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Survey of Active Acoustic Monitoring (AAM) Technologies

Volume IV: Proposal

E. MacNeil, J. Theriault, B. Maranda, L. Gilroy
Defence R&D Canada – Atlantic

J. Hood
Akoostix Inc.

Prepared For:
International Association of Oil & Gas Producers (OGP)
209-215 Blackfriars Road
London, SE1 8NL UK

Defence R&D Canada – Atlantic

External Client Report
DRDC Atlantic ECR 2010-041
March 2012

Canada

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Principal Author

Original signed by E. MacNeil

E. MacNeil

Project Manager

Approved by

Original signed by Daniel L. Hutt

Daniel L. Hutt

Head / Underwater Sensing

Approved for release by

Original signed by Calvin V. Hyatt

Calvin V. Hyatt

Chair / Document Review Panel

This report has been completed for International Association of Oil and Gas Producers (OGP) under contract JIP22 08-06.

Abstract

Under the Exploration and Production (E&P) Sound and Marine Life Programme, a research study was carried out on the feasibility of the Active Acoustic Monitoring (AAM) of marine mammals. The purpose of such monitoring would be to detect marine mammals in those ocean areas where E&P activities are being conducted, in order to allow due diligence in mitigating any potential impact of these E&P operations. The study did not include any direct experimentation.

First, the problem domain was delineated in an overview of offshore E&P activities and of the ocean environments in which they are conducted. To make the analysis more concrete, six specific ocean areas of relevance to E&P were selected and their properties described. Next, the potential performance of AAM was investigated via a parametric study of the sonar equation, incorporating available knowledge of sonar technology and environmental effects. Special effort was dedicated to investigating the target strength of marine mammals, as this is an area in which scientific knowledge is sparse at present. The parametric analysis included several generic examples, and was also applied to the six specific ocean areas. Finally, a survey was conducted of commercially available sonar equipment by collecting data from sonar vendors through an on-line form. The sonars were then ranked as to their suitability for AAM based on the factors identified as important during the earlier study of potential AAM performance.

This document is Volume IV of four volumes. It contains the original study proposal submitted to the Joint Oil and Gas Industry Programme (JIP) in response to request for proposals (RFP) number JIP08-05, Mitigation and Monitoring: Review / inventory of current active acoustic methods and technologies.

Résumé

Dans le cadre du programme de l'OGP portant sur l'impact du bruit causé par les activités d'exploration et de production (E et P) sur la vie marine, une recherche a été effectuée sur la faisabilité de la surveillance acoustique active (SAA) des mammifères marins. Le but d'une telle surveillance serait la détection des mammifères marins des régions océaniques où sont menées des activités d'exploration et de production, en vue d'agir avec diligence raisonnable pour atténuer les impacts potentiels de ces activités. Cette étude ne comportait aucune expérimentation directe.

Tout d'abord, on a circonscrit le problème par un survol des activités d'exploration et de production extracôtières et des environnements océaniques dans lesquels ces activités sont menées. Pour rendre cette étude plus concrète, on a pris en considération six environnements océaniques spécifiques présentant un intérêt pour l'exploration et la production et on a décrit leurs propriétés. Ensuite, on a évalué la performance potentielle de la SAA au moyen d'une étude paramétrique de l'équation du sonar en y intégrant les connaissances disponibles sur la technologie du sonar et ses effets sur l'environnement. Des efforts spéciaux ont été consacrés à l'étude de l'intensité des échos des mammifères marins, domaine dont la connaissance scientifique actuelle est assez faible. L'analyse paramétrique comportait plusieurs exemples génériques et elle a été appliquée aux six régions océaniques retenues. Finalement, une étude sur les équipements sonar disponibles sur le marché a été effectuée en recueillant auprès de fournisseurs de sonar des données dans un formulaire en ligne. Les sonars étaient ensuite classés en fonction de leur aptitude pour la SAA en fonction des facteurs estimés importants au cours de l'étude antérieure sur les performances potentielles de la SAA.

Ce document est le volume quatre de quatre; il contient la proposition d'étude originale présentée au *Joint Oil and Gas Industry Programme* (JIP) en réponse à la demande de propositions n^{o} JIP08-05 relevant du volet atténuation et surveillance et portant sur un examen et un inventaire des méthodes et technologies actuelles en acoustique active.

Executive summary

Survey of Active Acoustic Monitoring (AAM) Technologies: Volume IV: Proposal

E. MacNeil; J. Theriault; B. Maranda; L. Gilroy; J. Hood; DRDC Atlantic ECR 2010-041; Defence R&D Canada – Atlantic; March 2012.

Background: Under the Exploration and Production (E&P) Sound and Marine Life Programme, a research study was carried out on the feasibility of the Active Acoustic Monitoring (AAM) of marine mammals. The purpose of such monitoring would be to detect marine mammals in those ocean areas where E&P activities are being conducted, in order to allow due diligence in mitigating any potential impact of these E&P operations.

This document is Volume IV of four volumes; it contains the original study proposal submitted to the Joint Oil and Gas Industry Programme (JIP) in response to request for proposals (RFP) number JIP08-05, Mitigation and Monitoring: Review / inventory of current active acoustic methods and technologies.

Results: The proposal presented a comprehensive team of experts familiar with oil and gas E&P operations, marine mammal biology, active sonar signal processing, target strength modeling, and underwater systems design and employment. A work plan was proposed that divided the study into three phases: definition, survey and analysis phases. The definition phase proposed researching background information on E&P activities and environments to provide context for the study. Also proposed for this phase was a general performance assessment of AAM to identify the key sonar features required for AAM and to identify any fundamental limitations to AAM. The survey phase proposed circulating a questionnaire to manufacturers and users of AAM systems to gather information on commercially available sonars. The analysis phase proposed evaluating the AAM systems described in the survey responses for their suitability of use in monitoring marine mammals and for use in E&P activities, and finally outlining further development areas.

The proposal was accepted by the JIP and a contract was awarded to DRDC Atlantic and subcontractors Akoostix Inc, Canadian Seabed Research and Balaena Dynamics, to carry out the proposed plan.

Significance: The proposal presented a well balanced team and a structured plan that aimed to provide a comprehensive review on the suitability of AAM and current AAM systems for this application. The study, when completed, would provide the JIP with information that could be used in making decisions on whether AAM should be further considered for use in monitoring marine mammals in areas where E&P activities are being conducted.

Sommaire

Survey of Active Acoustic Monitoring (AAM) Technologies: Volume IV: Proposal

E. MacNeil; J. Theriault; B. Maranda; L. Gilroy; J. Hood; DRDC Atlantic ECR 2010-041; R & D pour la défense Canada – Atlantique; mars 2010.

