PAMGuard industry field trial 2008

Prepared by SMRU

E&P SOUND & MARINE LIFE PROGRAMME

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PAMGUARD Industry Field Trial 2008

Final Report

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Summary

The PAMGUARD software was tested on the Fairfield *New Venture*, an exploration and production (E&P) Industry seismic source vessel conducting a wide-azimuth, multi-source, seismic survey in the Gulf of Mexico from 8 – 18 November 2008. The primary objectives of the trial were to:

1. Verify the effectiveness of PAMGUARD as a mitigation monitoring tool.
2. Test PAM towed array deployment from an operational seismic source vessel during a survey.
3. Test PAMGUARD algorithms in the presence of an operational seismic airgun source.
4. Identify and fix bugs in the PAMGUARD code

Secondary objectives were to:

5. Compare acoustic detections with visual MMO data.
6. Compare with other PAM software packages (IFAWs RainbowClick and Ishmael).

During the trial period, the hydrophone array was deployed and continuous recordings made for a total of 208 hours (8.6 days). Hydrophones were monitored aurally for a total of 84.8 hours. The PAMGUARD software (running on two different machines) was operational for 293 hours (12.2 days).

Ambient noise levels from the multiple vessels taking part in the survey were high compared to noise levels during recent marine mammal surveys where similar equipment was used. At the frequencies important to detection of odontocetes, this noise was primarily cavitation noise from the propellers of the other vessels in the fleet. Detailed comparison of ambient noise levels between data from previous research surveys indicates that sperm whales should still have been detectable out to a range of approximately 2km. Possible distant sperm whales were heard faintly on headphones on four occasions. Two of these corresponded to times when sperm whales were seen by marine mammal observers. However, all were too distant and too faint to detect or track using PAMGUARD. Faint whistles were occasionally noted, but on no occasion were many whistles heard which would have been indicative of a group of dolphins. Many of the whistle sounds seemed to correlate with sounds from the seismic source and may be of mechanical origin. It seems likely that the low detection rate was in part due to a low density of animals in the region but may also be due to the high ambient noise levels masking sounds of more distant animals.

During the first half of the trial, the operator prioritised bug fixing and was only monitoring for cetaceans aurally. Unfortunately, severe weather, which caused a complete shutdown of all seismic operations, severely impacted monitoring time during the second half of the trial. Only one marine mammal detection (of high frequency dolphin clicks) was made with the PAMGUARD software during the trial. An additional five detections of sequences of high frequency click trains (which cannot be heard) were

made when data were reanalysed following the trial. It is likely that had the PAMGUARD user interface system been monitored continuously, then these would have been detected during the trial.

None of the six dolphin detections corresponded to an MMO sighting. Four of the six occurred at night when it would have been impossible to spot the animals. We do not know whether or not MMOs were active at the time of the other two. However, the night time acoustic detections and the visual sightings missed by PAMGUARD once again emphasise the power of using both visual and acoustic methods.

A total of 39 bugs were identified in the PAMGUARD software during the trial, of which six were in the two most severe categories, having a serious impact on PAMGUARD stability and performance. All severe bugs were fixed during the trial. Three minor bugs remain in the software, none of which have a serious impact on PAMGUARD operation and performance. These will be worked on as part of the ongoing PAMGUARD maintenance in St Andrews.

Due to the extensive bug fixing during the trial, PAMGUARD ran extremely reliably by the trial's end. Feedback from PAM operators using recent releases of PAMGUARD, which include bugs fixed during the trial, confirm that PAMGUARD is now stable and reliable and does not crash in the way that earlier releases did.

A number of new modules were added to PAMGUARD specifically for operation around seismic vessels. These were a seismic veto module (to remove sound events relating to the seismic source being activated), a playback module (so the operator can listen with sound from the seismic source removed), a hydrophone depth readout system and a user input form for recording listening effort and things heard. A National Instruments high frequency (up to 500kHz sample rate) Data Acquisition module was also developed shortly before the trial and was extensively tested.

As previous trials have demonstrated, this study confirms that PAM can contribute to effective monitoring by detecting animals missed by visual observations. However, effective PAMGUARD operation requires an attentive and competent operator, particularly for the detection of small, fast moving odontocetes. PAM efficiency will also be vessel dependent, deteriorating considerably on noisier vessels or during multi-vessel operations. In the future, careful consideration should be given to the most effective location for the PAM array, for instance, deployment from one of the guard vessels operating ahead of the main survey fleet may offer quieter, and therefore more effective, monitoring conditions.

Work to be conducted by Oregon State University, under the direction of Dave Mellinger, to compare Ishmael and PAMGUARD performance has not yet been completed. A revised report will be submitted when the Ishmael comparison becomes available.

1 Introduction

Passive acoustic monitoring (PAM) has long been proposed as an effective means of detecting cetaceans in the vicinity of seismic surveys. Once animals are detected, then mitigation actions can be taken, which can reduce the risks of sound exposure to the animals. A study which deployed a towed hydrophone from a guard vessel stationed ahead of a seismic vessel working off Scotland in the late 1990s showed that acoustic methods can be ten times more effective at detecting cetaceans than visual methods alone (Lewis et al. 2000). However, detection efficiency varied by species; large baleen whales (which can vocalise rarely at certain times of year and then only at low frequencies which are difficult to detect) being better detected visually. Other studies have not experienced this level of discrepancy between visual and acoustic detection rates (D. Hedgeland, pers. comm.) which is possibly due to improvements in visual observer performance or the particular mix of species encountered during the 90's trials.

The 'IFAW' Software, developed partially during the 1990s trials, has been used by companies providing PAM services to the seismic survey industry for the detection of marine mammals for mitigation in several countries. However, this software was not supported, was not open source, and was becoming increasingly unreliable as the Windows operating system advanced. The IFAW software could be configured for a maximum of two hydrophones and was limited to detecting only a few species. Increasingly, users were finding that it could not be configured to be optimal for the species likely to be present in a given area.

The basic functionality of the IFAW software has been incorporated into PAMGUARD as has that of Ishmael (Mellinger 2001), another free but unsupported software package, commonly used for the detection and localisation of marine mammals.

During previous trials, the PAMGUARD software (Gillespie et al. 2008) was tested by members of the PAMGUARD development team on board two scientific research vessels, and it had also been tested by a professional Marine Mammal Observer (MMO) during the CODA cetacean survey in 2007 (Gillespie 2009). While these tests have proven extremely useful in gaining experience of using the software at sea and have helped to identify bugs in many modules, further field trials were necessary in order to:

1. Inform us as to how PAMGUARD operations will integrate with seismic operations during real survey conditions.
2. Test algorithm performance in the presence of seismic operations (airgun and vessel noise).
3. Test new detection and localisation modules, added in 2007.
4. Compare with the performance of old IFAW and Ishmael detection systems.

Dr Douglas Gillespie (DG) from the Sea Mammal Research Unit, St Andrews University, UK, conducted the field trial on board the source vessel Fairfield *New Venture* between

8 and 19 November, 2008. The *New Venture* was operating on contract to CGG Veritas on a wide-azimuth seismic survey in the Gulf of Mexico (Figure 1).

Three visual Marine Mammal Observers (MMOs) were on board each source vessel and MMO data were made available for comparison with the PAMGUARD acoustic data, following the trial. During the trial however, the PAMGUARD operator and MMOs did not exchange data in real time. It was also agreed with the US Mineral Management Service (the relevant government authority) that the PAM operation was in place for field testing purposes of PAMGUARD only and would not be used as part of the marine mammal mitigation measures on board for the actual seismic survey. Therefore, PAMGUARD detections would not influence operational decisions, such as implementing a shut down of the source and PAMGUARD monitoring would not be used to confirm the absence of marine mammals prior to night time initiation of seismic sources.

The PAM system was deployed and was operational from Saturday, 8 November through to Tuesday, 18 November, 11 days in total. The system was operated only by DG during 8-16 November. Stephane Coatelan (Sercel; Brest, France), had planned to join the trial for its second week but was unable to transfer to the *New Venture* due to inclement weather until 17th and was therefore only present for the final 24 hours of PAM operation.

During the first week of operation, DG concentrated on bug fixing and "ruggedisation" of the PAMGUARD software. From Friday 14th, the system was run as much as possible, although poor weather caused the shutdown of seismic operations on Saturday 15 and Sunday 16 November.

In general, the PAMGUARD software was operating on two computers. One was left

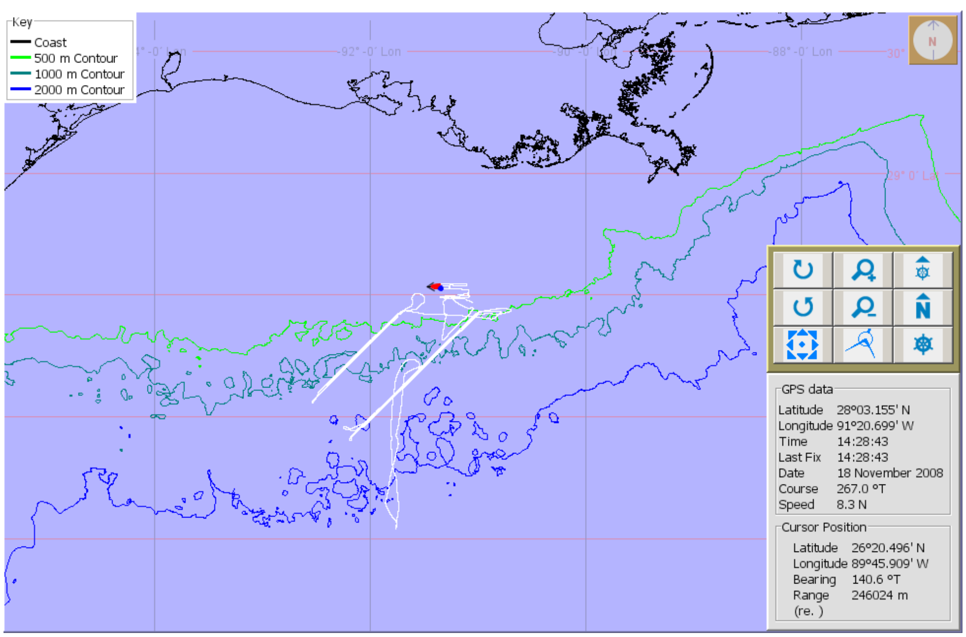

Figure 1. Map (from PAMGUARD Viewer) showing the ships track (white lines) during the trial.

running continuously day and night, generally with the latest and most stable version of PAMGUARD. The second machine was used for bug fixing and enhancement during the day and would then also be left running over night, often running modules that had been changed that day, or running a different configuration to the first machine.

2 HSE

A health and safety plan (Section 19.3) was prepared prior to mobilisation by DG, working with representatives of JIP, CGG Veritas and Fairfield. This largely followed the Fairfield vessel safety plan, drawing attention to areas of particular concern related to deployment of the PAM hydrophone array.

DG was transferred to the *New Venture* on board the *Justin Callais*. The *Justin Callais* departed Galveston at 6pm on Wednesday, 5 November and caught up with the seismic fleet at dusk on Thursday 6th. The weather was poor throughout most of Friday 7th and considered unsafe for a vessel transfer. Transfer finally occurred at approximately 7am on Saturday 8th.

On arrival on board the *New Venture*, DG was met by the HSE officer, given a safety brief, tour of the vessel, lifeboat assignment and instructions for abandonment, etc. DG was also issued with PPE equipment for use on the gun deck (hard hat, gloves and life vest, as well as own safety boots).

Hydrophone array deployment was discussed with the HSE officer and chief gun mechanic prior to starting work to spool the PAM array onto the winch, in preparation for deployment.

Being an industry vessel, strict HSE requirements were in place and were adhered to at all times, including wearing of appropriate PPE, toolbox meetings before any activity took place and compulsory attendance of safety meetings and exercises. The *New Venture* has an excellent safety record, a plaque on safety notice board currently boasting 807 days without a time lost accident (which is the time the current crew have been with the vessel). At no time did anyone on board feel that the PAM activities were conflicting with any HSE standards or policies.

Daily reports were emailed to the following list of people:

John Campbell	OGP Technical Director
David Hedgeland	JIP Project Coordinator
Reagan Woodard	Fairfield Operations Supervisor
Jim Thompson	Fairfield
Jackie DeLaughter	CGG Veritas
Danny Garcia	Fairfield
Simon Moss	SMRU Safety officer

The Party Manager on *Viking Vision*

Table 1. Vessels involved in the survey

Vessel	Purpose	Length x beam (m)
Viking Vision	Source + acquisition	105 x 24
Veritas Viking	Source + acquisition	93 x 22
Fairfield New Venture	Source	76 x 17
Vardholm	Source	57 x 14
Sigma	Source (on standby)	60 x 11
Father John Keller	Supply / chase	46 x 11
Hal Callais	Supply / chase	55 x 11
Justin Callais	Supply / chase	55 x 11

The hydrophone array was recovered and re-deployed twice during the field trial period. The first occurred when the *New Venture* was sent to scout over the shallow wreck of an oil rig, the second to show the array to members of the seismic crew from the vessel *Viking Vision*. The seismic source had already been recovered prior to both the PAM array recoveries for other operational reasons.

