array configuration, the writing of data to a database and a large number of graphics classes already exist and can easily be accessed or incorporated into new detection modules. This allows the developer to concentrate on algorithm development without necessarily becoming expert in the complexities of sound card and database interfaces. Each detector exists as a clearly defined and separate plug-in module allowing multiple developers to work simultaneously and independently. PAMGUARD is written in JAVA, which is available for free from Sun Microsystems. Development tools are also freely available, which again increases accessibility for many potential developers.

## PAMGUARD in the seismic arena: challenges and possibilities

*Jonathan Gordon, Ecologic UK, UK*
*Douglas Gillespie, SMRU, UK*

One of the most important applications for PAMGUARD will be in monitoring as part of mitigation during seismic surveys. Seismic surveys are the some of the biggest, most expensive, and noisiest, data gathering exercises routinely conducted in the modern world and carrying out PAM in the middle of this activity presents some challenges, as well as exciting opportunities. The PAMGUARD project has maintained a focus on providing a broadly applicable piece of software while recognizing that many of the solutions to these problems will be hardware dependent. The PAMGUARD team is also well aware that a huge body of expertise exists within the wider seismic industry which in most cases will be far better able to assess and solve these potential problems. This meeting and the workshops that follow, provide the ideal opportunity to move forward the dialogue that will result in practical and effective solutions.

In this talk, based on our (somewhat modest) experience of working in conjunction with seismic surveys, we lay out some of the issues that we anticipate needing to overcome and some of the potential advantages and opportunities of conducting PAM from seismic vessels, with the intention of stimulating a process of discussion and collaboration to develop solutions.

## Broader consideration of future development of PAMGUARD

*David K. Mellinger Oregon State University, USA*
*Aaron Thode Scripps Institution of Oceanography , USA*

To date, the PAMGUARD software has been designed primarily for real-time monitoring of marine mammals for mitigating the impacts of seismic surveys. Its design, however, is flexible enough that it ultimately could be used for a broad range of applications in marine and perhaps terrestrial bioacoustics. Such applications for

marine mammals include population assessment, studying acoustic population structure (demarcating clans, stocks, subspecies, etc.), estimating seasonal distributions from fixed long-term autonomous hydrophones, understanding impacts of manmade noise on marine mammals, studying marine mammal social interaction, including courtship and mating behaviour, and assessing impacts of marine mammals on fisheries. For each of these topics, the requirements of further PAMGUARD development are reviewed and links to other analysis software are discussed.

Current trends in bioacoustic monitoring suggest that software capabilities that exploit array gain, permit corrections in clock drift between autonomous recorders, exploit vector sensor capabilities, and incorporate more sophisticated propagation modelling will be increasingly important in the future. In addition to the areas mentioned above, experience with Ishmael shows that users will find a very wide range of other uses for bioacoustics software, including many having nothing to do with marine mammals

### PAMGUARD Sustainability

*Ron McHugh and Phil Trinder*
*Heriot-Watt University, Edinburgh, Scotland*

This talk covers the long-term future of the PAMGUARD software. A key issue is that PAMGUARD is Open Source, i.e. available for the community to use and to extend. The talk starts by exploring the philosophy of Open Source software, and how Open Source communities work. Like any other software, however, PAMGUARD requires maintenance and development and the talk moves on to discuss Open Source business models.

The second half of the talk reviews the funding history of PAMGUARD, looks at the required support infrastructure, and will outline preliminary ideas for future funding. The talk aims to initiate a discussion on ongoing funding with the PAMGUARD user community.

## Poster Abstract

### Passive Acoustic Monitoring during Seismic Surveys – a useful tool?

*Clark, N*, Robinson, N* and Walker, R**
**Gardline Environmental Ltd, Endeavour House, Admiralty Road, Great Yarmouth, Norfolk, NR30 3NG. Corresponding author, email: nicola.clark@gardline.co.uk*

Gardline Environmental Ltd have provided Marine Mammal Observers and Passive Acoustic Monitoring Systems (PAMS) to a number of Oil and Gas companies during Seismic Surveys in UK and International waters. In UK waters PAMS are primarily utilised in areas of high cetacean sensitivity. Results from surveys in waters West of Shetland and the Moray Firth show both the strengths and limitations of PAMS. In both cases, the hydrophone array consisted of two related pairs of hydrophones (medium and high frequency) connected to IFAW's Logger, Porpoise, Click and Whistle software. During a 14-day survey West of Shetland, a total of 118 visual detections were made, of which only 13 were detected by the PAMS, however there were 12 occasions when cetaceans were detected acoustically but were not seen. Animals detected acoustically included the sperm whale, pilot whale and Atlantic white-sided dolphin, as well as these species fin and humpback whales were sighted.