Contexte : Dans le cadre du programme portant sur l'impact du bruit causé par les activités d'exploration et de production (E et P) sur la vie marine, une recherche a été effectuée sur la faisabilité de la surveillance acoustique active (SAA) des mammifères marins. Le but d'une telle surveillance serait la détection des mammifères marins des régions océaniques où sont menées des activités d'exploration et de production, en vue d'agir avec diligence raisonnable pour atténuer les impacts potentiels de ces activités.

Ce document est le volume quatre de quatre; il contient la proposition d'étude originale présentée au *Joint Oil and Gas Industry Programme* (JIP) en réponse à la demande de proposition n° JIP08-05 relevant du volet atténuation et surveillance et portant sur un examen et un inventaire des méthodes et technologies actuelles en acoustique active.

Résultats : La proposition présentait une équipe complète d'experts familiers avec les activités d'exploration et de production de pétrole et de gaz, la biologie des mammifères marins, le traitement du signal sonar actif, la modélisation de l'intensité des échos de cible et la conception et l'emploi de systèmes sous-marins. Un plan de travail proposé divisait l'étude en trois phases : les phases de définition, d'étude et d'analyse. La phase de définition proposait d'effectuer de la recherche de fond sur les activités et le milieu d'exploration et de production pour constituer un contexte d'étude. On proposait aussi pour cette phase une évaluation des performances générales de la SAA pour identifier les caractéristiques clés requises pour effectuer la SAA par sonar et définir les limites fondamentales de cette dernière. La phase d'étude proposait la distribution d'un questionnaire aux fabricants et utilisateurs des systèmes de SAA pour recueillir des informations sur les sonars disponibles dans le commerce. La phase d'analyse proposait l'évaluation des systèmes SAA décrits dans les réponses au sondage afin d'estimer leur aptitude à une utilisation dans le suivi des mammifères marins et dans les activités d'exploration et de production, et la description de secteurs de développement additionnels.

La proposition a été acceptée par JIP et un contrat a été adjugé à RDDC Atlantique et aux sous-traitants Akoostix Inc, Canadian Seabed Research et Balaena Dynamics pour mener à bien le plan proposé.

Importance : La proposition a présenté une équipe bien équilibrée et un plan structuré qui visait la réalisation d'une étude complète sur la pertinence de la SAA et les systèmes SAA actuels pour cette application. L'étude, une fois terminée, fournirait au JIP des informations qui pourraient aider à décider si on devrait prendre en considération l'usage de la SAA pour la surveillance des mammifères marins dans les zones où des activités d'exploration et de production sont menées.

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1 Introduction

This proposal addresses request for proposals number JIP 08-05, Mitigation and Monitoring: Review / inventory of current active acoustic methods and technologies. Identification of potential areas of further development for the detection of marine mammals at sea during E&P activities offshore. It is part of the overall JIP Research topics of interest listing under category 4 mitigation and monitoring: "develop alternative sound sources or operating procedures, evaluate or improve existing mitigation measures or develop new mitigation measures that would lessen the risk of acoustic impacts on marine mammals".

Defence Research and Development Canada (DRDC) has assembled a comprehensive team of experts that are familiar with all required areas of oil and gas exploration and production (E&P) operations, marine mammal biology, active sonar signal processing, target strength modeling, underwater systems design and practical employment. We propose to follow a structured definition, data gathering, and analysis plan to arrive at an independent critical review and assessment of available active acoustic capability, including the viability of those systems to address specific E&P environmental mitigation requirements.

This proposal will demonstrate our understanding of JIP's objectives, our ability to meet those objectives, and our structured process.

1.1 Objectives

The overall objective of the JIP is to develop a capability that will address environmental impact mitigation requirements and allow continued E&P operations in sensitive areas. In this case, active acoustic monitoring (AAM) may be required to address shortcomings with passive acoustic monitoring (PAM) and visual observer mitigation strategies. The objective of this work is to survey, record and analyze the capabilities of current AAM systems, and systems that are still in an experimental stage or have only been deployed infrequently to make an assessment of the potential capabilities. The current and projected capabilities will then be compared to the E&P requirements for marine mammal detection, classification and localization. Deficiencies will be identified and a development plan will be broadly defined.

As a result, this work will define the current and potential capability to detect, classify, locate and track marine mammals at sea for either real-time or long-term monitoring, independent of visibility and animal vocalization.

The capability, or current lack thereof, to monitor marine mammals will provide valuable input into the development and justification of risk management and environmental mitigation plans for any given activity which will ultimately affect the conduct of E&P activities in those areas.

This study will not attempt to identify or assess any potential environmental impacts related to the use of AAM technologies for monitoring marine mammals; however, it should be noted that this consideration would need to be addressed prior to implementing an AAM solution.

1.2 Hypothesis

This work will test the hypothesis that *a comprehensive structured survey and analysis will result in a detailed understanding of the required way ahead and feasibility with respect to environmental mitigation using AAM systems*. This hypothesis will be tested by following the approach recommended in the Technical Approach section.

This hypothesis assumes that developers of AAM systems will share sufficient information to complete the survey, or that information will already be available in the public domain. It assumes that the number of candidate solutions can be sufficiently limited to fit within the scope of the proposed effort.

1.3 Approach

DRDC proposes to act as the prime contractor and to subcontract local experts in signal processing systems, in E&P operations and in marine mammal biology. The task has been broken into three phases, which have been allocated a budget of person hours and travel. Each team member is responsible to the project manager for completion of their tasks. Three meetings with the customer are planned, a Kickoff Meeting at the start of the project, a Progress Meeting following completion of the definition phase, and a Close-out Meeting at the end of the project.

1.4 Significance

The E&P community has been under considerable public scrutiny to minimize the effects of their activities on marine mammals. The first step in this process is to identify the capability or lack thereof, for detecting, classifying and locating marine mammals within range of E&P activities. With sufficient capability, data gathered from monitoring programs can be used to minimize the effect of E&P activities on marine mammals. AAM is significant because it has the potential to succeed in areas where other systems may fail:

- Low vocalization rate;
- Poor visibility or minimal surface presence; and
- Disruptive ambient noise due to E&P operations and environmental effects.

2 Technical

2.1 Background

E&P activities generating potential acoustic impact on the environment include seismic airguns, drilling, dredging, pile driving, construction equipment, explosive removal of offshore structures, and others. While the potentially impacted taxa would include marine mammal, fish (eggs, larvae, juveniles and adults), turtle, bird and invertebrate species, the focus of this proposal is on surveying technologies that will enable E&P activities to continue while providing improved measures of environmental protection for marine mammals.

Mitigating the potential impact on marine mammals requires a greater understanding of movement, distribution and abundance. It also requires further understanding of potential impact mechanisms for the large number of marine mammal species.

