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Best Practices in 3-D Land Seismic Acquisition in the Middle East and North Africa: Cost-Effective Acquisition in a Low Oil Price Environment

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ABSTRACT

Increasing expenditure in 3-D land seismic acquisition has driven the need to define Best Practices and improvement areas in the acquisition process. Petroleum Development Oman (PDO) and Arthur D. Little Management Consultants undertook a study to identify these Best Practices in the Middle East and North African regions by interviewing 34 companies and compiling data from 51 recent vibroseis surveys. Acquisition costs and duration from surveys over similar terrains, but with varying geometries, were compared on an equal basis to determine the most cost-effective method for acquiring high-quality (i.e. data density) 3-D data. High-quality surveys acquired using a Zig Zag geometry had lower costs than those acquired using conventional geometries over gravel plain terrain. However, there was no clear best geometry for other terrains. Acquisition performance was also improved by adopting a number of Best Practices covering the design, planning, contracting strategy, execution, processing and post-acquisition elements of the seismic acquisition process.

INTRODUCTION

The seismic industry has seen a rapid increase in the number of 3-D land surveys acquired in the past five years, especially in the Middle East and North African region. This increase has been driven by the arrival of new oil and gas companies, mainly western majors and independents, into this region coupled with the requirements of National Oil Companies (NOCs) to undertake extensive exploration and development programmes in order to replace and increase their recoverable reserves.

Proprietary 3-D seismic acquisition in this region is mainly undertaken for exploration purposes (60% in our survey sample) with only the larger operators using the full data set for both field development and reservoir management purposes. Of these companies, Petroleum Development Oman (PDO) of Oman and Saudi Aramco of Saudi Arabia have carried out the most extensive programs, with PDO having acquired some 33,000 square kilometres (sq km) of data since 1984. Both countries offer a range of terrain and environments of which the vast desert gravel plains, free from obstacles and complicated permitting requirements, have provided a nearly perfect setting for experimentation with various geometries and acquisition techniques (see also Al-Husseini and Chimblo, 1995; Onderwaater et al., 1996; Hastings-James and Al-Yahya, 1996; Rozemond, 1996; Wams and Rozemond, 1997; McGinn and Duijndam, 1998). This paper examines the current Best Practices in land acquisition in this region, the remaining challenges and the future uses of 3-D seismic in one of the world's richest oil provinces.

METHODOLOGY

PDO and Arthur D. Little Management Consultants undertook a bench-marking study between 1997 and 1998 to identify the Best Practices in 3-D land acquisition throughout the Middle East and the North African region. The purpose of this study was to:

- implement these Best Practices where possible within PDO,

* Focal Point of further Communication

- find current trends in land acquisition amongst Middle East NOCs and majors / independents in the Middle East and the North African regions, and
- bench-mark acquisition times and costs on both a unit area and a data density basis.

The study compiled technical, cost and time duration data from 29 oil companies (majors, independents, NOCs) and 5 seismic contractors who had operations in the region during the last four years. These companies were also interviewed to ascertain the processes used in acquiring the data, from initial survey proposal to survey delivery, and the communication between the acquisition, processing and interpretation departments during acquisition. To complement the data, some European and North American operators and contractors, acknowledged for their innovations, acquisition speed, or alliance-type relationships with acquisition contractors, were also interviewed. The results of these interviews, coupled with the quantitative cost and time duration data, provide the basis for the Best Practices section of this paper.

CURRENT SITUATION AND MANAGEMENT ISSUES

Geophysics, more than any other oil industry discipline, is often poorly understood by middle and upper oil company management, yet it is regarded as a critical element in their Exploration and Production (E&P) business. This lack of management understanding has meant that seismic acquisition and processing have been considered second in line behind drilling, even though the seismic budget for many companies now accounts for more than 30% of their exploration capital expenditure. Both activities are operationally driven but have the obvious difference in that one produces a conclusive result (i.e. dry hole, technical or commercial success) whereas the other needs to be acquired, processed and interpreted before it can be of any use. This lack of conclusiveness in seismic acquisition and processing, together with geophysics' academic reputation, has resulted in a three stage separation of the seismic process *viz* acquisition, processing and interpretation.

From recent Arthur D. Little studies, it is apparent that some surveys are designed and acquired, constrained by a fixed budget rather than being tuned to meet the required business and seismic objectives. This presents a potential problem for the quality of the survey. To return to the drilling analogy, the majority of poorly-drilled wells will flow some hydrocarbons, if any are present, whereas a 3-D seismic survey which has not been designed and processed to meet the appropriate objective will be virtually worthless. This has led to examples of 3-D surveys or even 2-D surveys being re-acquired and processed after an initial 3-D survey produced low-quality results.

In order to overcome these problems and to ensure that the survey budget is used optimally, some companies are adopting a team approach, consisting of users (interpreters) and service providers (acquisition, processing and contractors) who follow, and are responsible for, the survey from its proposal to interpretation. This has lead to an acquisition team that is more integrated into the seismic process and more focused on meeting the interpreters' requirements. This approach forms a platform to identify survey issues and capture learning experiences so that in spite of staff rotations, future surveys should not encounter as many of the problems suffered by older surveys.

INDUSTRY ENVIRONMENT

Industry Overview

It is important to analyse current and future seismic trends to put changes in the seismic industry in context and to see how Best Practices can optimise survey costs.

Major improvements in world-wide finding costs over the last ten years (Figure 1) have been aided by the increasing use of seismic (especially 3-D) for generating high-quality prospects and lowering overall costs (see also Aylor, 1998). Reductions in unit exploration costs have been even more impressive, as they have occurred against a backdrop of rising rig rates and increases in total seismic costs with 2-D surveys being replaced by 3-D surveys.