There are several reasons why the PAMS did not detect a number of the sightings; high background noise, distance to sighting, orientation of the animal to the hydrophone, frequency of cetacean vocalisation (detection range of the hydrophone was 0.1kHz to 150kHz, not low enough to detect some vocalisations of the larger baleen whales) and whether the animals were acoustically active. In the Moray Firth no visual observations of marine mammals were recorded during a 10-day survey, however, 27 cetacean acoustic detections were registered, all of which were of harbour porpoise. A wide variety of acoustic detections were recorded, the majority of which occurred at night (89%), when without the presence of the PAMS the animals would have gone undetected. During the survey, seismic operations were delayed on three occasions due to the close proximity of animals. Cetaceans spend the majority of their time submerged making visual detection difficult. In the case of harbour porpoise, due to their small size and elusive behaviour, the likelihood of detecting these animals is further reduced. Weather conditions during both surveys ranged from poor to good with the most common sea state recorded as force 5, limiting the chance of visual detection. The surveys show that PAMS is an invaluable mitigation tool during seismic operations and highlights the importance of continued use and the need for future development to ensure more comprehensive marine mammal monitoring.

## Program for Day 2: 29th of March 2007.

During the second day a number of workshops were held concurrently with two familiarization workshops and a coding workshop for developers. The venue for these events were lecture theatres and computer teaching laboratories of the Department of Electrical, Electronic and Computer Engineering of Heriot Watt University

### Training and Familiarisation Workshops

The introductory familairisation and training workshops were largely developed by David Mclaren and Paul Redmond of Heriot-Watt University. A small team of demonstrators were assembled and given a training session a few days before the conference so that they could act as demonstrators to provide support during the workshops.

The workshops took place in the computer teaching laboratories of the Department of Electrical, Electronic and Computer Engineering. This allowed each participant to have access to a dedicated computer preloaded with PAMGUARD software.

The course booklet and all the training materials, including sample sound files, are provided on the CD Rom proceedings of the conference.

### Facilitated Discussion Workshops

Six discussion workshops took place concurrently with the training and familiarization workshops. The titles, facilitators and suggested scope for these workshops are outlined below, followed by reports prepared by the facilitators for each workshop.

#### Testing, validation and quantification of performance

*Facilitator: Jonathan Gordon, Ecologic UK,*

(Testing, validating and quantifying the performance of Pamguard. It is important that the software be thoroughly tested in real world conditions and that relevant aspects of performance, such as detection probability and localisation accuracy, be quantified.)

#### Wider Applications for PAMGUARD

*Facilitator: David K. Mellinger, Oregon State University, USA*

**(**Wider applications for PAM within the PAMGUARD framework. Challenges and opportunities of using PAM on seismic vessels. Discussion of other uses, research, survey, non-marine mammal acoustics.)

Practical Experience and Feedback

*Facilitator: Roy Wyatt, Seiche Measurements, UK*

(Practical experience of using PAM, problems and opportunities. An opportunity to provide guidance and feedback to the development team.)

Training and Support

*Facilitator: Mary Jo Barkaszi, Geocet, USA*

**(**Training and support. Strategies and mechanisms for providing training in use of PAMGUARD and support to users.)

Regulatory Implications

*Facilitators: Zoe Crutchfield, JNCC, UK ; Carol Roden, MMS, USA; Inger Soderstrom, DTI, UK*

**(**Regulation. Discussion of realistic capabilities and constraints of PAM as part of regulation and mitigation.)

The future and long term viability

*Facilitators: Ron McHugh and Pil Trinder, HWU, UK*

**(**Development of a strategy for sustainability and long term support for the core software.)

**ASA Standards Working Group**

*Facilitator: Aaron Thode, Scripps Institution of Oceanography , USA*

(ASA acoustic monitoring standards workshop.)