There were no safety incidents during hydrophone deployment, retrieval, or any other PAM related activity during the trial.

3 Use of PAM during Seismic Survey operations

A total of eight vessels were involved in the ongoing survey, four of which were directly involved in seismic operations and four operating as supply or guard vessels. The four vessels involved in data collection would normally be spaced 1.2 km apart. All four vessels had operational seismic source arrays deployed. Two vessels were also towing seismic streamers for data acquisition. Each seismic source array consisted of three sub-arrays with nine airgun elements per sub-array. The total volume per array was 5260 cu. in.

The other vessels in the fleet would generally be stationed either ahead or astern of the streamer vessels. The guard vessels would often be sent off to perform other tasks, scouting ahead, chasing, or returning to port for supply / personnel changes. The eight vessels are listed in Table 1. Small work boats or Fast Rescue Craft (FRCs) were deployed as required. AIS data showing a typical formation of the vessels is shown in Figure 2

Seismic operations were already underway on 8th November and ceased on Saturday 15th due to poor weather. Acquisition restarted late on Sunday 16th. From Sunday 16th however, the *New Venture* only played the role of support vessel, stationed approximately 1 mile ahead of one of the streamer vessels or scouting ahead for shallows, the *MV Sigma* taking over the role of source vessel.

Deployment of the hydrophone from the seismic source vessel did not pose any problems with regard to either seismic operations or to health and safety. Operators from the *Viking Vision* (one of the seismic source and streamer vessels) visited the *New Venture* and gave the opinion that deployment and recovery from the streamer vessel would not pose any significant challenges.

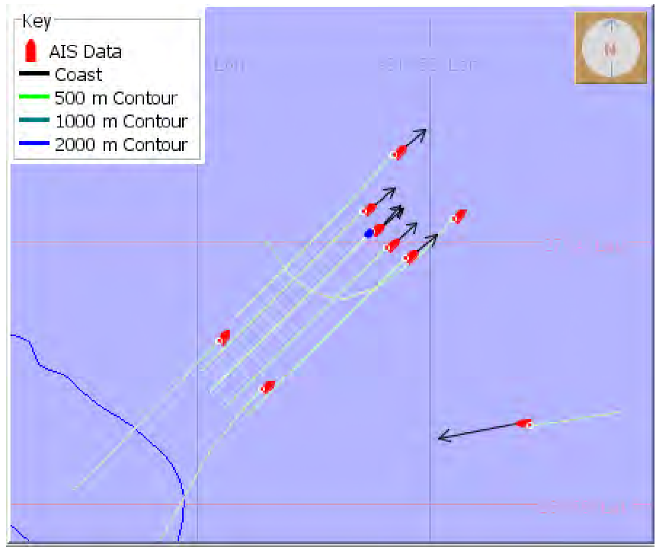

Figure 2. AIS Data from the eight vessels during a seismic survey line. The four seismic vessels are in a line, the *New Venture* being identified by the blue dots (representing the hydrophone positions) astern. The support vessels are stationed approx. 4km ahead and 10km astern of the survey vessels. A commercial vessel no associated with the survey is approaching from the East.

4 Equipment

Monitoring hardware was leased from Seiche Measurments Ltd, UK (SML).

4.1 In Water Equipment

Two hydrophones were provided, although only one was deployed, the other remaining on board as a spare. The hydrophone array used (hydrophone SML 43) consisted of two pairs of high frequency (2kHz to 200kHz) hydrophone elements. The spacing within each pair was 25cm and the spacing between pairs 250m. Total cable length was 400m, so the first pair of hydrophones were a little under 150m astern of the vessel and the second pair just under 400m astern (Figure 3). An analogue depth sensor was mounted close to each hydrophone pair. Each hydrophone pair was moulded onto the cable in a rigid polyurethane section approximately 40cm long.

The source array was deployed close to the vessel (approx. 20m) so it was not possible

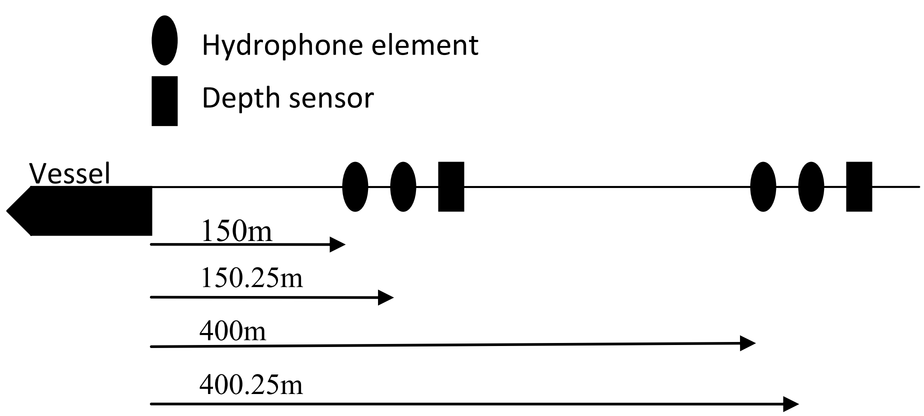

Figure 3. Schematic diagram of PAM array.

to deploy the PAM array in front of the source array as had been discussed prior to the cruise. The hydrophone was deployed from an outrigger normally used to deploy the starboard paravane, which pushed the hydrophone far enough outboard to be clear of the source array (Figure 4).

Figure 4. Photo of hydrophone deployment off the starboard side of the vessel.

The hydrophone cable was spooled onto a winch, normally used to deploy the Kevlar rope towing the starboard paravane. However, it was not possible to spool the solid / rigid hydrophone section containing hydrophones in the middle of cable, so the outer 250m cable were deployed and recovered by hand. At a speed of four knots, with four people present (one hauling, one coiling and two standing by), this was not considered hazardous by DG, the aft deck gun team or the HSE officer on board.

Although the PAM array was initially deployed after the source, given the relative positions of the PAM array and source, it was considered easiest to leave the array out if the source was recovered for any reason and at the end of the trial the source had already been recovered for other operational reasons before the PAM array.

Hydrophone depth was read using the Depth Readout module in PAMGUARD. Typically, the front hydrophones were at a depth of approximately 8m and the rear hydrophones at a depth of 25m.

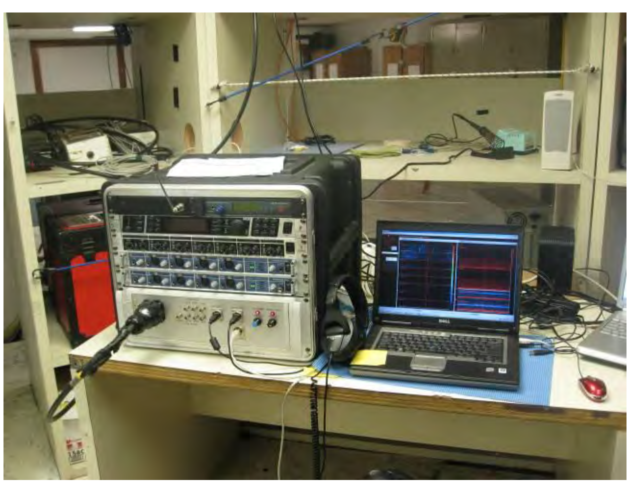

Figure 5. Photo of in board equipment.

4.2 On Board Equipment

Monitoring equipment was set up in the *New Venture* instrument room close to the main seismic navigation station.

A 50m deck cable was provided which was more than adequate to reach the *New Venture* instrument room. The cable run was via pipes intended for the purpose of bringing signal cables from the aft deck (they all started high above the water line), so the safety of the vessel was not compromised either by restricting water tight doors or creating a trip hazard. Once in the instrument room, the cable was run through a suspended ceiling to a point above the monitoring desk. Excess cable was spooled in a corner where it did not pose a trip hazard.

In board monitoring equipment (Figure 5) provided by SML consisted of the following items, the first five of which are built into the desktop 19 inch rack pictured in Figure 5:

1. An amplifier buffer box containing four signal amplifiers, two depth sensor read out devices (Measurement Computing USB-1208LS) and a National Instruments high speed data acquisition card (USB-6251)
2. Two RME Fireface multi channel sound cards (sampling rate up to 192kHz)
3. A Behringer Ultralink Pro mixer
4. A Behringer ultracurve pro equaliser
5. A Sennheiser stereo headphone cordless transmitter and receiver
6. Two Dell laptop computers (Inspiron 1720, Dual Core T5550 processor at 1.83GHz, 3GB Ram @ 987 MHz)
7. A handheld GPS receiver with a USB to serial adapter
8. A 110 to 220V power converter
9. Tools, manuals, spares

In addition DG provided:

1. A two channel USB sound card (Edirol UA-20)
2. An Acer laptop (Travelmate 8200, Dual core T2300 processor at 1.66 GHz, 2GB Ram)
3. A Dell laptop (Latitude D830, Dual core T9300 processor at 2.5 GHz, 3.5GB Ram @ 772 MHz)
4. Tools and spares
5. An AIS Receiver (NASA Marine AIS Engine 2), VHF antenna and cable.
6. A ship GPS with external antenna.
7. Two 2 Terrabyte hard drives for data storage
8. Spare mice

4.3 Ancillary Data (GPS and AIS)

PAMGUARD requires GPS data for localisation of sounds. GPS, and other navigational equipment, generally provide output data in an NMEA 0183 format. PAMGUARD can read NMEA 0183 data through a serial port. The handheld GPS provided by SML could not be used since it had no external antenna. It is also unlikely that the antenna cable on DG's ship GPS would have been long enough to reach the outside world. If however the PAM system had been deployed elsewhere on the vessel, such as the bridge, it is likely that either could have been made to work.

GPS NMEA 0183 data were taken from the *New Ventures* seismic navigation system, which had two Trimble differential GPS receivers. This required only a simple serial cable run for a few metres across the instrument room.

AIS data may also be used to facilitate tracking of other vessels, particularly those also deploying seismic sources. Receiving AIS data requires a VHF antenna[1]. A number of VHF antenna feeds were available in the instrument room, so there was no need to run a VHF cable to the outside.

110V mains power was taken from the ships mains generator, via a Computer Power Systems Corp. power conditioning unit which was used for all instrument room equipment. 220V power was created using a transformer provided by SML.

An open access internet connection was also available.

5 Data Recording

Data from one Fireface sound card were recorded to hard disk continuously using the IFAW Logger software. Four channels were recorded at a sample rate of 96 kHz.

Although this operation could have been performed by the PAMGUARD recording system, Logger was used for two reasons:

1. The Logger recording system has been in use for many years and is known to be very reliable. The PAMGUARD recorder was still under trial.
2. As part of the study, we required to run the IFAW monitoring suite, including RainbowClick (Gillespie & Leaper 1996) and the Whistle detector. Only two Fireface sound cards were available, one of which was needed for the IFAW system. Since the plan for computers running PAMGUARD was to 'crash test' them, testing many and varied configurations, it would not have been possible to collect continuous reliable data using PAMGUARD unless a third Fireface card had been available.

The PAMGUARD recording system was tested thoroughly with other PAMGUARD modules, recording at a sample rate of 96 kHz and was also used for making some calibration recordings using input from a National Instruments data acquisition card recording at 500 kHz.

A total of 208 hours of data were recorded, equating to 535 Gigabytes of data.

6 Module Stability

All PAMGUARD modules were tested during the cruise apart from the Patch panel and the 3-D location module. The 3-D location module requires a relatively clean signal in

[1] The simple NASA AIS receiver should not be confused with the AIS systems carried by commercial vessels which transmit the ships position. The AIS receiver only receives AIS data from other vessels and does not transmit. AIS receivers can be purchased for approx. £120 and do not need to be registered with international shipping authorities.

order to match surface echoes to direct path signals. Although localisation methods in the click and whistle detectors were enabled, the lack of encounters meant that testing of localisers could not be conducted.

Some modules, such as the database and NMEA acquisition were run continuously since they are fundamental to all other PAMGUARD processes. Other modules were tested for varying lengths of time depending on module importance, the suitability of incoming data and severity of any problems encountered.

The amount of time that each module was tested for is shown in Table 5 in Section 19.1. As documented in Section 11, bugs were found in several of the modules, most of which were fixed at sea or soon afterward. All the PAMGUARD modules, apart from the patch panel, are now stable and perform and run consistently.

7 Real Time Monitoring

7.1 Aural Monitoring

Sounds from the hydrophones were monitored aurally on headphones (Sennheiser HD 280 pro) for as much of each day as was practically possible (typically 8 – 12 hours). Headphones were generally connected to the sound output of PAMGUARD so that the seismic veto (see Section 12.2) could be used to remove airgun noise. On occasion other PAMGUARD filters were also used to try to improve signal quality.