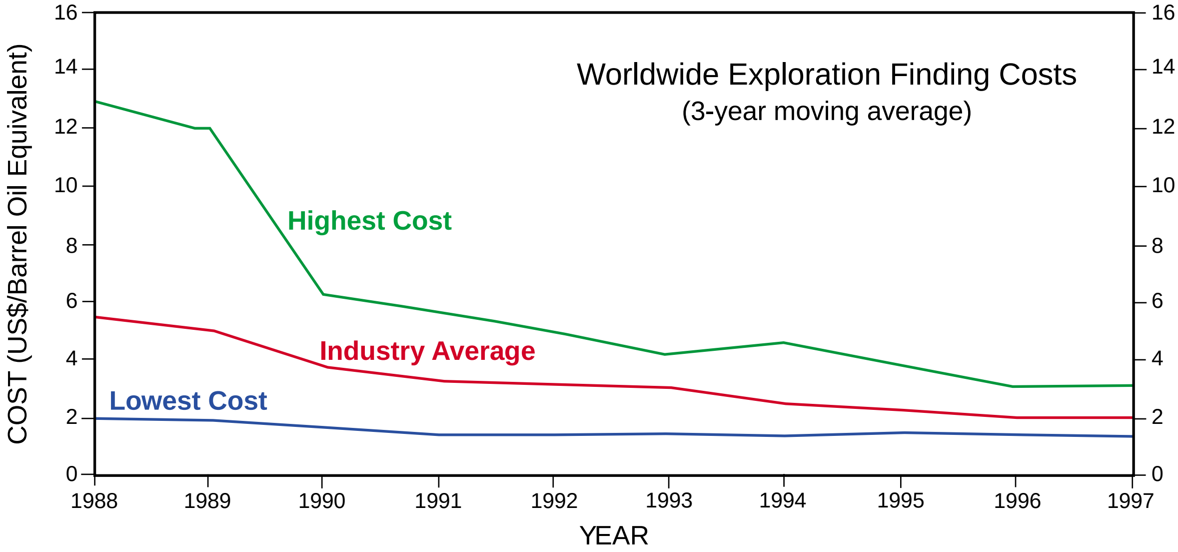

Figure 1: The decrease in finding costs over the past decade can be attributed to a more focused in exploration strategies and the widespread use of 3-D seismic and other new technologies (e.g. interpretation tools, Direct Hydrocarbon Indicators techniques). Highest cost operators have improved the most by adopting the new technology, improving their management of the exploration portfolio and by optimising their well costs. (Source: Arthur D. Little Research using SEC filings for eleven major and independent quoted companies). World Exploration Finding costs based on SEC 10-K filings of proven reserve additions over a three-year period – includes extensions/ discoveries but excludes acquisitions and Enhanced Oil Recovery (EOR). All cost data upto 1993 is normalised for special items. Exploration cost incurred includes both capitalised and expensed costs. Industry average (unweighted) is for the following peer group of companies: Amoco, ARCO, BP, Chevron, Elf, Exxon, Mobil, Phillips, Shell, Texaco and Unocal.

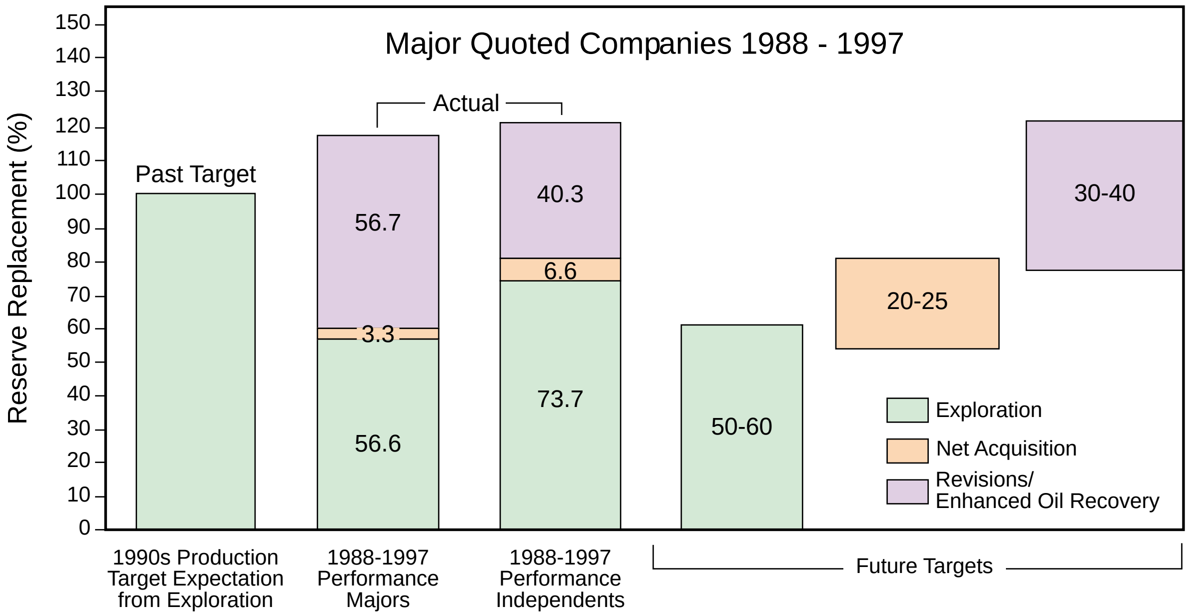

Figure 2: Although Exploration was expected to replace the majority of produced reserves throughout the 1980s and 1990s, in reality Exploration was unable to meet this target alone and the shortfall has been more than replaced through Reservoir Development practices. (Source: Arthur D. Little Research using SEC filings for twelve quoted majors: Amoco, ARCO, BP, Chevron, Elf, Exxon, Mobil, Phillips, Shell, Texaco, Total, Unocal and twelve independents: Amerada, Anadarko, BHP, Conoco, Enterprise, Kerr McGee, Lasmo, Marathon, Occidental, Phillips, Repsol (1991-1997), Unocal). Net Acquisition are reserve acquisitions less reserve sales.

Throughout the 1990s, companies expected to replace most of their reserves through Exploration alone. However, this target was optimistic despite the increased use of 3-D seismic with the actual percentage of reserves attributable to Exploration being between 50% and 70% (Figure 2). The remaining 30% to 50% has been more than replaced through Reservoir Development, Enhanced Oil Recovery (EOR) activities and reserve acquisitions. With future reserves replacement targets for Exploration and Reservoir Development similar to their historical levels, Reservoir Development has become the lowest risk, highest present-value prize. It will also be further enhanced through the increased use of reservoir geophysics, which now commands a greater proportion of research and development expenditure than it did in the past.