## Timetable for Workshops Day 2 29th March 2007

| 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|
| **PAMGUARD Familiarization A** | | **PAMGUARD Familiarization B** | | Lunch | **Coding** | | **ASA Standards Working Group**<br><br>Aaron Thode | |
| **Testing and Validation**<br>Jonathan Gordon | **Wider Applications**<br><br>David Mellinger | **Practical Experience Feedback**<br>Roy Wyatt/RPS | **Training and Support**<br>Mary Jo Barkaszi | Lunch | **Regulations**<br><br>Zoe Crutchfield/ Carol Roden | **Sustainability Long term Viability**<br><br>Phil Trinder | | |

## Workshop Facilitator's Reports

### Testing, Validation and the Quantification of Performance

**Facilitator: Jonathan Gordon, EcologicUK, UK**

The wide ranging discussions in this workshop emphasised how important it will be to test and verify a program as complex as PAMGUARD, especially when it will be used for a task, such as real time mitigation or survey, where it is crucial to know its overall performance. Many different areas in which validation and testing would be essential were identified and discussed:

1. Computer simulation of performance

2. Bench testing of software using realistic acoustic and auxiliary data streams

3. Trials, beta testing and feedback to improve usability. Field testing of software to trap bugs and improve usability. This will be an ongoing process as new modules and functionality are introduced.

4. Software/hardware tests of the performance of particular configurations

5. "Engineering testing" of system performance – e.g. establishing parameters such as detection efficiency and location accuracy

6. Quantifying of a complete system's performance in terms of its ability to perform primary tasks, e.g. reduce risk of exposure for real time mitigation.

It was clear that multiple types of testing and validation are required, ranging from computer simulation, through bench tests to field experiments and finally empirical observations in realistic field conditions. Generally, field tests are difficult to conduct, they can be extremely costly and may yield rather little data. They are essential as the only true test of the system and we should aim to make the best use of these precious opportunities by analysing their results in the context of a theoretical understanding of the process affecting performance, computer simulations and experimental field trials.

Usually PAMGUARD will operate as part of a passive acoustic monitoring system which will include different types of hardware deployed in a variety of configurations, and it will be required to operate in an underwater noise field which may be highly variable, being influenced by both "natural" factors, such as sea state and topography, and by anthropogenic sound sources including the survey vessel and survey equipment. In many cases it will make little sense to assess the performance of the PAMGUARD software outside this context.

There was some discussion of the need for standardisation and for the setting of minimum standards. It was recognised that while it is ultimately useful to have

standardised systems and configurations if these were imposed at too early a stage it could stifle innovation and development. By providing a common framework PAMGUARD is a step towards standardisation but the flexibility built into the program will allow procedures to improved and adapted. Setting of minimum standards is difficult at this stage when the field is still young. In some circumstances even low levels of performance might represent an improvement on the status quo and shouldn't be discounted. Rather that set minimum standards what is important at the moment is to properly measure the absolute performance of PAM and other detection and localisation methodologies and assess the contributions they can make to managing environmental risk.

**1. Computer Simulation.**

For many aspects of performance there is a theoretical understanding of how external factors should affect performance, and these could be combined within computer simulations to predict performance given a certain set of parameters. For example, the errors in calculated locations expected for a given degree of uncertainty in hydrophone locations could be simulated for particular hydrophone configurations. Such exercises don't remove the need for empirical testing, but field trials are generally costly to conduct and/or yield results slowly. The greatest value can be extracted from these valuable opportunities by considering results within a theoretic framework and comparing theoretical predictions with real world observations.

**2. Bench Testing**

Software should be thoroughly bench tested. To achieve this with PAMGUARD a series of multichannel recordings made in realistic conditions with associated auxiliary data (e.g. GPS, depth) are required. Some of these should be recordings which contain known signals. There was some discussion about the potential for creating test datasets by, for example by mixing signals with different levels of noise. Mitigation operations could provide suitable datasets for bench testing.

Routines for species recognition can also be tested in this way provided good recordings from know species are available for testing and development.

**3. Operator Field Trials to find bugs and improve usability.**

It is important for software to be tested and used by teams of users that are independent of the software developers. Program developers that may share a certain mind set and know how the program was written will often fail to find bugs in their own code. They may for example always do things in the same "obvious" way. They may also lack a compete understanding of how the programs will be used in the field and be poorly able to assess some usability issues. Getting the program used by field operators and receiving bugs lists and practical suggestions from them is thus a very valuable process.