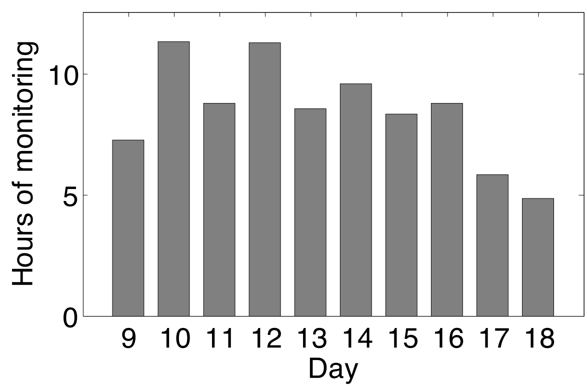

Figure 6. Hours of aural monitoring by day.

Listening effort and things heard were recorded in a PAMGUARD ‘Things Heard’ form (Section 12.5). The total number of hours monitored was 84.8. The number of monitoring hours each day is shown in Figure 6.

During the trial, DG noted that sperm whales could be heard very faintly on four occasions. All of these were at the limit of aural detection, and having listened to recordings again (see Section 0) we are unconvinced that sperm whales were actually there on three of those four occasions.

7.2 PAMGUARD Monitoring

During the planning of the trial, the operator had been expecting to detect and test the software with sperm whales which are often encountered in the Gulf of Mexico. Since sperm whales are a species easily detected aurally, the PAMGUARD displays were not continuously monitored, although they would have been used to confirm detections and to localise animals once detected aurally. None of the four sperm whale aural detections

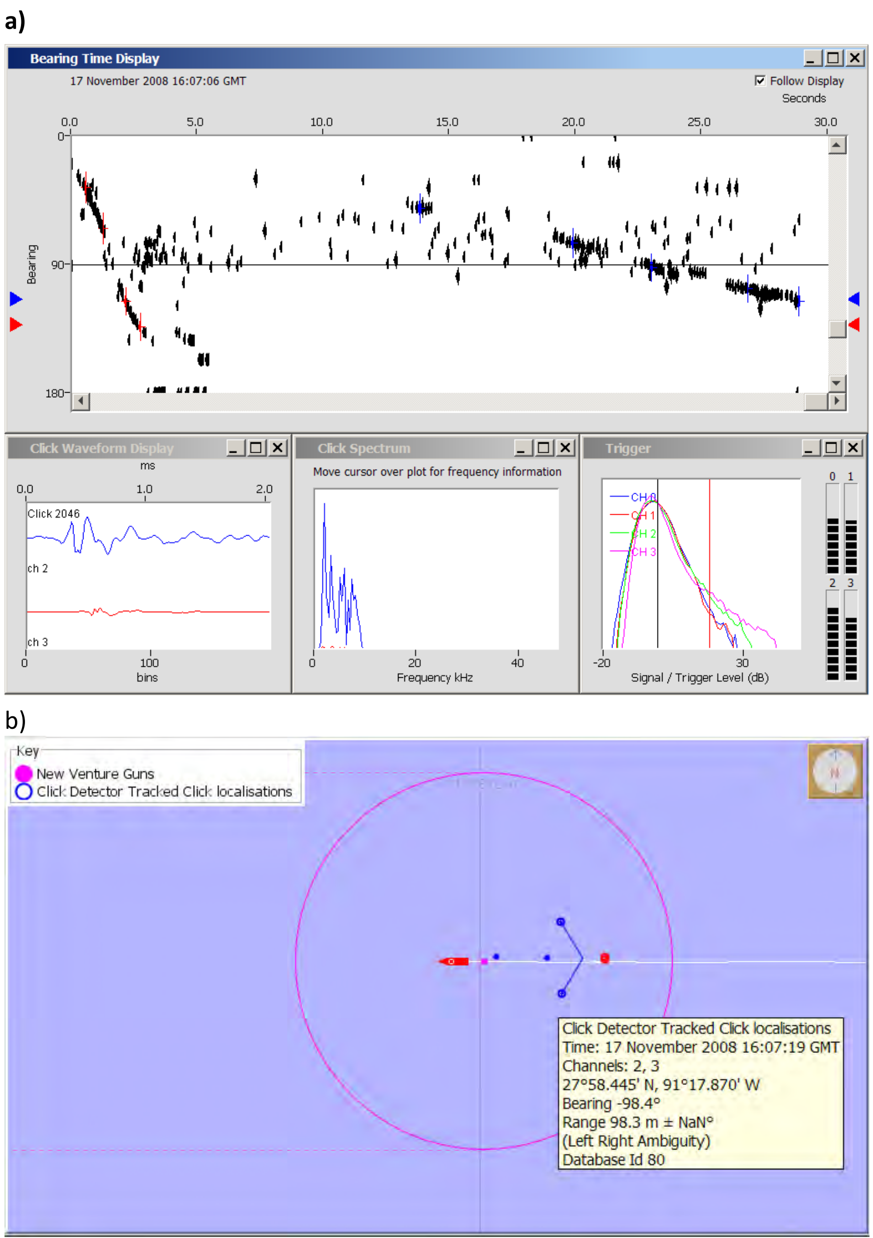

Figure 7. The click detector (a) and the Map (b) displays during an encounter with a group of dolphins

described above could be detected using PAMGUARD due to the extremely low signal levels.

Cetaceans were only detected using PAMGUARD in real time on a single occasion during the trial, the detection consisting of a series of high frequency dolphin click trains on 17th November at 16:26. These were inaudible to the operator but showed up clearly on the PAMGUARD click detector. They were localised using the click detector tracking algorithms (Figure 7).

8 Noise Analysis

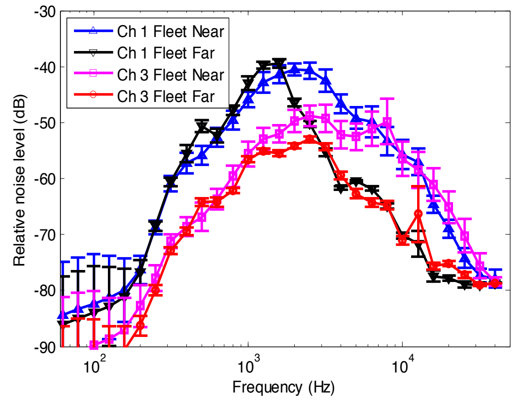

Figure 8. 1/3 Octave noise levels from the front and rear hydrophones during a noisy period, when the *New Venture* was close to the other vessels in the fleet and a quieter period during a turn.

Noise levels during the trial were high and also appeared to be at least in part due to the other vessels in the fleet. Recordings have been analysed offline which confirms this. Third octave noise levels from the first and third hydrophones in the array (i.e. ones 150m and 400m from the *New Venture*) are shown in Figure 8 for a period when the *New Venture* was close to other vessels in the fleet, and for a period when the other vessels were further away. It can be seen that lower frequency noise (below 1 kHz) is lower on the hydrophones furthest from the *New Venture*, and that these levels do not change when the other vessels were more distant. High frequency noise (>2 kHz) is more a function of the proximity of other vessels. i.e. when the other vessels were nearby, the noise levels on all hydrophones was high, irrespective of their distance from the *New Venture*, and when the other vessels were further away, high frequency noise levels dropped. This result can be explained by noise levels at low frequencies being dominated by the *New Venture* and noise levels at higher frequencies predominantly coming from other vessels in the fleet, the most likely source being propeller cavitation.

The triggers in the PAMGUARD click detector respond automatically to changes in background noise, so higher noise will result in high trigger thresholds and a reduced detection range. The most meaningful measure of background noise, in terms of

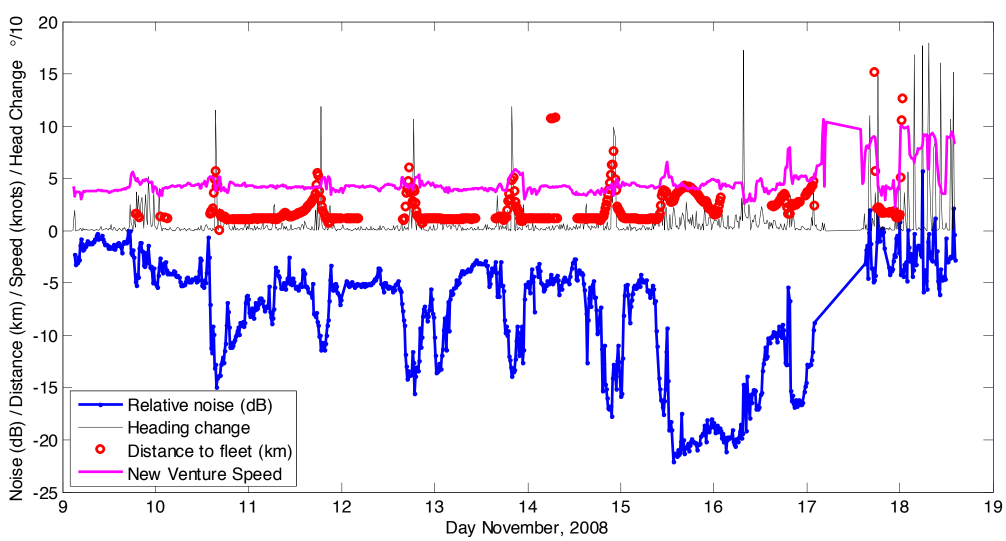

Figure 9. Click trigger noise measurement (relative dB scale) compared with *New Venture* heading changes, speed and the distance to the closest of all other vessels in the fleet.

assessing the effect on detection range, is therefore the output of the noise measuring filters in the click detector. This is shown for the front hydrophone in Figure 9 along with the vessels rate of turn (plotted as total course change in a 15 minute period), the vessels speed and the distance to the nearest other vessel in the fleet. For most of the study period, the *New Venture* speed was approximately 5 knots and noise levels can be seen to drop dramatically during turns when other vessels in the fleet tended to be further away. During the last day of the study, the *New Venture* speed increased to around 10 knots which also lead to higher noise levels. Using a simple spherical spreading propagation model, a 10dB increase / reduction in noise levels would reduce / increase detection range by a factor 3.2.

8.1 Comparison with noise levels from the CODA survey

Noise levels in the PAMGUARD click trigger have been measured in a similar way for two of the vessels taking part in the CODA survey (Gillespie 2009), the *Investigador* and the *Cornide de Saavedra*. During the CODA survey, trigger thresholds were set 10dB above the background noise measurement. On the *New Venture*, trigger thresholds had to be raised to 13dB above background to reduce the very high trigger rate caused by cavitation noise. Comparative histograms of the noise levels plus trigger threshold levels (10 or 13 dB) on hydrophones 1 and 3 of the *New Venture* and on hydrophone 3 of the CODA vessels are shown in Figure 10. Noise levels from the *New Venture* hydrophones are similar to those on the noisier of the two CODA vessels (*Cornide de Saavedra*) but are considerably higher than those from the quieter CODA vessel (*Investigador*) by 8 – 10 dB which should (assuming a spherical spreading propagation model) be expected to affect detection range by a factor of between 2.5 and 3.2.

Preliminary estimates of effective survey strip half width from the CODA vessels for sperm whales are 5.1km and 3.7km for the *Investigador* and *Cornide de Saavedra* respectively. Effective strip half width equates roughly to the perpendicular distance from the track line at which detection efficiency drops to 50%. (A more formal definition can be found in Buckland et al. 2001). The CODA data show high (close to 100%) detection efficiency at ranges of up to 3km and 2km for the two CODA vessels. We would therefore expect that in spite of the perceived high noise levels during the *New Venture* trial that it would be possible to track sperm whales out to a distance of approximately 2km.

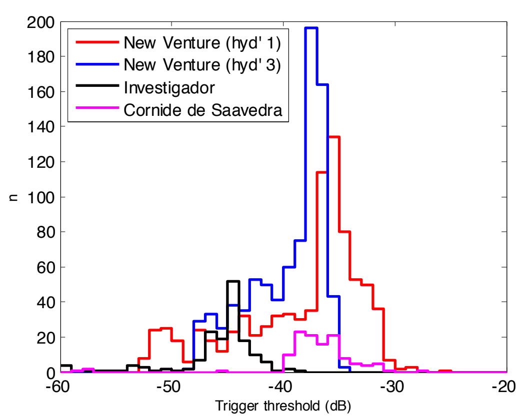

Figure 10. Comparative noise levels from hydrophones 1 and 3 of the *New Venture* and two vessels from the CODA survey.

9 Offline Data Analysis

9.1 Offline Aural Monitoring

Possible aural sperm whale detections were made on four separate occasions during the trial. All of these appeared distant and all were beyond the detection range of PAMGUARD (i.e. no click trains were detected on the screen). Recordings from these periods have been listened to again by Rene Swift (RS), who has also attempted to re-tune PAMGUARD to detect clicks at these times. Of the four possible encounters, only one (on 15 November) is clearly audible the other three being barely audible. Two occasions (14 November and 17 November) are close (< 2 hours) to times of visual sightings of sperm whale. It has not been possible to detect clicks at any of these times using PAMGUARD or the IFAW RainbowClick software.