There exists evidence to show that AAM systems can work to detect marine mammals (e.g., IMAPS, Faeroe Island whalers, etc.). However, assessing the performance of AAM requires characterizing the operators, systems, environments, and targets (marine mammals) and consideration of the interaction between the parameters.

For example, a simple characterization of an active sonar system may include display options, frequency, bandwidth, waveform types, transmitter and receiver directivity and source level. Complex display options may enhance system performance, but only when used by operators with extensive training. Simple intuitive displays limit sonar performance, but require less training and experience to operate. The acoustic transmission loss, reverberation, noise, and target echo strength are a function of frequency. The directivity of the system will affect noise and reverberation, with higher directivity improving the localization capability. Performance enhancements may be achieved through matched-filter processing of certain waveforms, but environment and target characteristics will limit theoretical improvements. Detection of echoes is undertaken against a background of noise and reverberation. Increases in detection performance are directly related to source level increases as long as the performance is limited by background noise (ambient + E&P activity) vice reverberation.

Active sonar performance is greatly affected by the interaction with the target – in this case marine mammals. This will be the most difficult area of this study to characterize. Little has been quantified regarding the target echo strength of marine mammals. There exists published material on the target strength of northern right, humpback and gray whales, but little is known regarding other species. Target strength is generally affected by frequency, size, resonance and acoustic impedance mismatch with the surrounding environment. Air-filled cavities and dense materials such as bones can generate such an impedance mismatch. Whales will take air down with them, even though they have completed gaseous exchange during several breaths at the surface. Lungs of deep-diving whales will be reduced to one percent of their at-surface volume at 1000m depth, suggesting that the target strength will be dependent on the behaviour of the animal. Seals do not take large volumes of lung air with them when they dive, having done much of their gaseous exchange (and oxygenation of blood) while at the surface suggesting that their target strength is likely to be small.

AAM systems can provide a capability to detect, localize, and track some marine mammal species. Classification of marine mammal echoes is at best difficult, but can be achieved through data fusion of multiple pings and with other systems, visual observation, passive sonar, mammal distribution and behavioral knowledge. In principle, AAM systems could be used to gather data on movement, distribution, and abundance, but the nature of AAM systems lends itself to be primarily used in the vicinity of E&P Operations and therefore can become an integral component of an E&P risk management capability.

A variety of active sonar systems exist that may be used for AAM. Some of these have been developed specifically for AAM purposes, while others have been designed for fisheries purposes, diver detection, or mine detection. This study will not limit itself to those systems that have been designed specifically for marine mammal purposes, but will consider systems that can likely be utilized for that purpose.

Clearly a critical evaluation and assessment of AAM system capability is a complex task requiring a diverse skill-set and structured process to be successful.

Figure 1: Beluga Whale swimming on surface (Photo Courtesy of V. Lesage, Fisheries and Oceans Canada).

2.1.1 Team Qualifications and Experience

DRDC has carefully considered the expertise required to ensure a successful project, and has assembled a project team whose expertise covers E&P operations, marine mammal biology, active sonar signal processing, target strength modeling, underwater systems design and employment, as well as project management. DRDC's in-house expertise has been developed through considerable experience with defence underwater acoustics, including environmental mitigation for active sonar. Defence mitigation efforts have considerable overlap with E&P mitigation requirements, though they are admittedly different in some ways. This in-house experience has been augmented with industry partners: Akoostix brings considerable systems design experience to the team, Balaena Dynamics provides a vast knowledge of marine mammal biology and functional morphology, and Canadian Seabed Research Ltd provides expertise in the

area of E&P operations. This section provides a high-level overview of our relevant qualifications and experience. More detailed information is provided in key investigator CVs and our publication references.

[Note: The overview of individual team member's relevant qualifications and experience was included in the original proposal submitted to the JIP; however it is not included in this report]

Figure 2: Two whales swimming on surface (Photo Courtesy of V. Lesage, Fisheries and Oceans Canada).

2.2 Technical Approach

The proposed approach is to divide the work into three distinct phases: Definition Phase, Survey Phase and Analysis Phase. In the Definition Phase, background information will be collected on E&P activities and environments, and marine mammals. This background will be used to assess the potential performance of AAM for marine mammal DCL. At the end of the definition phase a set of survey parameters will be developed that will assist with consistent data collection on a variety of AAM systems during the Survey Phase. The survey will be circulated to a large number of potential users and developers of AAM systems. The Analysis Phase will evaluate the AAM systems in the survey responses for their viability as a marine mammal monitoring solution and for their ability to meet E&P requirements. As well, areas for future development will be noted, and a recommendation made on the way-forward for development.

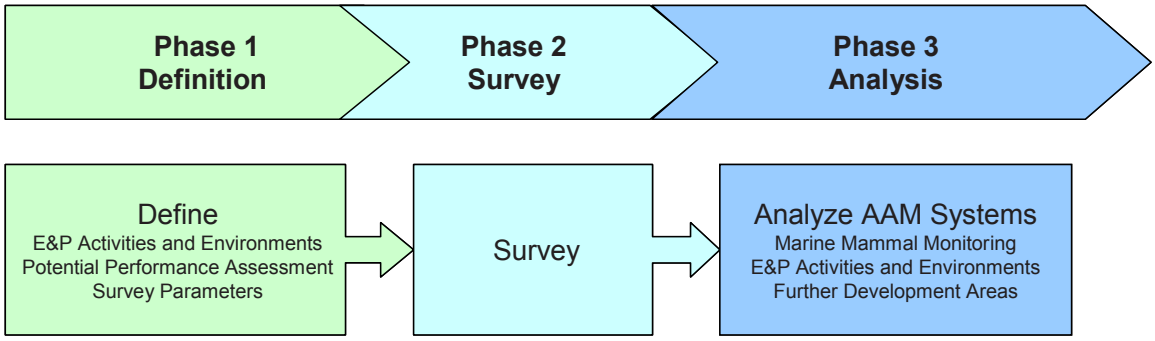

Figure 3: Workflow Diagram.

3 Phase 1 - Definition Phase

The Definition Phase consists of three main tasks, which aim to gather the background information required to complete the Survey and Analysis Phases. The first task will generally categorize E&P activities and environments to define the industry requirements for marine mammal monitoring and for system design. The second task will assess the potential performance of AAM. Within this task target strength estimates for marine mammals will be developed, a high level assessment of the potential performance of DCL will be conducted and concepts of use will be described. The third task will develop a set of parameters that will be used as the basis of the survey questionnaire.

The Definition Phase would include a Kick-off Meeting at the start of the phase and a Progress Meeting at the end of the phase. The kick-off will provide an opportunity for the Customer to provide input on the project plan and approach, while the Progress Meeting will present the findings of the Definition Phase and provide an opportunity for Customer feedback. Depending on input from the JIP, travel maybe required for one or both of these meetings.