As many mitigation exercises take place on platforms with very good communications, including internet access, consideration should be given to having software engineers provide a high level of support to certain operations, including speedy bug fixing and quickly posting revised modules.

This should be an ongoing process, especially as new modules and functionality are added to the program.

**4. Testing software and hardware performance for particular configurations.**

PAMGUARD is likely to be configured in different ways for different projects and to interface to different types of hardware on different vessels. The group pointed out that it would be useful to develop procedures for checking that a system was working as expected, these might be repeated regularly, perhaps every day, or whenever substantive changes had been made to it.
Some of this type of testing could be achieved by inputting standard acoustic and data files into the system that would be expected to provide known patterns of detections and locations.
It was also suggested that some tests of performance of the complete system, hardware and software, could be achieved if another vessel, e.g. the guard vessel during a seismic operation, towed a suitable sound source at a know depth within the array's receptive field. In addition, during seismic surveys, checks could be made by checking acoustically derived positions of known noise sources within the array (such as location pingers).

**5. "Engineering" tests**

This subject covered discussion of particular directed trials which were not part of mitigation exercises or surveys, which would be conducted to measure the system's capabilities using either artificial sound sources or animals in known locations. Examples of artificial sound sources might include sound sources suspended at known depths from buoys or attached to a moving ROV. It was also suggested that individual animals with attached fine scale telemetry devices (such as dTags) could provide realistic sound sources whose locations would be known. Another suggestion was that tests might be carried out within arrays of static hydrophones, such as those on some Navy ranges, so that the location of vocalising animals could be determined from time of arrival at hydrophones ins the static array.

**6. Field tests of Efficacy.**

The ultimate test of how well a system performs a desired function, such as mitigating risk through real time detection, is to make measurements during those operations themselves. One way of achieving this would be to borrow techniques used to measure detection functions (detection probabilities and how they are affected by range) during visual surveys for cetaceans using distance methodology. For example, an independent "tracker" could plot animal locations and movements as they moved into and through the receptive field of the PAM system and record when animals were first positively detected and where they were in relation to the airgun mitigation zones. Such methods would be reasonably straight forward to apply with species that remain near the surface (such as small cetaceans). One option would be to place additional visual trackers on vessels involved in mitigation monitoring. Alternatively, it might be possible to collaborate with existing visual surveys, place hydrophone systems on vessels conducting such surveys and take advantage of the large teams of visual observers employed in the survey. If opportunities like this could be utilised such research might not be particularly expensive, however, because researchers are dependent on chance opportunities of trackable animals coming within range, its likely that data would be collected only slowly.

The best progress will be made by combining such opportunities with experimental measurements and computer simulations.

## Wider Applications of PAMGUARD

**Facilitator: David Mellinger, Oregon State University**

This discussion was aimed at identifying users beyond the marine mammal observer (MMO) community who might be interested in using PAMGUARD. It was motivated by the realization that an open-source software project benefits by having a large user base, so that there are more people who can find new ways to use the software, develop new code, fix problems, etc.

The session started with a brief (5 min) overview of Mellinger's talk on this topic from the day before, followed by open discussion. The first part of the open discussion was focused on other marine monitoring needs -- research and management of fishes and marine mammals. Current users in these areas who use other software (RainbowClick, Raven, Ishmael, etc.) might be brought into the PAMGUARD fold.

The second part of the discussion branched out into other areas in which people might use acoustic monitoring software. This part of the discussion was probably less useful, since after a while it became a mere listing of areas where acoustic monitoring is useful, with no strong ideas about how to serve users in those areas and get them to adopt PAMGUARD.

The list of potential uses included; uses of PAM in marine mammal population survey and wildlife management; marine mammal behavioural research; research with other marine species, especially fish; use in terrestrial acoustic research; noise measurement and logging; harbour security.

## Pamguard Training and Support Workshop

**Facilitator**
**Mary Jo Barkaszi, GeoCet**

The training and support workshop was well-attended by participants representing a wide variety of interests that included research and academia, industry personnel, technical and development interests, marine mammal observers, agency personnel and PAM operators.