9.2 Comparison with IFAW Software

Table 2: Results of offline data analysis using PAMGUARD in offline mixed mode by three operators. False positive detections and missed detections are shown in red.

Date	Offline Detection Time	PG	DG	RS
11 November 08	10:24:32 - 10:31:45	10:23:53-10:31:40 And 10:37:12-10:37:14	10:24:00 – 10:31:47	None
11 November 08	None	12:06:13 – 12:09:51	None	None
12 November 08	None	None	None	None
12 November 08	05:19:36 – 05:20:06	05:18:44 – o5:20:33	05:19:39 – 05:20:30	05:19:40 – 05:20:33
17 November 08	None	None	None	None
17 November 08	16:06:26 – 16:08:38	16:05:21 – 16:10:59	16:05:58 – 16:08:37	16:05:57 – 16:08:37
17 November 08	16:24:41-16:24:53	16:22:45 – 16:25:34	16:24:42 – 16:24:52	16:24:42 – 16:25:28
18 November 08	03:29:56 – 03:30:03	03:29:59 – 03:30:02	03:29:56 – 03:30:02	03:29:56 – 03:30:01
18 November 08	05:08:36 – 05:08:37	05:01:26 – 05:03:53	05:08:25 – 05:08:36	05:08:36 – 05:08:36
18 November 08	None	06:01:56 – 06:13:32	None	None

Recordings made during the survey were reprocessed offline using the PAMGUARD click detector[2] and ensuing click data files viewed with the IFAW RainbowClick[3] software, by a single experienced operator (RS), to search for animals which may have been missed during the survey. Multiple high frequency dolphin click trains were found on six occasions. All of the clicks were too high frequency to be detected aurally. One was the group of click trains detected in real time on 17th November, the other five detections occurred at times when the operator was not monitoring the PAMGUARD display.

When analysing click data offline using RainbowClick, the operator can scroll back and forth through the data at their leisure, viewing the waveforms of individual clicks and taking as long as they like to make decisions. This is very different to detecting and localising click trains in real time, particularly with fast moving small cetacean species whose clicks may only be available on the screen for a minute or less. Therefore, to test both the efficiency and usability of PAMGUARD the six recordings containing the detected click trains and four recordings containing no click trains were reanalysed with PAMGUARD operating in offline mixed mode. PAMGUARD offline mixed mode presents the data to the operator in real time, plays the sounds back over headphones and also synchronises with GPS data from the database, so that the overall experience of the operator is exactly as it would have been in the field.

Three operators, each with different levels of experience, analysed the data independently. Two of the operators were Douglas Gillespie and Rene Swift, who are both experienced PAMGUARD and RainbowClick operators. The third was Popi Gikopoulou (PG), a student from Greece visiting SMRU, who had no prior experience of either PAMGUARD or RainbowClick. PG was trained in PAMGUARD operation prior to the trial using tutorial information available on the PAMGUARD web site.

Results of the trial are shown in Table 2 and screen shots of the click detector and the map are shown in Figure 7. Two of the operators each missed one detection, and the inexperienced operator (PG) made a number of false detections. The missed detection and false detections by PG can be put down to limited training and a lack of experience. The missed detection by RS appears due to him being provided with click detector displays incorrectly configured. In subsequent re-analysis with the correct settings, he easily found the click trains.

9.3 Comparison with Ishmael Software

The comparison between PAMGUARD and Ishmael software has not yet been completed by Oregon State University. A revised report will be submitted when these data become available.

[2] Note that the detection algorithms in the PAMGUARD click detector and in the RainbowClick software are identical, so it's unimportant as to whether this stage was performed using PAMGUARD or RainbowClick. PAMGUARD is however much more stable and less prone to crashing than RainbowClick.

[3] PAMGUARD does not contain the offline analysis features of RainbowClick which allow the operator to scroll back and forth through click files, selecting clicks for more detailed analysis, etc. this stage of the analysis could therefore only be performed with RainbowClick.

9.4 Comparison with MMO Sightings Data

There were seven cetacean sightings from MMO's during the time that PAMGUARD was operational. Only one of these sightings was from the *New Venture*, the other six being from other vessels in the fleet. These sightings are summarised in Table 3. Figure 11 shows the times of sightings along with the times at which sperm whales were possibly heard and the times dolphin click trains were detected offline.

The only sighting which occurred within 500m of the *New Venture* was that of a Frasers dolphin on 12th November. No clicks or whistles were detected, although any vocalisations of this species should have been within the frequency range of the detector. The next closest sighting was of spotted dolphin at a distance of 1350m which is probably beyond the detection range for this species. We would expect the sperm whales sighted at a range of around 2km to have been detected and it is possible that this animal (or another forming part of a group) was heard faintly on headphones, although it can be seen from Figure 11 that this corresponded to one of the periods of highest noise during the survey. It is also interesting to note that the sperm whales seen on 14th November at a range of 7km and more were faintly heard during a period when noise levels were low.

10 PAMGUARD Performance

10.1 Detection and Localisation

Marine mammal sounds were only automatically detected on a single occasion using PAMGUARD during the trial. These were high frequency dolphin click trains, detected

Table 3. MMO sightings

Sighting Time (UTC)	Vessel	Species	Closest Distance to hydrophone	Time of closest Approach
9/11/08 13:00	*Vardholm*	Unidentified	2100 m	13:14
12/11/08 13:30	*Veritas Viking*	Spotted Dolphin	1350 m	13:33
12/11/08 14:42	*New Venture*	Frasers Dolphin	50 m	14:47
14/11/08 22:18	*Vardholm*	Sperm Whale	7000 m	22:19
14/11/08 22:21	*Veritas Viking*	Sperm Whale	9450 m	22:15
17/11/08 21:27	*Veritas Viking*	Sperm Whale	2000 m	21:36
17/11/08 21:27	*Viking Vision*	Sperm Whale	6300 m	22:32

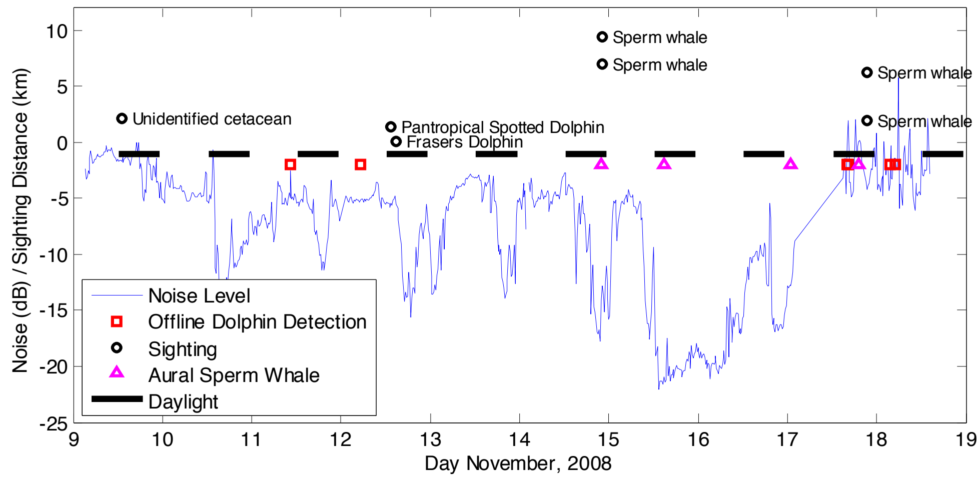

Figure 11. Sightings and acoustic detections during the trial. Closest distances to the New Venture hydrophone are plotted for sightings. Only the times (i.e. not distances) are plotted for acoustic detections.

while the *New Venture* was scouting for shallows far from the rest of the fleet.

As described in Section 9.2, six groups of dolphin click trains were identified offline and re-analysed using PAMGUARD in offline mode by three different operators. All operators were able to track click trains using the click train localiser built into the PAMGUARD click detector. The integration of the click detector, map and database interface into a single program greatly facilitated tracking with information on whale location being clearly displayed and annotated on the map. This is a marked improvement of the RainbowClick / Logger 2000 system which only passes some of the data from the click detector to the map and does not contain an automatic calculation of location.

None of the detections corresponded with sightings, and in the absence of accurate visual localisation it is impossible to state how accurately the animals were localised. A detailed study of localisation accuracy can be found in the report of PAMGUARD trials during the CODA cetacean survey of 2007 (Gillespie 2009).

An important lesson to learn from this is that many cetaceans vocalise at frequencies which cannot be heard by humans. Only aural monitoring on headphones while engaging in other activities (such as visual MMO work or, as in this instance, programming / bug fixing) will lead to many vocalizations being missed. The PAMGUARD click detector works well and is capable of detecting and localising sounds over a wide range of frequencies, covering all known cetacean click vocalisations. However, PAMGUARD is only a tool, and without an attentive operator, it will not perform.

10.2 Reliability

During the first two days, PAMGUARD would not run reliably, rarely managing more than two to three hours before crashing. Once the timing bug (see below) had been resolved however, PAMGUARD became extremely reliable, running unattended every night and only being stopped in the daytime for debugging or improvement.

The IFAW RainbowClick software was run continuously during the trial and crashed a total of thirteen times. Intervals between crashes varied between several days and less than an hour. Based on this, recent experiences using RainbowClick on other studies, and feedback from colleagues using PAMGUARD for the detection and tracking of beaked whales (Charlotte Dunn, pers comm.), it is our opinion that PAMGUARD is now more reliable and a lot more user friendly than RainbowClick.

11 Bug Reports

Bugs in the code encountered during the trial varied from the mundane (such as some graphics symbols not resizing correctly) to fundamental flaws in the core PAMGUARD data handling functions. Each bug was assigned a severity level, 1 being not at all serious and 5 having a serious effect on PAMGUARD operation (see Section 19.2 for details).

A full list of bugs is given in Table 6 in Section 19.2. This is a summary of information logged on the PAMGUARD sourceforge site.

Figure 12 shows the numbers of bugs in each category. Of 39 reported bugs, 28 were fixed during the trial and a further eight have been rectified since. The three remaining bugs are very minor and have little or no effect on PAMGUARD operation. These will be worked on as part of the ongoing PAMGUARD maintenance contract.

The most serious bug encountered, and the one that was probably causing the highest levels of instability in the software, was a timing problem resulting from the clock in the Fireface sound card running at a different speed to the clock in the PC. Timing is critical to real time processing systems. Data from acquisition devices may be flowing into the system at several megabytes a second. The data need to be processed, useful information extracted and the data discarded before the PC memory overflows. Some PAMGUARD processes require data to be kept for some time in order that they can check back once a detection occurs or for some other reason such as plotting on the map. Due to the difference in clock speeds, some data were being discarded based on the PC clock time, when calculations based on the detector information suggested that the data should still be in memory. This problem could only be cured through quite major structural changes to the way in which data and timing information are exchanged in PAMGUARD. Following the trial, DG worked closely with other development teams (Mellinger, Thode, Akoostix, etc.) to ensure that the necessary changes were effectively incorporated into their modules.

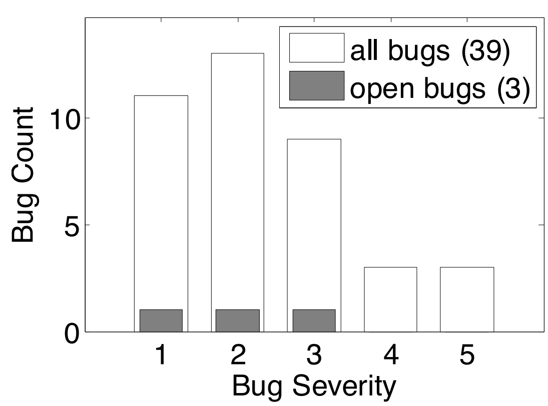

Figure 12. Bugs encountered at each severity level.

12 New Modules

National Instruments data acquisition functionality was added to the main PAMGUARD sound acquisition module immediately prior to the trial. Four new PAMGUARD modules were also developed by DG shortly before the trial. These modules are all of high relevance to PAMGUARD operation in the vicinity of seismic vessels.

12.1 National Instruments Data Acquisition

National Instruments Data Acquisition (NIDaq) is a plug-in sub module for the main PAMGUARD Sound Acquisition module.

Although there are now a number of sound cards available that have multiple input channels, the fastest sample rates on these cards is 192kHz, which is not sufficient for harbour porpoises and some other high frequency species. NIDaq cards can sample at higher rates and also have multiple channels.

There is no direct Java interface to NIDaq cards. The NIDaq PAMGUARD interface has therefore been written in C, and uses the Java native interface (JNI) to communicate with PAMGUARD. All control of NIDaq is from within PAMGUARD making it operate from a users perspective in the same way as other PAMGUARD sound input devices. One big disadvantage of using the JNI is that separate C libraries have to be developed for each operating system. Currently only a library for 32 bit Windows has been released. We are in the process of testing a 64 bit version.