Future Industry Trends

Seismic acquisition practices must take into account the changing uses and the future technologies associated with 3-D data. With the introduction of time-lapse, multi-component data, and Pre-Stack Imaging coupled with higher resolution processing, seismic will be used widely as the fundamental data set for reservoir development and reservoir monitoring. The routine use of seismic as a reservoir characterisation and fluid prediction tool using compressional (P-wave), shear (S-wave) and mode-converted wave processing will also allow more petrophysical information to be inferred from the data. As the repeatability, quality and phase stability of the seismic data continues to improve, seismic inversion may allow key lithological properties, such as shear and compressional wave velocity (V_S and V_P) and density to be derived more reliably. This predicted increase in the role of seismic in reservoir development will be aided by the integration of geophysicists into reservoir teams and the reservoir model building process.

In the area of seismic acquisition, in particular seismic recording, equipment continues to become more flexible. Recording channel count will continue to increase on seismic crews leading to an increase in numbers of recorded and processed traces. A key area of development is predicting how these channels will be used (Slawson et al., 1997). As seismic recording sensors become cheaper and more reliable and as time-lapse processing methods improve, producing fields (where the reservoir is suitably imaged on seismic) will increasingly have permanently installed seismic sensors (e.g. vertical arrays).

Changes in the acquisition tendering and contracting process will mean that less time will be spent on acquisition tenders and contracts as industry, or at least company-wide standards, are agreed upon or contracts are being written by external geophysical consulting companies. The seismic acquisition tendering process continues to evolve as fewer companies have “2-D type specifications” left in their 3-D contracts (e.g. a maximum of six dead adjacent traces). Operators are also looking for contractors to be more pro-active in suggesting survey designs. Contracting relationships have also developed over the past few years with an increased number of “strategic alliances” (e.g. Apache and BHP with Western Geophysical). We predict that this trend will continue based on companies surveyed in our study.

CURRENT SURVEY APPROACHES

Current approaches to seismic acquisition vary widely among operators. Cost constraints almost always govern the data density of the seismic survey. In this respect, operators commonly choose from three options:

- to acquire a 3-D over a defined area at a predetermined budget (usually cost per day or cost per sq km),
- to strive for a high-quality survey first, which will be their primary objective, but at a predetermined budget, or
- to have the flexibility to acquire a quality survey to meet an asset’s business objective (which includes seismic objectives, future potential uses and cost).

The following sections present ideas on how it is possible to acquire cost-efficient, high-quality data across gravel plains and dune areas.

3-D Cost and Time Bench-Marking

Information from 51 surveys (23,212 sq km) was collected from eight countries in the Middle East and North Africa during the period 1994 to 1997. Along with technical and objective data, this formed the basis for this bench-marking study.

Cost and duration of surveys from similar terrain types, of different geometries, were compared to identify the most cost-efficient method of acquiring high-quality 3-D vibroseis data (Table 1). The surveys naturally separated into two groups based on terrain types. These groups were:

- Gravel plain surveys (75% of surveys studied), and
- Dune surveys where dunes were a major feature in the survey area (the remaining 25% of surveys studied).

Table 1

Typical survey parameters for the geometries studied in this paper.

Terrain	Geometry	Fold	Channels/ Shot	Maximum Offset (metres)	CDP Bin (metres)
Gravel Plain	*Double Zig Zag*	80 - 300	640 - 1,200	3,000 - 7,000	25 x 25
	Double Zig Zag High Resolution	100 - 200	800	2,400	25 x 12.5
	Single Zig Zag	48	800	3,100	25 x 25
	Conventional	48	600 - 1,150	2,300 - 4,000	25 x 25
Dune	*Double Zig Zag*	48 - 70	480 - 780	4,000 - 5,000	25 x 25
	Orthogonal	80	960	5,500	25 x 25
	Other	24 - 90	700 - 1,200	4,000	25 x 25

In order to compare surveys on an equal basis, the survey cost and duration were normalised by trace density (total number of traces divided by survey area). Both survey types were normalised to the same high-quality survey parameters, being a survey with an area of 400 sq km and with a trace density of 200,000, equating to a fold of 80-100. This meant that if a survey was acquired over an area less than 400 sq km, or had a data density of greater than 200,000, its total recording time and total recording cost were multiplied by the factor that normalised the data to 400 sq km and 200,000 trace density, respectively.

The metric, trace density, was chosen as it can be used as a proxy for quality (if we simply assume that higher trace density per sq km gives higher data quality). The results of the analysis are shown in Figure 3 as the normalised time taken by different operators to acquire the same survey using different geometries. Due to confidentiality issues we have used time as an indicator of cost. When normalised using the same method, the costs of the normalised surveys showed a similar trend as the survey acquisition times outlined in Figure 3.

Normalising by survey area is an industry recognised method for comparing surveys and determining a survey's cost, but it was found that normalising by survey area alone did not take into account survey quality.

The results of the normalisation indicated that high-quality gravel plain surveys could be more efficiently acquired, in terms of cost and duration, by using a short-single or -double vibrator sweep and a Zig Zag geometry (Wams and Rozemond, 1997) than more conventional orthogonal acquisition. However, it goes without saying that any high-quality survey will cost more than one of lesser-quality even using the most effective geometry to reduce the overall price. Therefore, when cash constrained and a trade-off against quality must be made, the single Zig Zag geometry, rather than the double Zig Zag geometry, should be used for gravel plain.