Figure 4: Pair of Beluga Whales (Photo Courtesy of V. Lesage, Fisheries and Oceans Canada).

3.1 E&P Activities and Environments

The objective of this task is to develop a general categorization of E&P activities and operating environments to define the industry requirements and provide a basis for the Survey and Analysis Phases.

The approach to obtain this information is to conduct a review of literature, as well as drawing on the experience of the Mr. Ray Burke of Canadian Seabed Research and the experience of Ms. Erin MacNeil.

Activities related to the exploration, development and production of hydrocarbons in marine areas will be considered. This includes seismic surveys, installation of infrastructure, drilling, production and offloading activities. The task will summarize activities involving direct or indirect generation of significant acoustic energy where marine mammal DCL would be a requirement. A summary of operating environments will also be compiled, generally characterizing features such as water depth, proximity to land or infrastructure, other activity in the area and environmental considerations.

From this background information a general categorization of various E&P Activities and Environments will be compiled, describing the general marine mammal monitoring requirements (long or short term monitoring, detection ranges, relevant marine mammal groups, etc.) and other considerations for AAM (system design constraints).

This task has a significant overlap with a proposal submitted by DRDC Atlantic to RFP JIP07-09. If the work in that proposal is awarded, this task would be significantly reduced as the JIP07-09 work can be reused.

3.2 Potential Performance Assessment

The overall objective of this task is to assess the potential performance of AAM for monitoring marine mammals. Within this task target strength estimates for marine mammals will be developed, a high-level examination of the potential performance of AAM for marine mammal DCL will be conducted, and concepts of use for AAM will be described.

The overall approach is for Mr. Maranda to lead the performance assessment task, with target strength estimates developed by Mr. Theriault, Mr. Gilroy and Dr. Brodie.

For target strength estimates, the objective is to develop general groupings of marine mammals based on their estimated target strength. The approach is for Mr. Jim Theriault, Mr. Layton Gilroy and Dr. Paul Brodie to determine a reasonable basis for the grouping of marine mammals by target strength. In addition to their experience, available literature will be reviewed, such as Lowe[1], Lucifredi and Stein[2], and Miller et al[3]. DRDC Atlantic scientific resources will also be consulted, leveraging off the diver detection expertise of the Underwater Force Protection Group.

Target strength will be used as the basis for the general grouping of marine mammals, as it is a primary consideration for active acoustic detection. Early in the task, the team will decide on the most reasonable basis for estimating marine mammal target strength. Initial consideration suggests the target strength would be highly influenced by lung size, which would vary with the physical size and physiology of the mammal.

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[1] Love, R.H., "Target Strengths of Humpback Whales Megaptera novaeangliae," JASA, Vol. 54; No. 5, 1973, pp. 1312-1315.

[2] Lucifredi, I., Stein, P.J., "Integrated Marine Mammal Monitoring and Protection System (IMAPS): Gray Whale Target Strength Measurements and the Analysis of the Back-Scattered Response," IEEE Oceans 2006.

[3] Miller, J.H., Potter, D.C., "Active High Frequency Phased-Array Sonar for Whale Shipstrike Avoidance: Target Strength Measurements," FarSounder White Paper MTS 0-933957-28-9, FarSounder Inc., Warwick, RI.

Initial target strength modelling by Mr. Layton Gilroy suggests that ellipsoid air-cavity target strength models underestimate the published measurements of target strength for gray and humpback whales. This may indicate that more complex models of target strength are required; however development of a complex model will be beyond the scope of this study.

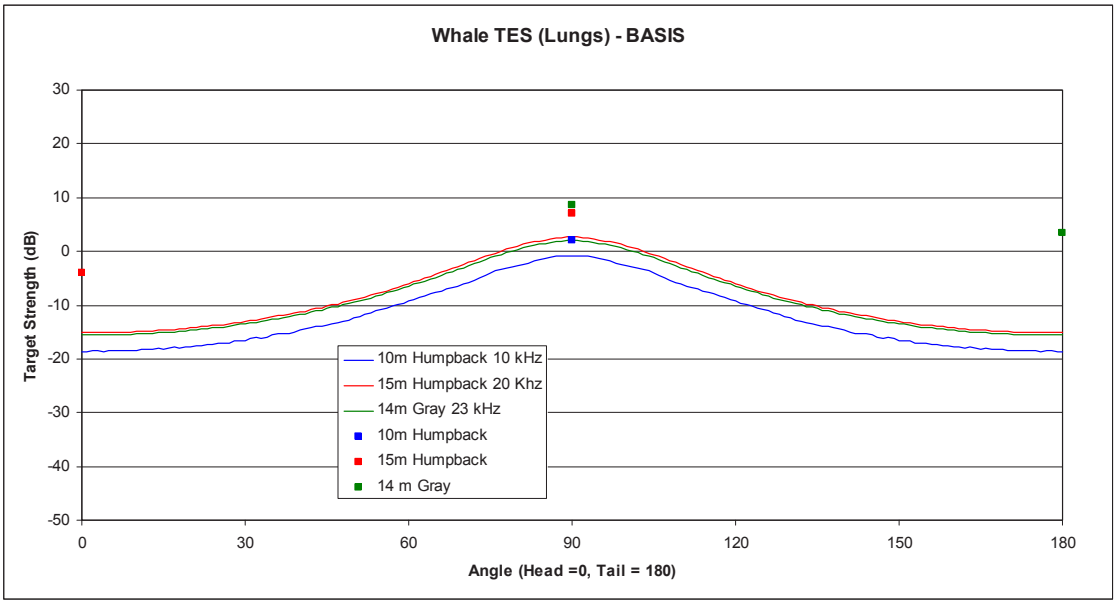

Figure 5: Target Strength Model Estimates (solid lines) compared with Measured Values (points)[4]

It is likely there will be areas of uncertainty in the target strength estimates or gaps in the knowledge or information available on this subject. The considerations and the assumptions used to arrive at the target strength estimates will be noted in the final report.

For the assessment of potential performance, a high-level examination will be carried out of the potential performance of AAM systems. The sonar equation will be used in conjunction with assumed values for system parameters (such as array gain, source level, pulse frequency and duration) to broadly assess the potential detection performance. This preliminary assessment will serve to identify the key parameters and the sensitivity of detection performance to these parameters, and also indicate whether a suite of AAM systems will be necessary to handle different species of mammals. Candidate methods for classification will be examined; examples are detection of target motion, detection of distinct mammals within a pod, etc. Finally, potential localization performance, and its dependence on system parameters (e.g., waveform type), will be considered.