The NIDaq system was tested over two nights, acquiring two channels sampling at 500kHz. Only a click detector, basic mapping functions (map, NMEA, GPS, AIS), a database and sound recording were included in the configuration, as would generally have been configured with the IFAW software for harbour porpoise detection. The system ran reliably on the Dell Latitude (the fastest of the laptops available), but CPU usage was high (often above 80%). The system would not run at that sample rate in either of the other laptops available. Running at these speeds would not have been possible without the multithreading data models implemented both in PAMGUARD as a whole and within the click detector as described in Sections 13.1 and 13.2.

On another occasion, the system was run overnight sampling 8 channels at a lower sample rate of 10 kHz. Nothing was connected to six of the channels since only a four channel hydrophone was deployed, but the system worked reliably.

At the end of the trial, the NI acquisition module was still unstable and would hang or stall and require re-starting by the user. Since the trial, additional funds have been made available from the JIP for further work on this and the NI acquisition is now stable and fully operational.

12.2 Seismic Veto

Many of the PAMGUARD detectors set detection thresholds automatically as a function of background noise. Loud sounds from airguns can upset this automatic threshold setting. It is of course extremely unpleasant listening on headphones when airguns are firing nearby and airgun sounds may even pose a risk to the operators hearing.

In the past, seismic signals have been gated out using specially built electronics which disconnect the amplifier inputs for a set time in response to a logic signal from the instrument room airgun electronics. While effective, this has required a certain amount of goodwill on the part of instrument room technicians (which has never been a problem). More fundamentally, such signals would not be available if the PAM system was set up in another part of the vessel or on a guard boat. During automatic threshold

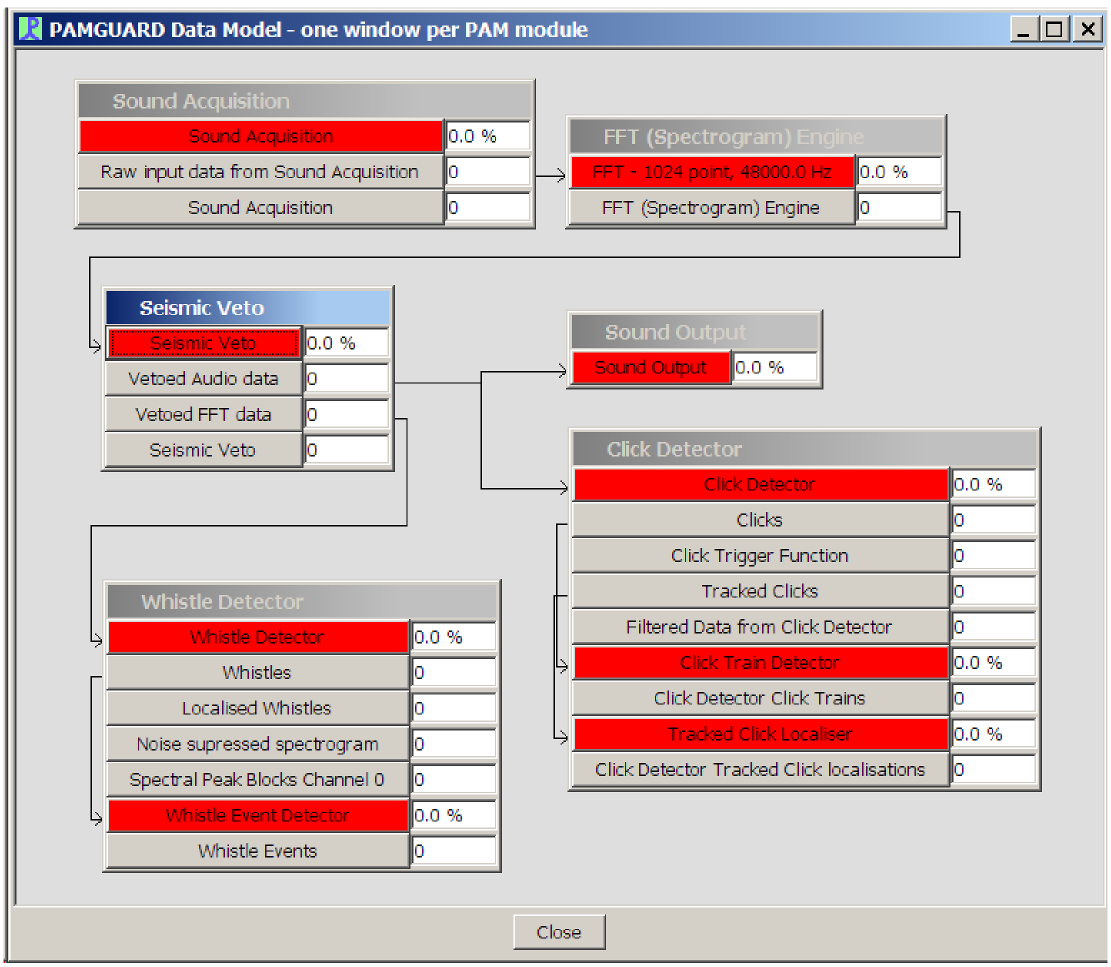

Figure 13. A simple PAMGUARD configuration showing output from a seismic veto connected to a sound playback module, a click detector and a whistle detector.

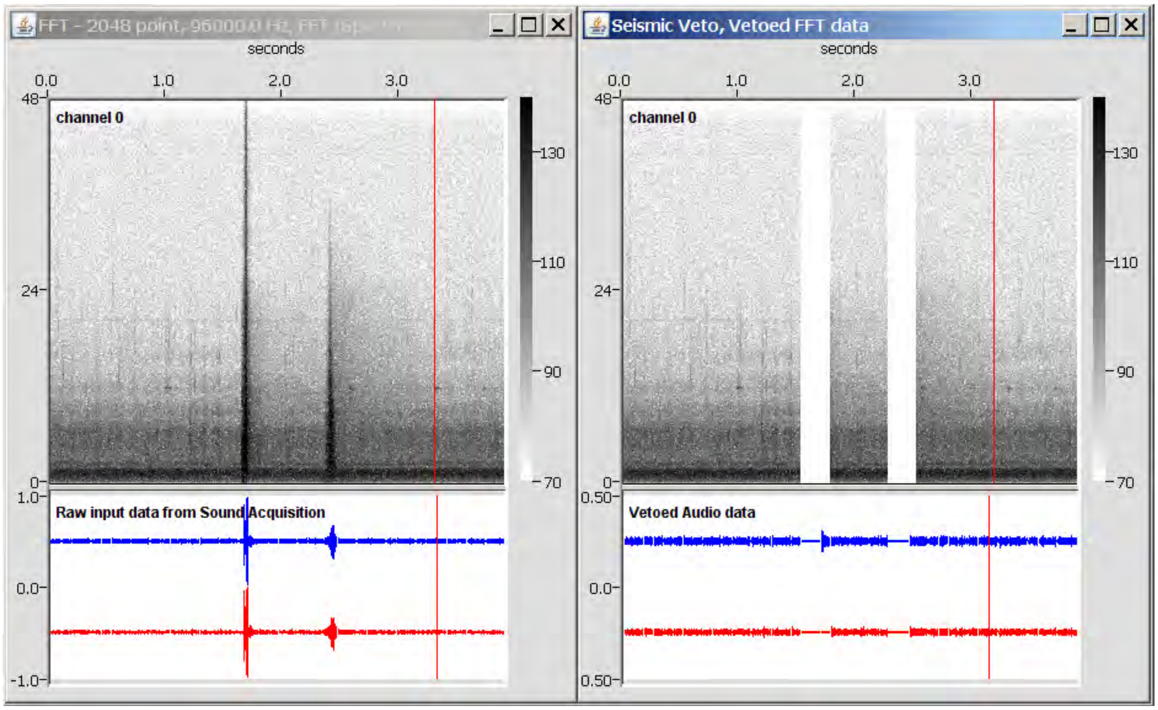

Figure 14. Spectrograms and waveforms before and after the veto.

setting, a period of zero signal can upset threshold levels almost as much as a period of too much signal for some detector types.

The seismic veto module detects the airgun pulse automatically using a simple in-band energy detector operating on spectrogram data. When the signal level exceeds some threshold, that period of sound is either taken out and set to zero, or replaced with randomly generated noise with the same spectral properties as measured in the signal prior to the airgun pulse. The time window of vetoed data can be set to continue after the signal has fallen below threshold to ensure the end of the pulse is discarded. It can also be configured to start the veto before the onset of the pulse (this is achieved by delaying the signal slightly in an internal buffer).

The seismic veto module has two output streams, the first containing vetoed FFT data and the second containing vetoed raw audio data. Other PAMGUARD modules can subscribe to the appropriate output of the seismic veto module and operate as normal, but without the loud airgun sounds.

Figure 13 shows a simple PAMGUARD configuration with the output of the seismic veto connected to a sound playback module, a click detector and a whistle detector. Figure 14 shows spectrograms and waveforms of data collected during the trial before and after the veto. PAMGUARD can easily connect multiple spectrogram and waveform displays to any part of the configuration shown in Figure 13 to show data in this way in real time.

12.3 Real Time Sound Playback

A sound playback module has existed in PAMGUARD for some months which could be used only when analysing data from file. For sound playback to operate during real time data acquisition, the playback must be synchronised with the incoming data. In practice, this can only be achieved by playing the data out through the same device that is acquiring the data. The ASIO sound system, which already has the most flexible options in terms of numbers of channels, was adapted so that it can output sound at the same time as reading it in. This required modification both the PAMGUARD Java code and also to the C based JNI interface code used to control ASIO sound card.

The great advantage of having a real time sound playback module is that rather than listening to the raw audio coming from the hydrophone, the operator can listen to the signal after it's been through a whole variety of PAMGUARD signal conditioning modules. The seismic veto module is the most notable, enabling the operator to hear the signal minus the airgun sounds.

The program structure for this module has been written in such a way that playback through other sound input systems can be supported in the future with the same basic program structures.

12.4 Depth Sensor Readout

Hydrophone depth information is essential for the 3-D localisation methods developed by Aaron Thode. The hydrophones supplied by SML contain analogue depth sensors which output a current proportional to the depth.

A depth readout module was developed which uses a Measurement Computing[4] data acquisition board to read the analogue signal and convert it into a depth in meters. Like the NIDaq system, the Measurement Computing DAQ boards cannot be controlled directly from Java, so the Java Native Interface is used to link PAMGUARD to a C library that communicates with the board.

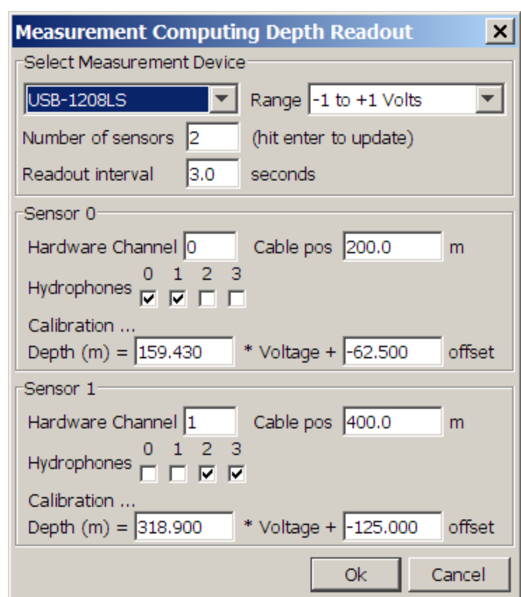

Figure 15. Depth readout configuration panel

The user configuration panel is shown in Figure 15. The user can configure any number of sensors (limited by the number of input channels on the board). For each channel, the user sets which hydrophone channels the sensor data are associated with and sets the parameters of a linear relationship to convert the output current or voltage from the sensor

[4] Measurement Computing Corporation, 10 Commerce Way, Norton, MA 02766, USA. www.mccdaq.com.

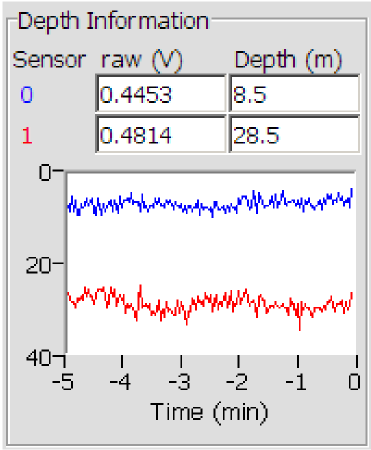

Figure 16. Depth readout side panel

to a depth. In the example two sensors are configured, one near each hydrophone pair. A small side panel (Figure 16) shows the latest depth information.

Although developed with the SML depth sensors in mind, the system will work with any analogue depth sensor, so long as the relationship between sensor output and depth is linear.