The results from the comparison of surveys acquired over dune areas did not reveal the most cost-effective geometry (Figure 4). Only a few surveys used a Zig Zag technique in this terrain and these were limited to areas that bulldozers could open a useable pathway for the vibrator trucks. In these instances, the Zig Zag surveys had high costs and duration, due essentially to the additional need for bulldozing, when compared to moderate fold surveys (60–90 fold), acquired with an orthogonal

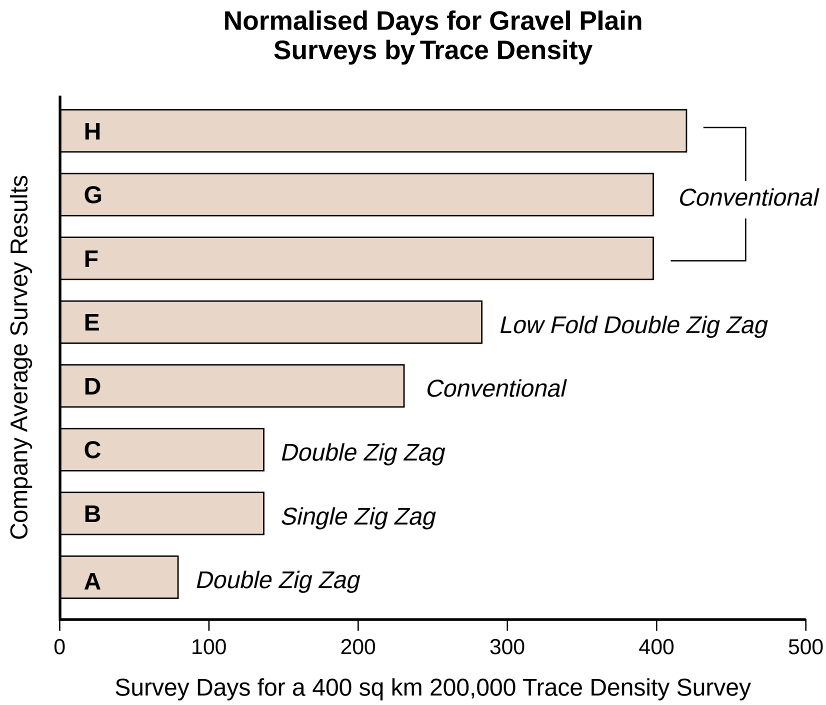

Figure 3: Comparison of acquisition times of high-quality, gravel plain surveys using different geometries and normalised on a trace density basis. Surveys with a low acquisition time are acquired with the most effective geometry, which in this case is the Zig Zag method.

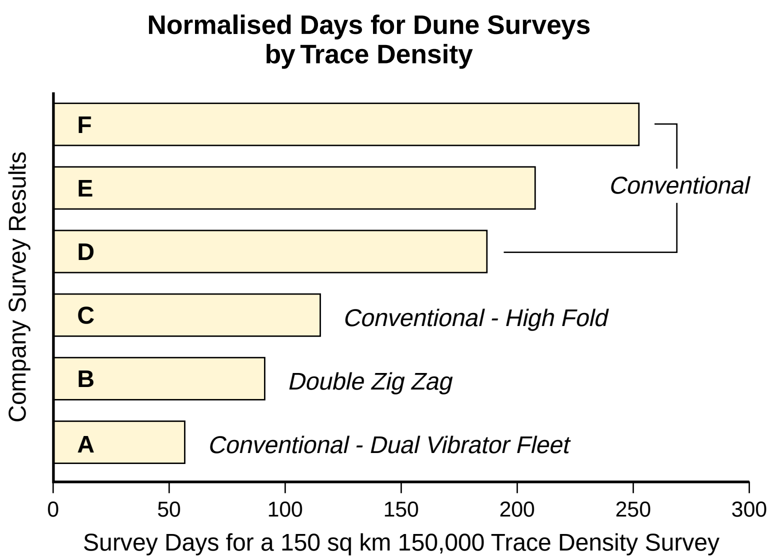

Figure 4: Comparison of acquisition times of high-quality, dune surveys using different geometries and normalised on a trace density basis. Unlike gravel plain surveys, the Zig Zag technique is not the only method of efficiently acquiring a high-quality survey.

geometry. Given the logistical difficulties of acquiring data with a Zig Zag geometry in areas of dune fields, the moderate fold orthogonal geometry appeared to offer the best quality to cost ratio.

Combining the conclusions from the survey comparisons, with detailed interviews from the participating companies, allowed the identification of Best Practices employed by them to acquire cost efficient high-quality data.

BEST PRACTICES

Survey Proposition

Seismic 3-D data will provide a great advantage to the interpreting geophysicist in most cases. However, in regions of low well costs and / or where there are shallow targets, a 3-D survey may not be the most cost-effective geophysical data source for both exploration and development surveys. In any case economic "value of information" (VOI) calculations (see Appendix and Aylor, 1995; 1996; 1998) should be made for each 3-D survey as it is important not only to justify 3-D versus 2-D survey but also to obtain the budget allocation which will allow the survey to be acquired in a manner that meets the overall business objectives of the asset. These objectives will ultimately determine data density of the survey and therefore its final cost.

Commonly surveys are budgeted, in their early stages, in a fixed dollar per sq km ($ / sq km) basis, which is similar to the method of budgeting for wells dollar per foot ($ / ft). This practice does not account for the required survey geometry or the seismic data density, and therefore, surveys should only be budgeted on their survey objectives and the quality of the data they require, rather than the area the survey will cover. Once the initial proposal of a survey has been accepted, the interpreter or asset team responsible for the survey must involve the acquisition and processing geophysicists and contractors at an early stage to fully explain the survey objectives and leverage all available local and company knowledge. Only with the complete and early involvement of the "key players" can an estimated cost based on the desired objectives be established.

The survey objectives should also be planned for both the short-term and the long-term as it must fit into the asset's long-term business strategy. Questions should be asked during this phase concerning the survey's future (e.g. will the survey have multiple targets?; what is the repeatability / requirement for a reshoot for this particular area?) so that unnecessary future expenditure with additional surveys can be avoided. In some areas companies in our study acquired exploration 3-D surveys for structural definition only, with a second 3-D being acquired on discovery for detailed reservoir analysis and field development.

Consistency - Links with Processing and Interpretation

Staff continuity and communication are key elements in delivering the objectives of the survey. Commonly in large companies, a rotation of staff between business units every three to four years was found to generate innovation, to improve team collaboration, and to transfer learning (Figure 5). This time duration appeared to be the optimum for both company and employees. Assignments shorter than three years meant that often the acquisition geophysicist who designed a particular survey had left the business unit before or during its acquisition. Assignments longer than four years were found to stifle innovation due to the lack of influx of new ideas and methods from staff entering the business unit. Staff also felt that motivation dropped after four years as they sought a new challenge and career progression.