**Training**

We began by discussing the topic of training dealing with questions of who, what, where, when etc. There was universal agreement that some form of standardized training needs to be provided as part of the PAMGUARD project to insure its widespread, appropriate and effective use. The training discussion also touched on the desirability of more general MMO training and accreditation. Here we focus on the discussion related to passive acoustics and PAMGUARD.

It was generally agreed that one of the responsibilities of the PAMGUARD project should be to develop training materials. It was suggested that a software-based training program including material similar to the hands-on workshop held during the conference should be developed. Some of the key points and suggestions in the development of training materials include:

- Hardware producers should be involved in the development of training materials to ensure users are trained on and utilize the appropriate hardware for the application.
- PAMGUARD should consider the possibility of conducting a series of regional training workshops, initially at least. In the longer term regional training capabilities should emerge.
- The development of an online training program, such as a distance learning program, would reach more people.
    - Online training would still need to be centrally managed perhaps through a University. It was agreed that online material should be set up as an organized course with certification to indicate successful completion and achievement of an adequate standard. Simply providing a DVD was not considered adequate.
- Training materials should be multi-lingual / multi-national / multi-regional..
- Training courses, either those set up regionally or available on line, should be put in place concurrently and equally in a variety of world-wide locations so that regions are not disadvantaged in terms of training.
- Training will need to evolve to keep pace with new PAMGUARD developments. Refresher courses may be needed to keep MMOs up to speed with new software developments. The long term costs of keeping operators informed and up to date need to be considered. These might be covered by a subscriptions for commercial use or be seen as part of MMO's professional development.
- Some training may need to be hardware and software specific. This could pose problems if hardware varies between operations and there may be proprietary issues with hardware configurations.
    - This led to the suggestion that hardware requirements should be established by PAMGUARD developers to establish a standard for hardware (and training) that allows PAMGUARD to operate fully. Companies would also be required to train their own personnel on their own specific hardware configurations. Additional features that may be added requiring additional hardware and would not be covered by standard PAMGUARD training material.

There may be different training needs for different stake holders. Two such stake holders are operators and regulators; however there are other groups within industry and the research fields that should be considered when developing training materials.

- Operators' needs & responsibilities
    - A standard training course to be developed and offered equally in different regions.
    - Operators need to gain experience in the field using, troubleshooting, and providing feed back and evaluation on PAMGUARD.
    - Pamguard training and field experience should lend itself to establishing recognized levels of operator expertise for a range of regions and species.
    - Operators need to be secure in identifying acoustic signals. There was a suggestion that the Pamguard committee develop an acoustic guide book (or electronic equivalent).
    - I was suggested that PAMGUARD operators keep logbooks detailing their experience that can be verified.

- Regulators' needs & responsibilities
    - Regulators should specify the operating protocols and standards that the operators will adhere to. These should be developed to take advantage of realistic capabilities of the current state of the art PAM systems.
    - Pamguard developers need to keep regulators abreast of what can be realistically provided / accomplished in field conditions. In this way PAMGUARD performance and the expectations of regulators can be aligned. It is important that PAMGUARD developers and users establish what standards can be achieved so that "nobody promises something they cannot deliver" or operators are not held to an unrealistically high standard of performance.

**Support**

The second portion of this workshop, which dealt with support, produced the most diverse discussions.

Support is a difficult topic because it addresses the long term use of PAMGUARD. The long-term functionality of the software will ultimately depend on the level of support it receives for maintenance. However, provision of support will cost money. How these costs could be covered was discussed at length and a number of suggestions were discussed.

The importance of a high level of field reliability was highlighted. In this context the advantages and disadvantages of MMOs rather than the seismic company providing PAM were discussed as was responsibility if PAM systems, including PAMGUARD should go down. Industry needs consistency, dependability, accountability.

Two types of support were identified.
1. Operational support such as provision of advice on configurations of hardware and software for particular applications, expert advice on how to use software etc.
2. Core support to include basic software maintenance, bug fixing and incorporation of new functionality.
There was a general understanding that the support and maintenance of the software should not cross any proprietary boundaries regardless of the hardware that is used.

- Participants discussed the level and extent of support that might be required, the costs of varying levels of support and how they might be covered? Who will be responsible for

support when the initial Pamguard project / funding are over? Will the JIP or other entity continue to fund support for operators?