The current system only works with Measurement Computing DAQ cards. It would be possible to extend it to work with other cards (such as National Instruments). Measurement Computing cards are low cost and it should be noted that it is not generally possible to set up a single NIDaq card to acquire data continuously for sound acquisition and for depth sensor readout.

12.5 Aural Monitoring Form

In order to keep track of periods of aural monitoring and sounds heard by the operator, a module was developed which consists of a single form on the PAMGUARD display containing buttons to switch effort on and off and to record things heard. Data from the form can be displayed on the PAMGUARD map and are written to the database. Although used during the trial, the list of species was fixed in the code. Work has recently been undertaken to rectify this and the module is now fully operational with online help and a species list that can be configured by the user. This module will be included in the next PAMGUARD release.

13 Enhancements to the PAMGUARD core and to Existing modules

13.1 Multi Threading

In PAMGUARD versions up to V 1.1.01 (the October '08 release) data were passed from module to module in a single execution thread. That is, once a block of raw data were acquired from the sound input device, that block would be passed through each module in turn before execution would return to the sound acquisition module and the next block of data acquired from the input buffer and passed in turn through the modules. While simple and reliable, the single thread model has the disadvantage that it can only ever execute on a single processor. Most PC's now have a dual core processor which is effectively two independent processors on a single chip. The single thread model was therefore only ever able to use half of the available processing power in the PC. Macintosh computers with 8 cores are already available and support for more cores will be available in future Windows versions.

By separating data processing into multiple threads, some threads can run on one core and some on the other, thereby utilising all available processing power. A good analogy is asking someone to do something at work. With a single thread model, when you want someone to do something, you go to their office, ask them, they work on your task and your task only while you wait at the door. You do nothing at all while you wait. When they complete the task they hand the results of the completed task back to you and you go on to the next task. With a multi threading model, it's as though you've sent someone an email. As soon as you've sent the email, you get on with something else, quite possibly sending another email to another person asking them to do something else at the same time. At some point the emails arrive in the other persons in tray and they deal with them in turn after completing any other tasks already in their in tray. They then send you back the result which you can only deal with when you get time away from whatever else you decided to do while you waited. With careful program design, this can lead to significant increases in processor utilisation. Multithreading can also improve program stability since threads handling critical tasks, such as control of a data acquisition card don't have to wait for all other tasks in the program to complete before they service any requests made of them by the acquisition.

A multi thread model was implemented in PAMGUARD shortly before the cruise. It's been written in such a way that multi threading can be switched off by the user since the Akoostix likelihood detector is currently incompatible with multithreading.

13.2 Multithreading of the Click Detector

When running a high frequency click detector for porpoises, it is likely that the click detector will be the only module utilising significant CPU power since PCs are currently not powerful enough to run multiple PAMGUARD detectors when sampling at 500 kHz. In this case, the advantages of separating the different modules in PAMGUARD into multiple threads doesn't exist. The click detector itself has therefore been split so that half the detection process runs in one thread and half in another. The first thread handles pre-filtering of the data and triggering. Once candidate clicks are detected they are passed to a second thread which computes bearings using cross correlation, runs species classifiers, writes data to file and other CPU intensive tasks. The two threads put similar loads on the CPU, thereby maximising efficiency (although the exact load on the second thread is a function of trigger rate, whereas the load on the first thread is more or less purely a function of sample rate).

Like the multithread model for the PAMGUARD core described above, this feature can be disabled by the user.

13.3 GPS Data Readout

A number of improvements have been made to the way in which PAMGUARD reads GPS data.

Previously, all GPS data were stored, creating a large database and using a lot of memory. Now there are three options:

1. Read and store everything (as before).

2. Read and store at chosen time intervals.

3. Read and store at a (generally longer) chosen time interval OR if the speed or heading change.

The latter option means that when on straight tracks, very little data will be stored, but more data will be stored during turns. The map display and hydrophone location modules have been adapted to display the ships position based on interpolation or extrapolation (assuming straight lines) in order to correctly geo-reference the ship and hydrophones for a time between or following GPS reads.

An unforeseen consequence of this extrapolation is that if the GPS readout fails for any reason, the map looks perfectly normal, with the ship continuing in a straight line at constant speed. Additional information giving the time of the last read fix has been added to the GPS text area on the map panel and the panel turns red if GPS data have not been successfully read for 60 seconds.

13.4 Spectrogram Colours

In response to a request from a user, the spectrogram display has been updated to that multiple colour options are available.

14 Software Releases

Table 4 shows a list of software releases which have taken place since the field trial and contain features and / bug fixes resulting from the trial. Further details are available in the download area of the PAMGUARD sourceforge site.

Table 4. Software releases containing bug fixes and enhancements from the field trial

Date	Release	Features
16 December 2008	Beta 1.2.00	All bug fixes and new featured implemented during the field trial.
21 January 2009	Beta 1.3.00	New Likelihood detector from Akoostix Bug fixes to multithreading and depth sensor readout (features added during the field trial)
26 February 2009	Beta 1.3.02	Improved graphics speed Improved online help files Support for multiple displays / multiple screens Improved National Instrument card support
26 February 2009	Core 1.3.00	As for Beta 1.3.02, but without unstable or undocumented modules: Utilities Group Simulator (unstable)

		Hydrophone Depth Readout (requires testing and help) Sound Processing Group Patch Panel (unstable and requires help file) Seismic Veto (requires help) Visual Methods Group angle Measurement (requires help) Video Range (requires help) Fixed Landmarks (requires help)
June 2009	Beta 1.4.00	Release of Viewer and offline mixed mode operation Improved documentation detailing developments made during the trial Multiple display windows Minor bug fixes in user interface
July 2009	Beta 1.5.00	Fully functional (and documented) National Instruments Support

15 Data

The following data have been collected:

From the IFAW Software
Continuous recordings, four channels at 96 kHz. 535 Gigabytes total.

RainbowClick clk files.

Whistle detector wsl files.

Logger database with GPS track and hydrophone depth readout.

From PAMGUARD
Test recordings, varying channel numbers and sample rates.

Calibration recordings, 500kHz, two channels from NI card.

PAMGUARD Databases which include records of PAMGUARD operation and module configuration as well as GPS and AIS data.

PAMGUARD configuration files.

Clk files (RainbowClick format) from the click detectors in a variety of configurations, including 500 kHz high frequency NIDaq.

16 Conclusions and Recommendations

16.1 Performance

16.1.1 Program Stability

In our opinion, PAMGUARD is now a more stable package than the IFAW RainbowClick software. PAMGUARD is also better documented with better online help and user tutorials available through the PAMGUARD web site (www.pamguard.org). Indeed, in our own research, we now mostly use PAMGUARD in preference to the IFAW software for reasons of reliability as well as the additional, more flexible, features offered by PAMGUARD.

16.1.2 Detection and Localisation

It is not possible to assess overall PAM detection efficiency from the limited number of cetaceans encountered in this study. Readers should refer to earlier work (Lewis et al. 2000) and the results of the PAMGUARD trials during the CODA survey (Gillespie 2009). It should however be reiterated that PAMGUARD is only a tool and it will only perform optimally in competent hands. When used by a trained operator it can detect animals which vocalise at frequencies inaudible to the human ear and can also estimate locations of sound sources.

As part of the ongoing PAMGUARD maintenance contract in St Andrews, a training day for PAM operators from selected PAM service provision companies was provided using funding from the JIP. We are in the process of developing training courses at SMRU Ltd which will run on a commercial basis from November 2009.

Visual and acoustic detection efficiency varies by species, odontocetes generally being more easily detected using acoustics, and baleen whales more easily detected visually. The most effective mitigation will always be achieved through the use of both acoustic and visual methods.

Should further studies be conducted to compare visual and acoustic detection during seismic survey operations, we recommend that visual data collection procedures be modified or enhanced to facilitate comparison with the acoustic data. From the MMO data provided for this study, we were unable to determine visual effort (i.e. when observers were on watch) and there was also no information on sighting conditions, which are known to have a dramatic effect on overall visual detection rates. Extracting accurate positions from the MMO data proved extremely difficult.

16.2 Operations

Most PAM detection is conducted at frequencies above the dominant energy peak in the seismic pulses themselves and the seismic pulses can be removed from the data using the seismic veto module (Section 12.2). The most significant problem encountered in this study was vessel noise, which appeared to be dominated at important frequencies by cavitation from the other vessels in the fleet. It is quite possible that the noise was dominated by one particular vessel, but where multiple vessels are present, the chances of at least one vessel being very noisy increase.

Deployment of the PAM hydrophone from the seismic source vessel did not pose any problems in terms of HSE or operations. Seismic operators from the *Viking Vision* who visited the *New Venture* were of the opinion that the PAM array could also have been deployed from the *Viking Vision* without difficulty. Similar PAM arrays have been successfully deployed from seismic streamer vessels in the past.

During early PAM trials in the 1990's, the PAM array was deployed from a guard vessel stationed approximately 1 mile ahead of the seismic vessel (Lewis et al. 2000). Deployment from the guard vessel has both advantages and disadvantages. Advantages are that:

1. Noise levels ahead of the fleet are likely to much lower, particularly in the case of wide azimuth surveys.
2. Animals are detected well ahead of the seismic survey vessel thereby giving forewarning of any animals likely to enter the mitigation zone.

On the other hand there are also disadvantages:

1. The guard vessel may have other duties to perform and may not be able to remain on station ahead of the seismic vessel.
2. Small cetacean vocalisations may have only limited detection range so animals could be in the vicinity of the seismic boat without being detected on a hydrophone deployed from the guard vessel.

The most suitable PAM configuration should be decided on a case by case basis.

16.3 Recommendations for future improvements to PAMGUARD

As part of the ongoing PAMGUARD maintenance work in St Andrews, working with JIP representatives, we developed a list of four priority developments for PAMGUARD. These are:

1. Development of a multi threaded data processing model
2. Support for multiple monitors
3. Network sharing of data and resources
4. Transfer and testing on new operating systems

The first two of these features are now implemented and work is underway testing PAMGUARD on other operating systems (Mac, Linux, Windows Vista, and 64 bit Windows versions). Work on network sharing of data and resources have not yet been started.

As a result of the Industry field trial, other areas of development which would improve PAMGUARD operation in the field have come to light. A brief description of these is given below. We are also preparing a more detailed report to the JIP on the ongoing

PAMGUARD maintenance work in St Andrews in which we will elaborate further on these possible work areas.

16.3.1 Data Scrolling

PAM detections during this study were all of high frequency dolphin click trains. These animals tend to pass the hydrophone quite rapidly and vocalisations are often only visible on the PAMGUARD display for a minute or two. Adding features which would enable the operator to scroll backwards through the data while continuing to process in real time, to check vocalisations, would improve the usability of the software.

16.3.2 Real time noise analysis

So that operators in the field can immediately assess the likely performance of PAMGUARD, we recommend the development of a module to measure background noise and to then estimate, based on data from other surveys, the likely detection range of the system. Currently, this would only be possible for a few species, but over time, as more data are gathered, it will be possible to estimate performance for more and more species. For instance, other work currently being conducted at SMRU should shortly enable us to estimate detection ranges for beaked whales. Such a module would be of benefit to regulators as well as operators.

16.3.3 IFAW software features not implemented in PAMGUARD

Although PAMGUARD is now our software of choice in place of the old IFAW system for research conducted from the University of St Andrews, areas of our other research where we still use the IFAW software in preference to PAMGUARD are:

1. User Defined Forms for user configurable data entry – this is a feature only existing in Logger and funding has not been available to incorporate this feature into PAMGUARD.
2. Offline data analysis of click files. Again, this feature has not been incorporated into PAMGUARD.

Although these features are not essential for real time mitigation monitoring, the Logger data entry forms are useful for visual data collection and feedback from PAM operators suggests that additional Logger data entry forms are also used during PAM operations. Offline click analysis is essential step in post survey data interpretation.

17 Acknowledgements

I am extremely grateful to all those who facilitated in the smooth running of this field trial. David Hedgeland of PGS, Reagan Woodard at Fairfield and Bernard Padovani of CGG Veritas were all extremely helpful prior to mobilisation. The crew of the *Fairfield New Venture* were fantastic and I am particularly indebted to those who stuck their arms, and occasionally their heads into filthy cable ducts in order to complete a nightmare cable run from the gun deck to the instrument room. Rene Swift conducted the offline analysis of noise levels and detailed searches for click trains using

RainbowClick. Thanks to both Rene and Popi Gikopoulou for their efforts in reanalysis using PAMGUARD. Funding for this work was provided by the OGP Sound and Marine Life JIP, Contract Reference JIP 22 06-10, Schedule 0708.

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19 Appendices / Tables

19.1 Module Testing

Table 5. Testing notes for each PAMGUARD module. Note that some of the module names, such as National Instruments data acquisition are plug in modules to other PAMGUARD modules and were therefore not listed. Numbers in the Outstanding and Fixed bugs columns refer to the bugs table in Section 19.2.