Staff continuity is equally important within the project team. Interviewees commonly agreed that the interpreter who proposed the survey should remain responsible for it until its delivery. This also applied to the acquisition and processing staff involved. To help maintain some continuity, 12 out of the 29 oil companies surveyed employed a database that captured survey parameters, cost and duration information and on occasions lessons-learnt. These advantages of continuity cannot be directly measured in terms of cost and time improvements, but it ensures that the survey is aligned to the asset's requirements.

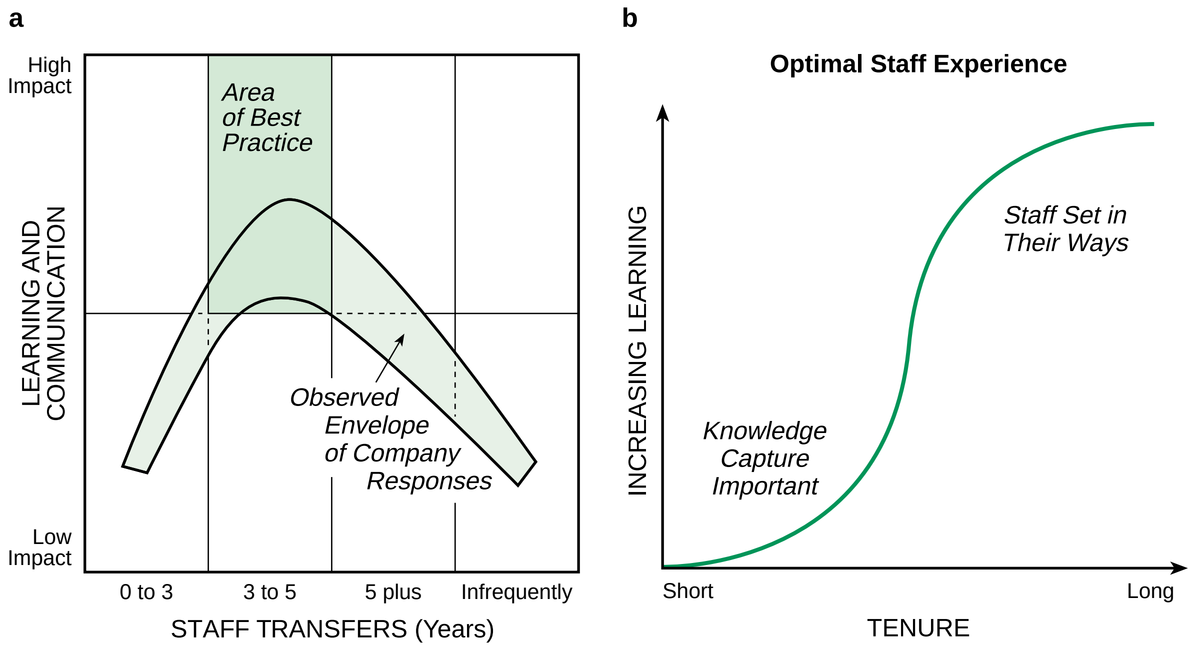

Figure 5: The effect of staff rotations can have a significant effect on the learning and communication within a business unit. (a) Of the companies in our survey the most optimum rotation for both staff and the business unit appeared to be 3 to 5 years. (b) The optimal staff experience requires a balance between short and long tenures. Short tenure increases innovation and motivation but requires a good knowledge capture system for consistent high-quality. Long tenures could act as a "blocker" to new ideas.

Some operators are now implementing the concept of a team being responsible for the acquisition of a survey, rather than either contractors, the acquisition group, or the interpreter. However, many large companies still work in a "factory-like" sequential process involving the handover of information from the acquisition group/contractors to processing and on to the interpreter. In many cases this process breaks down as the staff and contractors responsible for acquisition and processing become further removed from the full objectives of the survey.

The solution to this problem for seven of the companies surveyed was to form an Acquisition, Processing and Interpretation team (coined the API team in PDO) responsible for each new survey (Figure 6). The benefits of such a team were to increase the communication between the interpreter, acquisition and processing staff. More specifically:

- In planning, all parties are made aware of the key geophysical and business objectives. All relevant parties have the opportunity to provide input into the survey design and can jointly plan any field testing or modelling.
- At the start of operations the interpreter briefs the crew on the main objectives and verifies data quality at an early stage with the processing geophysicist either in the field or in the processing centre.
- The interpreter works closely with the processing team during the final processing phase and accesses preliminary data volumes on their workstations.
- Finally, the main learning experiences from the survey are captured during a survey close-out meeting and feed-back throughout the various geophysical functions.

Contracting Methodology

A relationship should be built with contractors to ensure the availability of highly qualified and committed staff through time. This may decrease the need to tender for every acquisition project, as preferred contractors will be favoured, especially for smaller surveys. Contractors should be encouraged to offer support (including research and development) from their company headquarters as well as