[4] Experimental results were obtained from References 1, 2. Model results were prepared by Mr. Gilroy as a simple demonstration, using a target strength model, in which he modeled a marine mammal lung as an air-filled ellipsoid

The results of the foregoing analysis will feed into a formulation of concepts of use and possible limitations. One of the main factors affecting concepts of use will be the detection range, as the achievement of long-range detection will allow more time and hence flexibility, in implementing mitigation measures. However, adequate range performance may come at the expense of added system complexity or weight, and these in turn will affect the possible modes of deployment and use. For example, if the DCL analysis indicates that significant array gain is desirable, it may be necessary to increase system size and weight, or use a more advanced design based on vector sensors. Other concepts of use may compensate for marginal detection ranges by placing the AAM system(s) off-board the main platform, carried either by small watercraft or by UAVs. Possible limitations may include restricted azimuthal coverage, inadequate warning against mammals transiting at high speed, restrictions on use in high sea-states, etc.

3.3 Define Survey Parameters

The objective of this task is to develop a set of parameters that will enable a consistent, unbiased survey of various AAM systems, which will allow for a better evaluation and comparison of the systems in the Analysis Phase.

The approach is to have the team generate an initial list of parameters, which will then be reviewed for relevance to industry needs, concepts of use and limitations.

The survey responses must provide sufficient information to support the Analysis Phase, which will assess the potential performance of the surveyed systems for marine mammal monitoring and assess the best solution for E&P operations. The survey parameters will be taken from key assessment areas as appropriate, such as sensing hardware, algorithms, software, computing hardware, deployment platforms, data transfer and data formatting. For example, survey parameters for sensing hardware could include source level, frequency(ies) of operation, pulse types, receive sensitivity and dynamic range, directivity, cost, depth and temperature operating range, which would lead to an assessment of species that could be monitored, potential operating environments, potential localization accuracy, potential detection range, etc.

4 Phase 2 – Survey Phase

The objective of this phase is to collect data, based on the survey parameters identified in definition phase, on potential AAM Systems. These can include current systems and, where information is available, in-development active acoustic systems.

A variety of approaches will be used to identify potential contacts for AAM systems, including:

(1) Identify contacts known by the team, including military, academic and industry contacts;

(2) Undertake literature search for systems or users of systems to supplement the known groups;

(3) Post a request for information on the MARMAM list server; and

(4) Approach the fish finder, diver detection and whaling communities for potential systems or users of systems.

This approach is based on the assumption that system developers will freely share available system information. It is likely that one or more systems will be identified for which information will not be available. In this case, any publicly available information will be included along with discussion of attempts to attain additional input.

It is recognized that some systems may be more mature than others and therefore it may not be possible to properly estimate all of the survey parameters. In addition, less mature systems or those intended for other purposes, may contain innovative components which warrant further development.

An electronic database will be created for the survey responses. The database will allow Web-based entry of survey responses for ease of reply and reduction of data entry errors. The database will securely store survey responses and allow efficient query and reporting on the responses.

5 Phase 3 – Analysis Phase

The objective of this phase is to assess the suitability of the AAM systems identified in the survey for their potential ability to detect, classify and localize marine mammals, and their suitability for E&P activities and environments. This will be approached as two tasks, the first focusing on the ability of the surveyed systems to monitor marine mammals, and the second task focusing on the suitability of the surveyed systems for E&P activities and environments. A third task in this phase will identify further development areas and provide recommendations on the way forward.

This phase includes a Close-out Meeting, which will present the project findings to the JIP. It is anticipated that travel to the meeting will be required.

5.1 Use of AAM Systems for Marine Mammal Monitoring

The objective of this task is to assess the capability of the systems identified during the survey phase to accomplish the required DCL function, regardless of whether the sonars were designed for AAM of marine mammals or not.

The approach will be for the team to review the survey responses and rank each system against a matrix of weighted performance categories. The assessments of potential performance will be as quantitative as possible, applying the methods of analysis developed earlier in the definition phase; when available, at-sea performance data as provided by system manufacturers or operators will be included. The outcome of the analysis will be a list of systems ordered from the best potential performance to those which are likely unsuitable for the AAM role.

It is anticipated that some systems will be eliminated in a first-cut analysis owing to their obvious unsuitability for the AAM role. However, those systems that are ranked as marginally suitable will still be assessed for their potential use in E&P activities and environments as this may identify areas for further development.

5.2 Use of AAM Systems in E&P Activities and Environments

The objective of this task is to assess the AAM Systems identified in the survey for their suitability for use in E&P environments and activities.

The approach is to review the survey responses and evaluate the suitability of each system for the concepts of use identified in the performance assessment task. This evaluation will consider a number of different aspects, including deploy / recover / depth of operation, proximity to existing systems, remote vs autonomous, temporal scale of monitoring versus E&P activity real-time vs. delayed, spatial scale and accuracy of monitoring and suitability for various marine environments. This comparison will have been made easier through the careful selection of survey parameters in the definition phase. The suitability of each system will be compared for each of the concepts of use and an attempt will be made to divide the systems into groups, ranging from the most suitable to those which are not likely suitable for a particular concept of use.

5.3 Further Development Areas

The objective of this task is to identify further development areas that have the potential to improve the effectiveness of AAM Systems for detection, classification and localization of marine mammals and that have the potential to improve the suitability of systems for use in E&P activities and environments. From the further development areas a recommendation will be made on the way forward to progress development.

The approach is for the team to draw on their experience and knowledge of systems and active sonar R&D to identify potential development areas, particularly those that would address limitations or gaps identified in the preceding tasks.

The potential performance assessment combined with the knowledge of specific systems will make it evident if current technology adequately fills the solution space for AAM, or if further development could potentially lead to new AAM systems that deliver improved capability in one or more performance metrics.

Consideration will be given to identifying potential areas of further development in order to improve both effectiveness and accuracy of detecting, classifying and localising marine mammals at sea, identifying ways forward to provide or improve effectiveness of AAM technology for use during E&P activities offshore and to identify innovative technologies.

In recommending a way forward, consideration will be given to the feasibility of successful capability development, likely development costs and timing of availability, perception of need and its urgency, and product delivery route.

Beyond individual capability this will also include an analysis of the various platforms, licenses, capabilities, architectures, etc. to recommend a path forward to develop the required monitoring solution. The overall recommendation for further development may be a system of systems approach, within which a number of identified development areas could be inserted and operated. This approach would need to consider work on individual capabilities to mature them and the development of the overall framework that would house the capability. The “framework” may actually cover several levels (autonomous systems, shipborne, monitoring center, etc.).

6 Work Plan

The work plan in the figure below outlines the estimated schedule and resources required to complete the technical approach described in the preceding section.