Module	Notes / Developments required prior to cruise.	Days, Hours of Testing	Outstanding bugs	Fixed bugs	Notes
Array Manager					
The Array Manager is fundamental to PAMGUARD operations. Since the last deployments at sea, this has been modified to accurately predict the location of hydrophone elements during turns. Since this is one of the key times for PAM operation, this functionality must be rigorously tested.	The array locator predicts the x,y coordinate based on GPS data. A module was written to read out the simple depth sensors incorporated into the Seiche arrays prior to the cruise (section 12.4). Continuous testing throughout cruise	12d5H	No	No	Ran throughout the trial. Appears to working correctly based on visible hydrophone locations on the map and interpolates position correctly even when GPS data are collected infrequently. Analogue depth sensor readout added and tested (section 12.4). It was noted that on some transects, the vessel was 'crabbing' by up to 15˚ to compensate for side currents. Since the array location prediction is based on vessel course over ground (the basic information coming from GPS), the true angle of the array would be inaccurate which would

					adversely affect localisations.
Maps and Mapping Utilities					
Map					
The PAMGUARD Map and detector data overlaid on the map are one of the most important components of PAMGUARD. The effectiveness of the map in presenting data to the operator in a clear way, which can be used to provide information affecting vessel operations is one of the key tests of this cruise. Map comments (double click anywhere on the map and a dialog appears where you type in a comment which is displayed and logged to the database) are a new feature added during the analysis of the CODA data. This feature is not yet tested at sea.	Fundamental test. Will use continuously during the cruise.	12d5H	No	No	Ran throughout. No problems encountered. Made improvements to base map contour display and synchronised drawing to cope with multithreading. Map comments rarely used due to lack of detections. Test comments worked OK. Changes were also made to speed up map drawing after the cruise.
NMEA Data Collection and GPS Processing					
These have been well tested during previous cruises. Some further testing of new modules for direct reading of serial ports by PAMGUARD is required	Will run continuously throughout the cruise.	12d5H	No	Yes 4.	Also had reliability problems with one make of USB to serial adapter. New GPS readout options implemented and tested (section 13.3)

AIS Processing					
The AIS processing module allows the map to display the locations of other vessels operating in the area. This may prove particularly useful during multi vessel surveys or when the PAM system is deployed from a guard vessel since the locations of all airguns relative to the PAM array will then be known.	Currently only tested on data from file collected by a colleague in the English Channel. Will attempt to bench test prior to cruise. Will test early on in the cruise and hopefully run throughout (low priority)	11d23 H	No	Yes 6, 17	Found AIS display very useful for keeping track of all four vessels in the fleet, particularly during turns. During operations, knowing the positions of all sets of guns was extremely helpful.
Airgun Display					
Part tested during CODA field trial. This display plug in allows the operator to view the position of the guns, a simple circular mitigation zone around the guns and the predicted mitigation zone in the coming minutes. Gun positions can be plotted relative to either the GPS data from the PAM vessel or relative to AIS data received from a different vessel.	As for AIS processing.	12d2H	No	Yes 9	Found to be extremely useful, especially in conjunction with AIS
General Utilities					
Simulator					

The simulator is designed for offline development and will not be tested at sea.	No Testing	0			No testing
ODBC Database					
The Database interface was rewritten early in 2007 and was successfully tested during the CODA field trial. Further testing, particularly of database output from new modules, is required	Will run continuously throughout the cruise.	12d5H	No	Yes 14.	Ran throughout. All analysis plots of effort and module usage in this report used data extracted from the database.
Terella Control					
This module was written specifically to read out hydrophone location devices used by Aaron Thode. We will not be using these devices, so this module will not be tested.	No Testing	0			This module was never completed and will be removed from the next release. Basic depth information readout can be achieved using the new analogue depth readout module (section 12.4).
Hydrophone Depth Readout	New module	3d18H	No	Yes 36.	See section 12.4 for details
Aural monitoring form	New module	12d5H	No	No	See section 12.5 for details. Needs further work before release
Displays					
User Input					
Has been tested during previous field	Continuous use	12d5H	No	No	Works fine. No comms with bridge.

trials.	throughout the cruise. Will generate a log of all activities including bridge communications.				
Spectrogram and Radar Displays					
These have been thoroughly tested during previous cruises. Further testing, particularly of graphic overlays from the detectors is required	Continuous use throughout the cruise.	9d6H	No	Yes 16, 21, 22.	Worked well and reliably throughout the cruise. Small bugs in plug in displays resolved and added a choice of colours to spectrogram.
Sound Processing					
Sound Acquisition					
Sound acquisition has been well tested during previous cruises.	Continuous use throughout the cruise.	12d5H	No	Yes 2,3, 10	Large improvements in reliability and implementation of National Instruments data acquisition achieved during the cruise. Further work is required to get PAMGUARD to stop and restart the acquisition in a controlled way when the system overloads. This currently works for some devices and not for others. Tests included over 34 hours sampling at 500 kHz with NI Daq.
Sound Output					

Sound output is a relatively recent feature which enables the operator to listen to signals processed by PAMGUARD modules, rather than just the raw audio coming out of the hydrophone. The enables the operator to filter the signal and also to veto out seismic airgun pulses (see seismic veto below)	Continuous testing throughout cruise	8d13H	No	Yes 37	Extremely useful. All aural monitoring was done via the PAMGUARD sound output module so as to make use of the seismic veto and other PAMGUARD filters.
FFT (Spectrogram Engine) ***IIRF Filters*** ***Spectrogram Smoothing Kernel***					
These three modules have been extensively tested during previous cruises and are known to be reliable. It is likely that they will be in operation as pre-processing stages for other modules during most of the cruise.	Testing as part of testing of other modules.	6d17H	No	Yes 8, 29, 31, 35.	All ran very well. Small bugs in dialogs and how they initially link to other data resolved.
Decimator					
The Decimator has recently been debugged and requires testing (low priority)	Testing during parts of the cruise.	13H	No	No	Short test, ran well.
Sound Recorder					
The sound recorder has been modified slightly and debugged (to	Will run continuously to	9d18H	No.	Yes	Made two sets of recordings simultaneously from the same data stream, one raw, one

avoid small gaps between successive recordings). It has been bench tested, but requires testing at sea.	provide a data archive from the cruise.			20, 27, 32, 34.	filtered and amplified. Works fine. Would help to have support for 24 bit file formats (currently only does 16 bit).
Signal Amplifier ***Patch Panel***					
These modules have been added during 2007 and have not been tested at sea. They have been extensively bench tested and will be 'low priority' for testing at sea.	Low priority testing	1d16H	No	No	Worked well during relatively short tests. Amplifier tested for 1d16H, patch panel not tested.
Seismic Veto					
The seismic veto is a new module which will cut out very loud sounds, replacing the vetoed signal either with zeros or with spectrally shaped random noise. This can a) prevent detectors from behaving erratically and b) makes operator listening more comfortable.	Medium priority testing. Will attempt to assess detector performance both with and without the veto.	6d7H	Yes 30.	Yes 12.	Extremely useful module. Essential for aural monitoring while guns are operational. The current version only works on FFT data. A simpler version working on time series data would be useful for applications where only the click detector is in use in order to conserve CPU.
Detectors					
Click Detector					
The click detector has been tested during previous cruises and is being further tested as part of the CODA	Expect continuous testing, possibly in > 1 basic configuration	12d5H	Yes 11.	Yes 1, 7,	Worked reliably, but was only able to track animals on very few occasions using the semi automatic target motion methods.

field trial analysis. New tracking functions have been added as part of the CODA project and require testing at sea. The click detector also forms the main input to Thode's location modules and will therefore also be used for that purpose. Additional click train and species classification modules are being developed as part of a separate JIP funded project. These modules will be tested if available at the time of the cruise.	to test internal click train and location functions and to provide input to Thodes locators. Low priority testing of modules from the Odontocete classification project.			19, 25, 26, 33, 38.	Tested extensively at 96 kHz using the ASIO sound card and also at 500 kHz using NI data acquisition. Modules from Odontocete Classification project not ready for testing.
Whistle Detector					
Has been tested during previous cruises. Depending on the timing of this cruise it may be possible to test new whistle classification modules being developed as part of a separate JIP project.	Will run continuously. Low priority testing of modules from the Odontocete classification project.	6d17H	No	Yes 13.	Ran reliably, but no detections. Also ran the prototype whistle classifier. The user interface worked reliably and it caused no problems.
Ishmael Detectors					
Most of these detectors are designed for baleen whale call detection, species which are unlikely to be encountered in gulf of Mexico. Modules suitable for tracking sperm	Testing of modules suitable for sperm whale tracking on line. Comparison with Ishmael offline.	16H	Yes 23.	No	Ran reliably, but no detections. Locator results may have a problem with how they plot on the map and write to the database.

whales will be tested at sea and may also be tested and compared with Ishmael output during offline analysis.					Needs user help Energy sum tested 16H Spectrogram corr' tested 0.25H Locator tested 13H Matched filter not tested
Workshop Demo Detector					
The module is primarily for user and developer training and will not be tested during field trials.	No Testing	0			Not tested
3D Towed Array Localiser					
This module takes input either from the click detector or from one of the Ishmael detectors and contains five different methods for localising sounds. We will attempt to test as many of these different combinations as possible during the cruise.	High Priority Testing of multiple combinations.	0			Not tested since no suitable detections.

19.2 Bugs

Each bug has been given a severity on a scale of 1 to 5. The severity is a combination of how badly the bug affects the operation of the module in question and how often the bug occurs.

1. Not important. e.g. a map symbol not resizing correctly
2. Annoying, but doesn't really affect operation
3. Affects operation of that module or causes occasional crashes
4. Affects that module frequently, or has a knock on effect on downstream modules.
5. Severe errors that make PAMGUARD inoperable.

Table 6. Bugs encountered in the PAMGUARD software during the trial.

No., Date Sourceforge Request Id	Module Affected	Details	Severity and Status
1. 9/11/2008 2249237	Click Detector	Click Detector stops after parameter changes. This has now been cured for basic changes to thresholds and filter settings. It may still cause problems if channel grouping is changed during a run. This very rarely happens though.	3 Closed
2. 9/11/2008 2249242	Sound Acquisition ASIO Sound card readout	ASIO C code was not returning channels in the correct sequence which had severe knock on effects and would crash the click detector. Fixed by adjusting code in thread that sends the buffers back to Java to ensure that they get sent in order.	4 Closed
3. 9/11/2008	Sound Acquisition	ASIO C crashes when acquisition stops. This was due to the playback system trying to write to buffers that have just been deleted.	2 Closed

2249287	ASIO Sound card readout	Fixed. Checks DAQ is still running when playback data arrive and don't do anything if DAQ has stopped.	
4. 9/11/2008 2249305	GPS Readout Crashing	Unpacking of GPRMC strings crashed due to data from New Venture GPS not having one of the fields (I think to do with magnetic variation at the end of the string). Altered code so it checks variation data are there before attempting to unpack. Also, noticed that New Venture GPS data has many more decimal places than other systems we've used. Have altered code so that all decimal digits are unpacked and used.	4 Closed
5. 9/11/2008 2249322	All Modules (Core data handling)	Multithread version of PAMGUARD hangs. This was due to lock up as threads simultaneously wait for one another. Cured through stopping recycling of data units and careful synchronisation of data moving in and out of data blocks.	5 Closed
6. 9/11/2008 2249347	AIS Readout	AIS Symbols not resizing. AIS symbol colours were not changing correctly when the user adjusted them from the display menu. Cured. Also added additional options to Symbol selection dialog to allow user resizing of symbols.	1 Closed
7. 9/11/2008 2251706	Click Detector	Click detector filters were not initializing correctly. Fixed. All filter initialization was happening before the sample rate was set. With sampleRate = 0, the filters would not initialise. The code now recreates the filters when setSampleRate() is called, which guarantees they are set up correctly.	3 Closed
8. 10/11/2008 2252576	Spectrogram Smoothing Kernel	Spectrogram smoothing kernel would not work connected to the output of the Seismic Veto. Fixed by reorganizing the data streams that carry fft data so that the data streams can also carry essential information such as fft lengh and overlap.	3 Closed
9. 10/11/2008	Airgun Display	Airguns don't show when set up to use AIS data from a different vessel. Was only picking up the first data from each vessel and not updated data. Fixed, by correctly	2 Closed