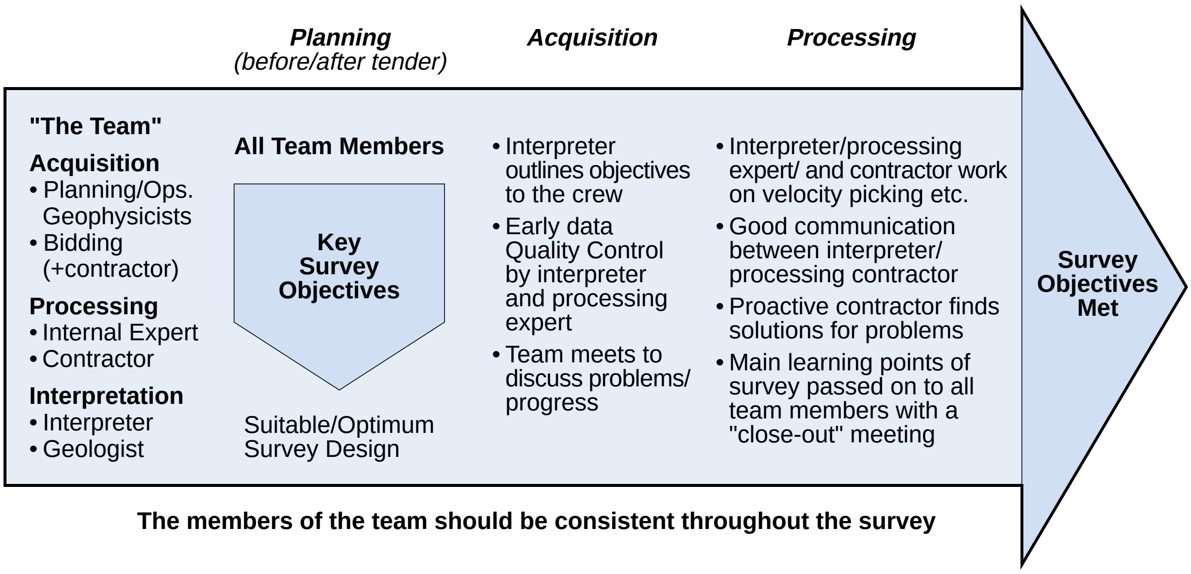

Figure 6: Staff continuity and cross-function communication are key elements in achieving the survey objectives.

the local office and ideally to propose objective surveys design (Figure 7). Contractors need to be involved in the planning process and should conduct a scouting trip to the survey site as early as possible so that they can influence the initial plan. During the field acquisition, the operator should outline the survey objectives, (e.g. cycle time, quality) to the crew, who should be personally motivated (through bonus payments, etc.) using clear, simple and visible measures (i.e. on the wall of the party chief's office).

The Planning Phase

Detailed planning of 3-D surveys should not rest wholly with the acquisition team or contractors. As mentioned above, it is essential that the survey's business and geophysical objectives be transferred across departmental functions so that the final product achieves the survey goals. The key to this is overriding the belief that 'only' company staff "need to know" the survey objectives.

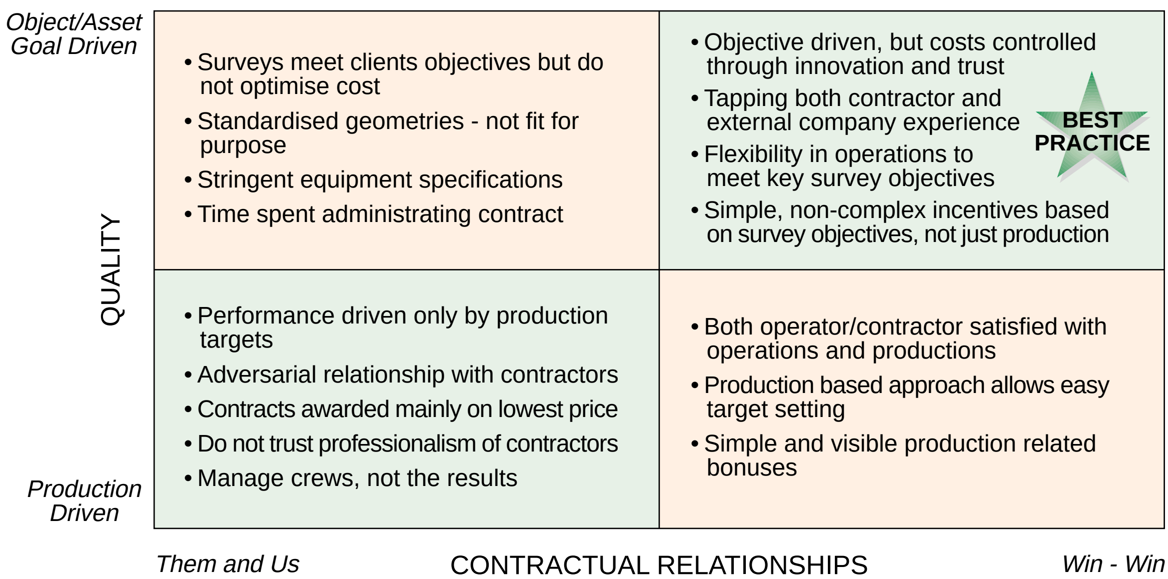

Figure 7: A good working relationship with contractors can create a "win-win" situation for both parties when there is sufficient quantity of challenging work and participation.

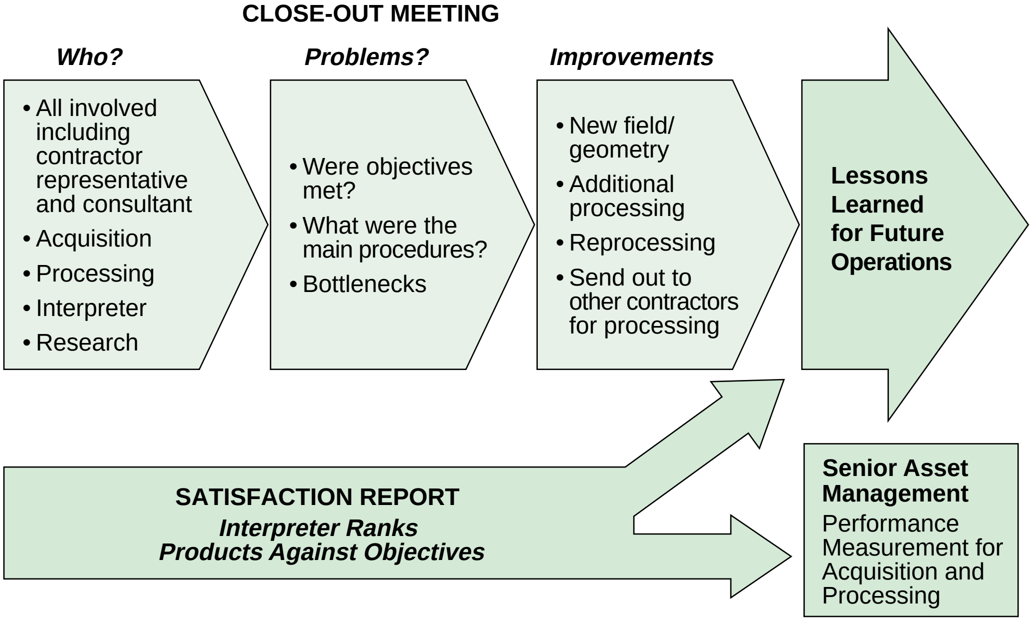

Figure 8: Responsibility for the survey should include both a formal close-out meeting and a customer satisfaction report to be filed at the end of every survey and incorporated into a "lessons-learnt" database.