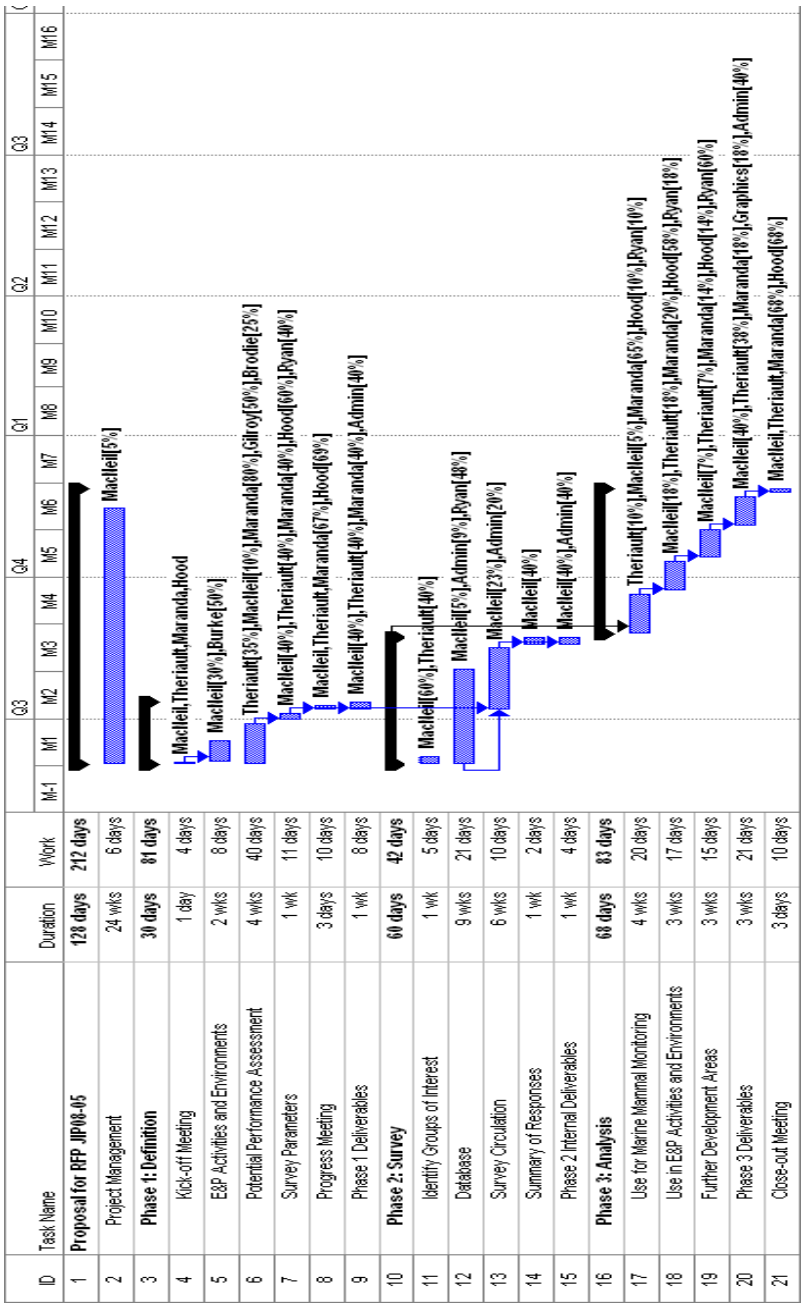

Figure 6: Project Work Plan

7 Availability

Personnel at DRDC are tasked through a research programme as well as external contracted work. The flexibility of the deliverables within the research programme allows the allocation of appropriate resources to carry out contracted work. The work load of personnel identified for this work has been reviewed and they will be made available to carry out the work to completion. Some of the work will be carried out by contractors, and they have indicated that they will be available to complete this work in the proposed schedule.

8 Team Members' Relevant Publication Listing

1. J.A. Theriault, D. Mosher, J.D. Hood, D. Flogeras and T. Murphy, Detection of Beaked Whales using Autonomous Underwater Vehicle (Glider), 3rd International Workshop on Detection and Classification of Marine Mammals using Passive Acoustics, Boston, US, July 24-26, 2007.

2. J.A. Theriault and J.D. Hood, Acoustic Cetacean Detection Capability Performance with the Workshop Dataset, 3rd International Workshop on Detection and Classification of Marine Mammals using Passive Acoustics, Boston, US, July 24-26, 2007.

3. V.W. Young, P.C. Hines, F. Desharnais, and J.A. Theriault. Perception-based automatic classification of marine mammal transients, 3rd International Workshop on Detection and Classification of Marine Mammals using Passive Acoustics, Boston, US, July 24-26, 2007.

4. F. Desharnais, G.J. Heard, and R. Dittman. Computer interfaced video positioning system module (CIVPM), Canadian patent No. 2,408,414. US patent 7,139,082. 19 Dec 2006.

5. A/SLt. M.R. Matthews, G.R. Ebbeson, G.J. Heard and F. Desharnais. Broadband Target Localization in Very Shallow Water, DRDC Atlantic TM 2004-178, May 2005.

6. P. Fortescue (NATO AFSOUTH), S. O. Hole (School of Maritime Operations, Norway), R.M. Robichaud (NATO Undersea Research Centre), J.R. Conforto Sesto (Instituto Hidrográfico de la Marina, Spain), J.A. Theriault (DRDC Atlantic), R. Hensley, N. Weaver, B. Maughan, (UK Maritime Environment Information Centre), MARINE MAMMALS AND ACTIVE SONAR, A paper prepared for the NATO Military Oceanography Group, Proc. of 2005 Military Oceanography Group Meeting, Victoria, BC, October 2005.

7. J.A. Theriault, Environmental Impact Risk Assessment Approach, Proc. of UDT Hawaii 2004, Waikiki, Hawaii, October 2004.

8. J.A. Theriault and J. Hood, Using Directional Sensors to Enhance the Performance of the Towed Receiver Array of Active Sonar, Proc. of UDT Hawaii 2004, Waikiki, Hawaii, October 2004.

9. [Note: This publication was listed in the original proposal submitted to the JIP, however it is not included in this report]

10. F. Desharnais, M. Laurinolli, A. Hay and J.A. Theriault. A scenario for right whale detection in the Bay of Fundy, Proc. of Oceans 2000 conference, Providence, RI, September 2000, Vol. 3, pp 1735-1742.

11. J.D. Hood, A Laboratory Study using Broadband Active Acoustics for Target Localization and Classification, Royal Military College of Canada, 1998.

12. Brian H. Maranda, "Passive Sonar," chapter 97 in Handbook of Signal Processing in Acoustics (editors D. Havelock, S. Kuwano, and M. Volander), Springer, 2008.

13. Brian H. Maranda, “Architecture of the front-end in an ultrasonic communications receiver,” DRDC Atlantic TM 2006-234.