2253080		monitoring for updated as well as new AIS data. Also added features to control the length of the tail and any prediction arrow shown on the map.	
10. 11/11/2008 2266165	Sound Acquisition	Discovered and dealt with major timing issues which occurs if the sound card clock or PC clock is inaccurate so that times based on the PC clock and times based on sample number gradually get out of synch. Details in bug reports on sourceforge. Resolution of this bug is probably the most significant achievement of the trial and has resulted in a massive increase in PAMGUARD reliability.	5+ Closed
11. 12/11/2008 2266174	Click Train Detector	Click train detector uses too much memory The Click detector click train detector creates very large numbers of click trains which never really turn into a full click train, but all of which link back to clicks, therefore holding them in memory and using too much. This occasionally makes the system unstable. Further work is planned on click train detection as part of the JIP funded Odontocete Classification project.	3 Open
12. 12/11/2008 2266180	Seismic Veto	Plug in graphics module for seismic veto display doesn't look good when displaying under vetoed spectrogram data with the display having many gaps in it. Rearranged graphics so that callback from spectrogram is not used to clear ahead on the display. Clear ahead on the main drawing call from the data source observable	2 Closed
13. 12/11/2008 2269568	Whistle Detector	Whistles and whistle peaks not appearing on spectrogram. Nothing wrong with code- just bad settings, so nothing detected. Have adjusted and also altered defaults for new whistle detectors.	3 Closed
14. 12/11/2008 2269575	Database	Database selection messes up when switching between configurations. Have re-written code that loads settings from databases in PAMGUARD viewer and PAMGUARD mixed mode.	1 Closed
15. 12/11/2008	All Modules	Settings files lose settings If program is exited while it's still starting, settings file gets corrupted.	3 Closed

2269579		If program is manually shut down before configuration is fully loaded, then the half created configuration overwrites the settings file, so settings are lost. This tended to happen with very complex configurations or configurations with small bugs, where the operator would lose patience waiting for it to load and would shut down to start again. There is now a check to ensure that all settings are fully loaded before a settings file can be overwritten	
16. 12/11/2008 2271381	Spectrogram Display	Spectrogram display crashes This is a multithreading problem. If the panels are changing / recreating themselves as new data arrive, then they crash with a null pointer exception. Synchronized the two functions that a) create the image panels and b) draw the data on them.	4 Closed
17. 13/11/2008 2277913	AIS Readout	AIS unpacking crashes occasionally Trying to unpack beyond the length of the bit array. Occurs when corrupt NMEA AIS strings arrive from receiver. Added checks on string length into AIS unpacking code to protect against above bug.	3 Closed
18. 13/11/2008 2277949	Sound Acquisition National Instruments Cards	Work on the NI Data Acquisition module has been completed under a separate JIP funded contract. The NI module is now stable and fully documented. It was released in July 2009 (Beta 1.5.00)	2 Closed
19. 14/11/2008 2281151	Click Detector	Click storage error Problem with multi threading synchronisation in click file. Second problem with check for file folder only being done when acquisition starts. Have synchronized all methods in the RainbowFile object. Have moved the check on the file folder to the dialog which won't close unless the	3 Closed

		folder exists. Not totally fool proof, but it will help.	
20. 14/11/2008 2285305	Sound Recorder	Crashes as soon as it starts to store Problem was synchronisation in multi thread model	5 Closed.
21 14/11/2008 2299134	Radar Display	Scaling of Detectors panel in the configuration dialog is awful. Need to repack - Done Clicks seem to stay on display for far too long - Code was all wrong – would probably have displayed everything. Fixed using new timing monitor (bug 10) to deal with clock problems.	2 Closed
22 14/11/2008 2299139	Spectrogram display	Spectrum plug in. Doesn't remember scale settings between runs and could do with a hover text to say what's up. Fixed – had to alter the PluginPanelProvider interface and set up a recycling scheme for plug in panels so that it doesn't continually create new ones every time spectrogram panel parameters are adjusted. Also sorted out axes drawing and added hover text info.	1 Closed
23 14/11/2008 2299151	Ishmael energy sum graphics.	Lost graphics displays when I changed the horizontal scale of the spectrogram. Came back when I stopped and restarted. Standard PAMGUARD channel colours would be nice (See PamColors class). At wrap around point, it draws a line all the way back from maxX to minX. It should realize this and not draw that line. Vertical scaling doesn't adjust when window size changed. Some scale information or auto scaling would be nice. Seems default scale in dialog is 50, but you need to set to about 0.2 to see anything.	2 Open
24 14/11/2008 2299163	Raw Data Display plug in	Scale is wrong. It's drawn for a single channel, not for n channels. Fixed. Now correctly draws scale for multiple channels.	1 Closed

25 14/11/2008 2299174	Click Detector	Tracking. It would help if tracked click lines took the colour of the track. Hard to deal with multiple animals otherwise. Fixed Clicks were being coloured on the map by species, not by train colour. I've changed it so they colour by train.	1 Closed
26 14/11/2008 2299187	Click Detector	Creation of new files out of synch with click writing. Clicks therefore go in at the start of the file with a small –ve sample number. File therefore won't open with RainbowClick for offline analysis. Fixed by monitoring sample number in the "halfbuiltclick" monitor using the timing monitor (from bug fix 10) and creating new files in the same thread as the detections are being written from.	2 Closed
27 14/11/2008 2299195	Sound Recorder	Recorder, occasionally attempts to write to closed pipe. Does not seem to affect operations. Was probably just losing the last 1/10 s of data when it starts a new file. Now fixed through synchronization of threads as files are closed.	2 Closed
28 14/11/2008 2299204	Model Viewer	Keeps popping on top of main PAMGUARD window after parameter changes. This is caused by the lack of Frame reference in dialogs, so when they close, PAMGUARD jumps to the highest frame in the internal list. A reference to the main GUI frame is now available through the PamControlledUnit class, so use it. Fixed in the following modules: Map, Spectrogram, FFT Plug in, Radar display, Click bearing display, Video range, Dependency Manager, Module Removal, Filter settings (stand alone, in click detector and in decimator). There may be others, if so they are now easily fixed.	1 Closed
29 14/11/08 2299216	FFT Engine	Names of FFT engines are all the same in the Detection settings menu Fixed. Have now replaced with module Name, which is more descriptive and unique to each module.	1 Closed
30	Seismic Veto	Seismic veto pseudo random noise generator comes over headphones as an annoying buzz. Investigate better random noise generation techniques.	1

14/11/08 2299245		Random FFT data is too similar frame to frame and can create whistles	Open
31 14/11/08 2299247	Filters Dialog	Null pointer exception in filter dialog getSettings(). Did not seem to crash or affect anything. Fixed – needed a dummy instance of parameters object the first time it ran.	1 Closed
32 14/11/08 2299248	Sound Recorder	Does not find modules at startup if they are further down the list and throws up the configuration dialog. Fixed. Makes the checks as new modules are created or destroyed, but only after program initialization has been completed.	2 Closed
33 14/11/08 2299257	Click Detector	When going from no trigger filter to a trigger filter, I'm not convinced that it actually creates the trigger filter until the program is restarted (I think they are made in the constructor of the sub detectors, so may not get recalled). Fixed. Have checked code and all is working as it should	2 Closed
34 15/11/08 2299264	Sound Recorder	Number of level meters on sound recorder does not change when the number of channels in the acquisition changes. Fixed, correct number of channels is now shown.	1 Closed
35 15/11/08 2299280	FFT Engine	Parameters dialog does not resize enough to show lots of channels (trying to run with eight). Fixed. This turned out to be a more general problem throughout PAMGUARD dialogs. The cure required changes to the source panel dialog component and may require other developers to implement the same changes.	2 Closed
36 15/11/08 2299294	Depth Readout	Does not seem to be changing the time delay on the timer when it's changed in the dialog box. Definitely OK after a restart. Problem was that if the delay was reduced, it would wait until the next callback using	1 Closed

		the old delay time before switching to the new delay time. Fixed by stopping and starting timer and giving it a new initial delay of 0 to make it read immediately.	
37 16/11/08 2303389	Sound Playback	ASIO sound playback does not allow anything but channels 0 and 1, even with a stop and a start it can't deal with other channels. Must modify so channels can be changed on the fly. Fixed. Can now select any two channels.	2 Closed
38 17/11/08 2339199	Click Detector	At program start up, the click detector would not find a data source if that data source had been created after the click detector in the modules list. Fixed – all modules should only try to find their data source after, or when, they receive the INITIALIZATION_COMPLETE notification.	2 Closed
39 17/11/08	NI Library	If the JNI dll that links PAMGUARD into the National Instruments code is present, the PAMGUARD required all of the NI driver libraries. Fixed. The PAMGUARD NI JNI code now links dynamically to the NI libraries at run time and will not crash if they are absent.	3 Closed

19.3 Safety Plan

PAMGUARD Industry field trial safety plan
Douglas Gillespie 22 October, 2008

Field work will be carried out by Douglas Gillespie (DG) – SMRU lead investigator for this activity. (Ref SMRU Proposal / Draft contract reference JIP 22 06-10, schedule 0708)

Safety plan for PAMGUARD field trial to be conducted on board the RV New Venture, owned and operated by Fairfield.

The New Venture has a vessel specific safety plan that meets OGP 317 and ISM (Ref Fairfield Safety Plan). Before any deployment will take place, procedures will be drafted, reviewed, and approved. All tasks are covered by a toolbox meeting before commencement.

Vessel Safety is detailed in the document 'Vessel Safety NV.doc' received from Reagan Woodward on 20 October, 2008. This document refers to specific sections in the vessel safety plan using the notation VSP7.9 to refer to section 7.9, etc.

The PAM operator (DG) will work directly under the supervision of the vessel Captain and Party Chief (PC). The PAM operator will be made aware of and will abide by all rules of the seismic company/vessel owner hosting the field trial, including health and safety policies. In addition, since DG is employed by St Andrews University, St Andrews standard field work risk assessment will be carried out prior to departure.

Training
DG will be in possession of a valid OPITO approved Basic Offshore Safety Induction and Emergency Training Certificate (BOSIET) and a valid medical certificate.

Insurance
As an employee of the University of St Andrews he has public liability insurance to £5,000,000 (Five Million Pounds) and personal accident insurance provided by the university. (please advise if proof of this is required).

PPE
PPE has been discussed with vessel representatives. DG to provide steel toed boots. Other equipment to be provided on board vessel (hard hats, life vests, survival suits, harnesses as required)

Transfer
Transfer to the New Venture will be crew transfer vessel organised / operated by Fairfield. DG to obey all safety instructions during transfer including wearing of survival suits, life vests, as directed. (VSP7.9)

On Arrival

(VSP 5.3) Report to Captain / Party Chief. Receive safety tour of vessel (VSP1.4.3), assignment to muster station, lifeboat. Receive evacuation instructions. Receive instruction on use of PPE equipment (e.g. which area require work boots, life jackets, etc, which areas require soft shoes, etc). Any secure areas DG not to enter, or not enter without permission. DG to me made aware of danger areas, such as high pressure hoses.

Equipment Installation

Discuss equipment location and cable runs with PC. Establish risks to other operations from cable runs and risks to personnel while installing cables (e.g. use of ladders). Discuss cable attachment.

A dry area will be provided for setup of audio and computer equipment. Cable runs to the outside are required for
1. The hydrophone array
2. A VHF antenna for reception of AIS data (to get position of other vessels on survey)
3. A GPS (probably this will not be required if we can tap into the vessel system).

If antennas are to be mounted, discuss locations with PC and ensure there is no interference with other nav' equipment (both the GPS and AIS antennas are purely passive receivers and none of the PAM equipment transmits RF energy).

Equipment Storage

Establish a safe storage area for unused equipment / spares.

Prior to deployment.

(VSP 7.10 ad VSP 7.11) Discuss with PC and vessel crew. Plan hydrophone deployment and recovery and discuss potential interactions with seismic array. Hydrophone cable to be deployed from winch suitable for the purpose, operated by suitably competent personnel. Establish command chain / who needs to be informed prior to deployment or recovery. Draft procedure and have reviewed / approved by PC and/or captain.

Deployment / Recovery.

Toolbox meeting (VSP7.11) to take place prior to commencement of any task. Appropriate number of personnel to be present on deck. PPE equipment to be worn as for all other aft deck operations.

Reporting

Daily email reports to be sent to:

John Campbell/OGP Technical Director	John.Campbell@ogp.com
David Hedgeland/JIP Project Coordinator	David.Hedgeland@pgs.com
Reagan Woodard/Operations Supervisor	rwoodard@fairfield.com

Copied to:
Jim Thompson jthompson@fairfield.com
Jackie DeLaughter Jackie.DeLaughter@cggveritas.com;
Danny Garcia dgarcia@fairfield.com
Simon Moss (SMRU Safety officer) sem6@st-andrews.ac.uk

Emergency contact Numbers

In the event of an emergency, all of the above should be contacted. Additional contact telephone numbers are

Vessel: New Venture (phone no. removed from report)
Reagan Woodard (phone no. removed from report)
Doug Gillespie Next of Kin: (phone no. removed from report)
Doug Gillespie Employer: Sea Mammal Research Unit, University of St Andrews.

References:

SMRU Proposal “PAMGUARD Industry Field Trial” /OGP Contract no (Draft contract reference JIP 22 06-10, schedule 0708)

Fairfield New Venture Vessel Safety Plan, Available from Reagan Woodard rwoodard@fairfield.com.

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