Contractors are now deeply involved in other E&P activities, such as drilling, where major advances have been made in recent years in communicating, through offsite meetings, the key well objectives from the geologist and reservoir engineer, all the way to the tool pusher on the drill floor. These meetings allow everyone to become aware of key issues, while undertaking operations, which can easily be overlooked when focusing solely on cost or time.

Involving contractors and consultants is also essential from a logistical point of view if they have worked in the area before and know of potential hazards or difficulties. Many operators conduct a scouting trip to the survey area as early as possible in the planning process which included contractors so that they can influence the survey design and provide information on logistical constraints. In addition, companies who acquired relatively few 3-D surveys, and therefore have less experience in this area spent a considerable period planning, modelling and evaluating other company's design concepts prior to the start of operations. Smaller operators were also found to spend more time conducting survey-specific field tests to verify survey parameters, due to their lack of experience in the area of interest, while field testing for larger companies was mainly undertaken for longer term design improvements. In many cases, companies took the simple step of gathering planning information by contacting joint venture partners or other operators who had previously acquired surveys in the area.

Survey Execution

Field representatives should have decision-making power and provide advice to the acquisition contractors in the field, not just quality control. Data quality should be checked by an interpreter and a processing expert early in the acquisition process so that the survey parameters can be adjusted and optimised during the initial stages of the survey. A number of the companies surveyed placed an internal processing expert on the field crew during the first few weeks in order to tighten quality control. The main processing contractor must be involved to some degree during field operations so that they are aware of how the data has been collected and the various field constraints that existed. Some companies are actively upgrading their field processing capabilities so that the majority of processing can already be carried out in the field. In situations where time is of the essence, these extra services have been found to be worth the extra cost. In general, most of the companies surveyed processed data to brute stack in the field. In some operations the field processor, the field processing sequence and the velocity model were sent to the processing centre to assist final processing.

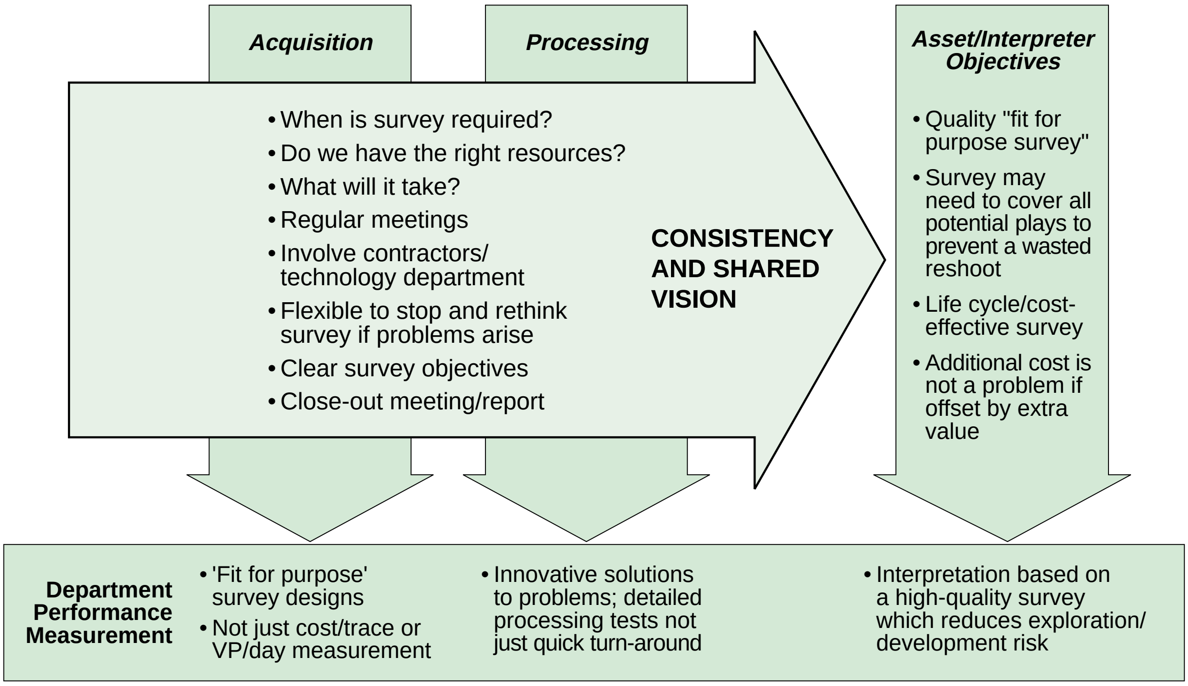

Figure 9: The quality of the survey can only be guaranteed if the original objectives are fully explained initially and if all parties are involved in planning and execution.

Close-Out Meeting

Responsibility for a survey should include both a formal "close-out" meeting (Figure 8) and a customer satisfaction report which should be incorporated into a "lessons-learnt" database. The close-out meeting does not have to be complex and the report may only consist of a few pages. These databases capture such information as: the success of a survey geometry in a particular terrain, data quality versus geometry, strengths and weaknesses of modelling and field testing, contracting success and the costs of not transferring best practices. Along with a "lessons-learnt" database, it allows all the used and generated knowledge obtained from the acquisition of the survey to be captured.

CONCLUSIONS

In summary, quality costs but there are methods for reducing expenditure (such as the Zig Zag geometry) in order to ensure that the survey objectives are met (Figure 9). The process recommendations are:

- Companies intending to make seismic acquisition an integral part of their E&P core skills should have access to seismic acquisition expertise, either fully-supported by company staff or from geophysical consultants.
- Surveys should be planned only to meet business unit objectives (containing both geophysical and financial elements). Planning must involve acquisition, processing and interpretation staff, including contractors (especially in new areas) so that their activities are fully aligned with the survey goals.
- A relationship should be built with contractors to ensure quality and continuity of staff involvement through time. Contractors should be requested to offer the support of the contracting company's headquarters rather than support from just the local office.
- Company interpreters and processing staff, and ideally the contractor that will process the data, should be involved during the early stages of acquisition so that problems may be identified and overcome from the start. During post-acquisition processing, the field processors should interact with the main processors who should also be given access to all relevant field data.