- Increasingly the responsibility for operational support should move from the PAMGUARD programming team to the individual PAM operators.
- Operational field support, such as expert set-up and use of equipment and software for particular operations could be provided by experienced PAM/MMO providers themselves, or offered to them as a commercial service by specialist firms. Some of this support could be delivered remotely 24/7, especially on vessels that had internet connection. There's a clear commercial model for companies to provide this service to individual operations.

Core support involving program maintenance, bug fixing and incorporation of new functionality should be carried out centrally by a team with expert knowledge of the PAMGUARD program itself. It was suggested that to fund this commercial Pamguard users should subscribe to a fund based on the level of their commercial use of PAMGUARD. This might take the form of a daily levy. PAM operators would pass these costs on to clients. It was suggested that such an entity would most likely operate through a university or similar establishment.

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## Regulatory Implications. Discussion of realistic capabilities and constraints of PAM as part of regulation and mitigation.

Facilitators
Zoe Crutchfield, JNCC, UK
Carol Roden, MMS, USA
Inger Soderstrom, DTI, UK

In order to get the most from the workshop session the attendees, which included Marine Mammal Observers (MMOs) and MMO agencies, Passive Acoustic Monitoring (PAM) operators and suppliers, regulators, industry, conservation agencies and academics, were split into four groups and each asked a series of question by the facilitators working in teams. It should be noted that these questions referred mainly to the general use of PAM and not specifically PAMGUARD. The group answers to questions are summarised below.

### Question 1 - What (do you think) are the current capabilities of PAM within the regulatory framework?

It was generally agreed that PAM is capable of detecting some species of marine mammals however, there exists a degree of disagreement as to the accuracy and confidence with which this can be achieved for all species in a commercial situation. For instance, there was concern that the use of PAM for baleen and beaked whales, at this time, would add little benefit during an activity such as seismic surveys and that other approaches to mitigation such as visual observation and the use of historical distribution data would be more beneficial. However, most agreed that for some species, including sperm whales and harbour porpoise, PAM was an effective tool

and could add to the current visual mitigation measures. One limitation which should always be born in mind is that PAM will only work when a marine mammals is vocalising or echo-locating.

The lack of confidence in PAM systems was focused on three main areas:

**Range Estimation Inaccuracies**. If PAM is to be used in mitigation for industrial activities it is likely that the requirement will either be for activities not to commence or for activities to be halted should marine mammals be detected within a certain distance of the noise source. Errors in locating animals may lead to operations being halted unnecessarily or conversely, continuing when animals are too close.

**Existence of Experienced PAM Operators**. It was recognised that, as with visual MMOs, there are experienced and less experienced PAM operators. PAM is not yet a 'black box' technology and skilled and experienced operators are required to operate the PAM equipment. The skills needed to operate and maintain PAM systems are different to those of visual MMOs and it will take some time for sufficient acoustic MMOs to gain the appropriate training and experience.

**Quality and Capability of PAM Equipment**. As with many commercially supplied systems some PAM hardware may be more effective than others depending on factors such as the quality of the equipment used, its age and state of repair, the ability of the operators to deploy the hydrophones in a suitable position etc.

From discussions, it seems that some form of a training course or level of competence in using PAM is required to improve confidence in PAM operators. In addition to further functional development of PAMGUARD, development of standards for the hardware used in PAM operations is also needed and consensus is required on the most effective methods for deploying this from vessels of different types.

**Question 2 - What are the realistic capabilities/improvements likely within the next 2 - 5 years?**

PAM users and developers believed, that with adequate support, development of software that was capable of automatic species recognition was a possibility within the next five years. This would be of particular value in those locations around the world where some species of cetaceans are afforded stricter protection than others. It was also felt that a higher degree of automation within PAMGUARD was possible and that this sould allow for further integration of PAM and visual MMO operations.

However, there was a great deal of discussion as to how improvements can be driven by industry, regulators and PAM users:

- Some felt that PAM systems were too immature to be part of regulation others that compelling industry to use PAM was the only way forward at present. It was suggested that this could be achieved by using existing legislation to encourage PAM use until a 'critical mass' of companies were using PAM as part of their day to day activities. It was felt that, in order for this to work, industry would probably need some form of incentive to use PAM.

- Others argued that without some sort of governmental actions, PAM development would be slow and eventually stall and that unless 'forced' industry would not be willing to undertake the additional resource spend which may be associated with PAM use and development. It was suggested that without setting timelines within which PAM must be used (i.e. by 2012 all seismic surveys will use PAM technology capable of detecting X species) further development of industrial uses for PAM will be limited.