14. Brian H. Maranda and Nicole E. Collison, “Beamforming a bent array,” Canadian Acoustics, vol. 32, 2004, pp. 190-191.

15. Brian H. Maranda, “The statistical accuracy of an arctangent bearing estimator,” in Proc. Oceans 2003, held 22-26 Sept 2003 in San Diego, CA, pp. 2127-2132.

16. P.C. Hines, A.L. Rosenfeld, B.H. Maranda, and D.L. Hutt, “Evaluation of the endfire response of a superdirective line array in simulated ambient noise environments,” in Proc. Oceans 2000, held 11-14 Sept 2000 in Providence, RI, pp. 1489-1494.

17. P.F. Brodie, D.D Sameoto and R.W. Sheldon. 1978. Population Densities of Euphausiids off Nova Scotia as Indicated by Net Samples, Whale Stomach Content and Sonar. Limnol. Oceanogr. 23: 1264-1267.

18. L. Orton and P.F. Brodie. 1987. Engulfing Mechanics of Fin Whales. Can. J. Zool. 65. 2898-2907.

19. P.F. Brodie. 1978. Cetacean Energetics, an Overview of Intraspecific Size Variations, p. 88-101. In B.E. Sokolov and A.V. Yablokov (eds.), Advances in Pinniped and Cetacean Research. USSR Academy of Sciences (in Russian).

20. W.H. Sutcliffe Jr and P.F. Brodie. 1977. Whale Distributions in Nova Scotia Waters. Fish. Mar. Serv. Tech. Rep. 722.

21. P.F. Brodie. 1981. Energetic and Behavioral Considerations with Respect to Marine Mammals and Disturbance from Underwater Noise. In: N.M. Peterson (ed.), The Question of Sounds from Icebreaker Operations. Arctic Pilot Project Workshop.

22. P.F. Brodie. 1993. Noise Generated by the Jaw Actions of Feeding Fin Whales. Can. J. Zool. 71: 2546-2550.

23. P.F. Brodie. 2001. Field Investigations on the Physiology and Mechanical Adaptations of Marine Mammals. p. 337 in: Secondary Adaptation of Tetrapods to Life in Water. V. de Buffrenil and J.-M. Mazin (eds.) Verlag Dr. Friedrich Pfeil, Munich, Germany. ISBN 3-931516-00-0.

24. P.F. Brodie. 2001. Feeding Mechanics of Rorquals (Balaenoptera sp.). pp 345-352 in: Secondary Adaptation of Tetrapods to Life in Water. V. de Buffrenil and J.-M. Mazin (eds.) Verlag Dr. Friedrich Pfeil, Munich, Germany. ISBN 3-931516-00-0.

25. P.F. Brodie and A.J. Pasche. 2001. The Mechanics of Cetacean Respiration: the Significance of Rapid Gas Exchanges in a Selectively Tuned System, with Emphasis on the Rorquals (Balaenoptera sp.). pp. 353-362 in: Secondary Adaptation of Tetrapods to Life in Water. V. de Buffrenil and J.-M. Mazin (eds.) Verlag Dr. Friedrich Pfeil, Munich, Germany. ISBN 3-931516-00-0.

9 Deliverables & Milestones

The deliverables and milestones for each phase of the project are described in the following sections. A general summary is outlined in the figure below.

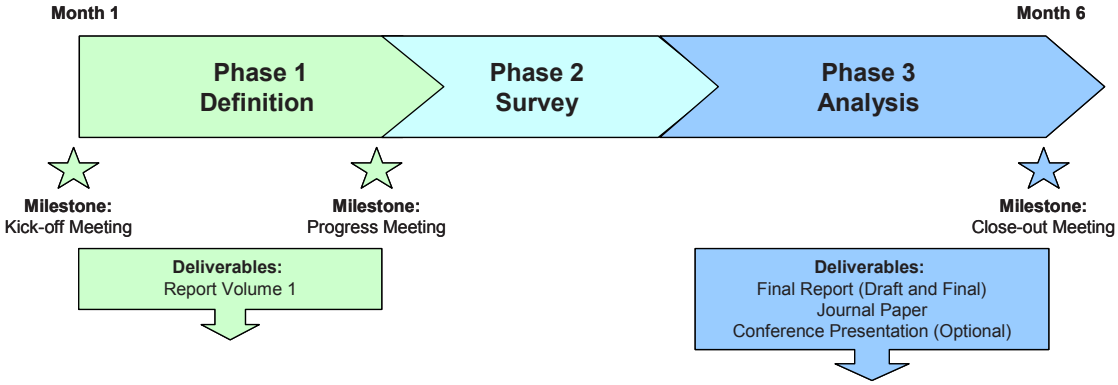

Figure 7: Summary of Project Deliverables & Milestones

9.1 Definition Phase

There is one contract deliverable proposed in the Definition Phase: Report Volume 1. This report will also form part of the Final Report delivered to the JIP at the end of the project.

1. Report Volume 1 will contain the following sections:

    - E&P Activities and Environments;
    - Marine Mammal Target Strength Estimates;
    - Potential Performance Assessment of AAM for Marine Mammal DCL;
    - Concepts of Use for AAM;
    - Limitations of Use for AAM;
    - Definition of Survey Parameters; and
    - Survey Questionnaire.

It is proposed that Report Volume 1 be presented to the JIP in the Progress Meeting at the end of the Phase. Due to the short timeline for the project there will not be time included in the schedule, outside of the presentation, for return of comments by the JIP on the Report Volume 1. However, comments after the presentation are welcome and will be addressed to the extent possible, depending on when they are received.

There are two contract Milestones proposed in the Definition Phase: Kick-off Meeting and Progress Meeting.

It is proposed that a Kick-off Meeting be held at the start of the Phase, which will provide an opportunity for the JIP to provide input on the project plan and approach that are outlined in this proposal.

It is proposed that a Progress Meeting be held at the end of the Phase in which DRDC Atlantic can present the work contained in the Report Volume 1. This will provide an opportunity for the JIP to review and provide feedback on the progress to date.

Based on the preference of the JIP, travel may be required for one or both of these meetings.

9.2 Survey Phase

There are no formal contract deliverables proposed in the survey phase; however, there are two internal deliverables. The internal deliverables will be made available to the JIP contracting authority, comments are not required, but are welcome and will be addressed to the extent possible, depending on when they are received.

The Report Volume 2 will also form part of the Final Report delivered to the JIP at the end of the project.

Internal Deliverables:

1. Report Volume 2 with the following section:

    - Summary of AAM technologies and methods based on survey responses.

2. Database of Survey Responses.

There are no contract Milestones proposed in the Survey Phase.

9.3 Analysis Phase

There are three contract deliverables proposed in the Analysis Phase: Draft Final Report, Final Report, Paper Submission. A fourth optional deliverable is also proposed in the Analysis Phase: Conference Presentation.