**Question 3 - What are the potential problems with a requirement for PAM within the regulatory framework?**

Concerns were raised that, current regulations require information that current PAM systems are not realistically capable of providing reliably. This is partially dependent on a different variables for each particular activity such as location, PAM system used and operator. If unreliable and inaccurate PAM systems are used which result in unnecessary or incorrect mitigation measures being applied, the use of PAM for industrial activities may be challenged further by industry,

There was also concern raised that, as is sometimes the situation with visual MMOs, PAM operators can be placed in difficult situations where there interpretation of signals received is challenged by those wanting to undertake industrial activities.

From a regulatory perspective, if the use of PAM is to be legislated for, it was felt that the existence of a wide variety of PAM systems would pose difficulties in policing or monitoring compliance emphasising the need for standardization in software and hardware. PAMGUARD is an attempt to provide standardised software.

**Question 4 - What are the greatest advantages of a requirement for PAM within the regulatory framework?**

The greatest overall advantage for the use of PAM within the regulatory framework is improved protection for marine mammals from activities which have the potential to produce damaging levels of noise. Any technology which can provide accurate information on marine mammals in an area where industrial activities are taking place can help to improve the effectiveness of the mitigation measures available. PAM is effective 24 hours a day and, unlike visual observations, has the possibility to continue in bad weather conditions such as fog.

PAM can also be used to collect data on occurrence and densities with could be used to improve the knowledge of marine mammals distribution. This could improve risk assessments produced prior to activities taking place and be used for other mitigation measures such as timing restrictions. This would be of particular value for those marine mammals which are more difficult to detect visually. If PAM use was part of a regulatory system it may be possible for the regulator to collect information of marine mammal acoustic detections and better co-ordination of this data source for this purpose should be considered.

Incorporating PAM into regulations may also lead to the development of guidelines for PAM use similar to those for visual observers leading to a more standardised

mitigation strategy which made better use of the type of information that PAM can provide. Development of such guidelines would encourage use of PAM and may help with voluntary use in areas not currently covered by regulation.

## Future Guardianship Workshop

*Facilitators Ron McHugh and Phil Trinder*
*Heriot-Watt University*
*Edinburgh, Scotland*

This workshop discussed the need for ongoing guardianship of PamGuard and initiated discussion on possible funding mechanisms.

PAM software is in transition with older packages like IFAW and Ishmael becoming less usable due to minimal maintenance, and PamGuard intended as the preferred replacement. After 4 years of funded development, some 9-person years of international collaboration, and large quantities of Intellectual Property freely given, PamGuard is now a substantial, multidisciplinary software package and capable of becoming the *de facto* standard PAM system. It incorporates the functionalities of both widely-used IFAW and Ishmael packages and has been validated and robustified by sea trials.

In short, PamGuard is a complex, evolving, and multidisciplinary software system and has the potential to be useful in a broad range of applications for many years to come.

To reach its full potential, and indeed to remain usable, PamGuard requires *guardianship*. In essence this entails both continual maintenance to track the evolution of components e.g. porting PamGuard to MS Vista, and integrating new technologies developed by the PamGuard community into the PamGuard core. Without effective guardianship it is likely that, although PamGuard will continue to be used, it will never reach its full audience or potential.

To ensure that the PamGuard community enjoys unbroken support, guardianship is required to continue in 2008 and beyond. The specific guardianship activities that we propose to undertake are: bug fixes; integration of components developed by other groups into the PamGuard repository; maintenance of the PamGuard web site and repositories; annual and minor releases to enable standardisation.

The sustainable business model for ongoing PamGuard guardianship that was proposed was for the JIP to support the establishment of a daily levy for PamGuard usage. The levy is to be paid by industrial users for each day of PamGuard usage. An industrial user is any company that generates revenue using PamGuard, e.g. a PAM provider on a survey or some other seismic or hydroacoustic monitoring activity. In the case of a seismic survey using PamGuard the PAM provider invoices the survey company for the levy amount, who in turn invoice the commissioning Oil and Gas company. The PAM provider remits the levy funds to the Guardians who record the revenues and will make financial reports available to the JIP.

# Appendix 1

*List of Attendees*

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