1. Draft Final Report, including the following:

    - Report Volume 1, which addresses the following: Overview of AAM capabilities and viability for detecting/classifying/localizing marine mammals at sea;

    - Report Volume 2, which addresses the following: Description of various AAM technologies and methods currently available and potential new systems currently being developed, which are likely to be available in the next 2-3 years;

- Report Volume 3, which will address the following:
    - A critical review and assessment of the various active acoustic technologies and methods ability to successfully detect/classify/localize marine mammals at sea;
    - A critical review and assessment of which AAM capabilities are best suited for the various marine environments prone to E&P development and the various activities conducted throughout the life cycle of an E&P development;
    - Identification of potential areas of further development and suggested ways forward in order to provide or improve effectiveness of AAM technology for use during E&P activities offshore; and
    - Recommendations for a path forward to address the potential areas of further development.

2. Final Report
    - A final revision of the Draft Final Report that incorporates JIP comments.

3. Paper
    - Paper ready for submission to peer reviewed journal. Suggested journals include: Journal of Oceanic Engineering.

Optional Deliverable:

4. Conference Presentation
    - At the decision of the JIP, an abstract presenting the results of this project can be submitted to a conference such as Oceans or another as directed by the JIP. While submission of the abstract could be completed within the six month timeframe, conference attendance and associated travel costs would likely not be incurred within that timeframe.

There is one contract milestone proposed in the Analysis Phase: Close-out Meeting.

It is proposed that a Close-out Meeting be held at the end of the Phase, in which DRDC Atlantic will present the Draft Final report to the JIP. This will provide an opportunity for the JIP to review and discuss the findings of the report with DRDC and to provide feedback for the Final Report. Based on the preference of the JIP, travel may be required for this meeting.

10 Budget

This section provides an estimate for the work described in the work plan and includes the Definition, Survey and Analysis Phases. This proposal will remain valid for a period of one hundred and twenty (120) days after the closing date of the request for proposal.

Table 1: Project Resources and Budget

RESOURCE NAME	EST EFFORT (DAYS)	TOTAL 2008 ($ CDN)
DRDC Atlantic	152	$140,000
Subcontractors	60	$47,000
Labour Subtotal	**212**	**$187,000**
Travel		**$15,000**
Total Estimated Price (excluding applicable taxes)		**$202,000**

Payment Schedule: Payments will be based on milestones. Payment terms are in accordance with the sample contract provided.

1. Payment Milestone One is the delivery of the results of the first phase, and is a formal report as noted on the List of deliverables and the schedule. The first invoice will be for 50% of the fixed price, plus any travel expenses that may be incurred to date.
2. Payment Milestone Two is the delivery of the final report. On acceptance of the report, the remainder of the fixed price contract plus any travel expenses will be invoiced.

11 Abbreviated Curriculum Vitae

Jim Theriault, DRDC Atlantic

Erin MacNeil, DRDC Atlantic

Brian Maranda, DRDC Atlantic

Layton Gilroy, DRDC Atlantic

Joe Hood, Akoostix

George Ryan, Akoostix

Ray Burke, Canadian Seabed Research Ltd.

Paul Brodie, Balaena Dynamics Ltd.

[Note: CVs for the team members listed above were included in the original proposal submitted to the JIP, however are not included in this report]

12 Health, Safety and Environment

DRDC Atlantic has health, safety and environment policies consistent with its role as a Canadian federal research facility. The policies are part of the extensive health, safety and environmental policies of the Department of National Defence.

Because of the type of work this project envisages, no project specific policies will be generated.

13 Intellectual Property

Any information generated from this project will be provided to the JIP as part of the research programme for distribution within the JIP. Further distribution will be at the discretion of the JIP. The publication of a peer reviewed paper will provide public access to the information generated from this project.

14 Animal Care

DRDC Atlantic is bound by the Tri Council Guidelines on Research Ethics (www.pre.ethics.gc.ca) as well as Guidelines for the Canadian Council on Animal Care (www.ccac.ca). See websites for policy details.

Because of the type of work this project envisages, there is no expectation that any research or direct interaction will occur with either humans or animals and the research protocols will not be submitted for ethics approval.

Acronym List

AAM	Active Acoustic Monitoring
AOL	America Online
CSR	Canadian Seabed Research Ltd.
CV	Curriculum Vitae
DCL	Detection, Classification, Localization
DRDC	Defence Research and Development Canada
E&P	Exploration and Production
IMAPS	Integrated Marine Mammal Monitoring and Protection System
JIP	Joint Industry Project
MARMAM	Marine Mammal Mail List Server
PAM	Passive Acoustic Monitoring
R&D	Research and Development
RDS	Rapidly Deployable System
RFP	Request For Proposal
UAV	Underwater Autonomous Vehicle

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3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)

Survey of Active Acoustic Monitoring (AAM) Technologies: Volume IV: Proposal

4. AUTHORS (last name, followed by initials – ranks, titles, etc. not to be used)

E. MacNeil; J. Theriault; B. Maranda; L. Gilroy; J. Hood

5. DATE OF PUBLICATION (Month and year of publication of document.)

March 2012

6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.)

42

6b. NO. OF REFS (Total cited in document.)

0

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

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Joint Oil and Gas Industry Programme on Sound and Marine Life (JIP 22)

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)

11cj52

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JIP22 08-06

10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.)

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Under the Exploration and Production (E&P) Sound and Marine Life Programme, a research study was carried out on the feasibility of the Active Acoustic Monitoring (AAM) of marine mammals. The purpose of such monitoring would be to detect marine mammals in those ocean areas where E&P activities are being conducted, in order to allow due diligence in mitigating any potential impact of these E&P operations. The study did not include any direct experimentation.

First, the problem domain was delineated in an overview of offshore E&P activities and of the ocean environments in which they are conducted. To make the analysis more concrete, six specific ocean areas of relevance to E&P were selected and their properties described. Next, the potential performance of AAM was investigated via a parametric study of the sonar equation, incorporating available knowledge of sonar technology and environmental effects. Special effort was dedicated to investigating the target strength of marine mammals, as this is an area in which scientific knowledge is sparse at present. The parametric analysis included several generic examples, and was also applied to the six specific ocean areas. Finally, a survey was conducted of commercially available sonar equipment by collecting data from sonar vendors through an on-line form. The sonars were then ranked as to their suitability for AAM based on the factors identified as important during the earlier study of potential AAM performance.

This document is Volume IV of four volumes. It contains the original study proposal submitted to the Joint Oil and Gas Industry Programme (JIP) in response to request for proposals (RFP) number JIP08-05, Mitigation and Monitoring: Review / inventory of current active acoustic methods and technologies.

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Oil and Gas Industry; Active Acoustic Monitoring; Marine Mammals; Marine Mammal Monitoring; Active Sonar;

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