- Post-project meetings and customer (interpreter or business unit) feedback should be formalised. Lessons and useful measures (geometry, production data, costs and times) should be captured for future reference. Where the acquisition group is physically separated, this database should be available on the company intranet and updated regularly to encourage staff to use it.

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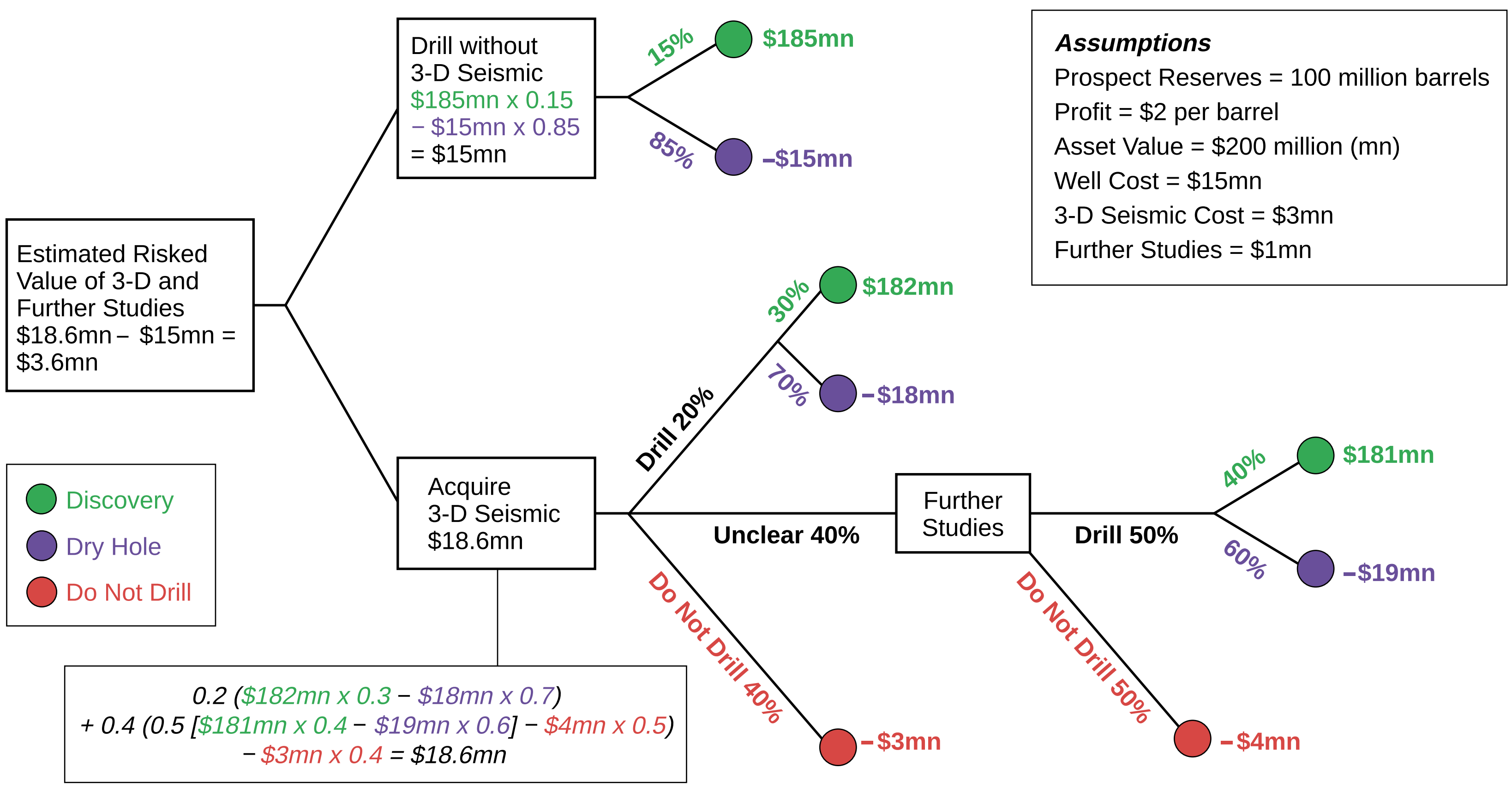
APPENDIX

VALUE OF INFORMATION FOR 3-D SEISMIC: AN EXAMPLE DECISION TREE



An example of a value of information exercise using a decision tree that a typical Exploration team might use. As an Exploration team you may have to decide if it is worthwhile acquiring a proposed 3-D survey prior to drilling a well. Based on preliminary research and historical information in this basin and throughout the company you have devised decision steps and placed a value on them. By calculating the estimated risked value (EV) of the prospect with and without a 3-D survey the Exploration team can establish the "value" of acquiring the survey. When this "value" is positive the team should strongly consider acquiring the survey. If the value is small or negative then the Exploration team should revisit the survey proposal to establish if it still makes business sense.

ABOUT THE AUTHORS

Neil McMahon is a Manager with Arthur D. Little Management Consultants specialising in the Upstream Oil and Gas Industry. Neil's work covers strategy and organisation issues as well as benchmarking key areas of E&P expenditure. Prior to Arthur D. Little, Neil worked as a Geoscientist with British Gas and British Petroleum. He holds BSc (Hons) and PhD Geoscience degrees from the University of Edinburgh.

Steve Slawson received a MSc in Electrical Engineering from the University of Houston, where he studied high- frequency wave propagation and scattering. He joined Shell Development full-time in 1989 and worked as a Research Geophysicist developing gravity and magnetic software applications with signal processing and multi-dimensional modelling and graphical capabilities. Steve then transferred to Shell Western as a 3-D Geophysicist responsible for designing, planning, supervising and processing proprietary 3-D seismic surveys. In late 1993, Steve joined Energy Innovations as a Senior Geophysicist responsible for 3-D surveys around the world. In 1994, he co-founded Energy Innovations Technical Services and served as Vice President of Technical Services until 1998. In 1999, the Energy Innovations Group merged with Walden Visualization Systems to form Continuum Resources and Steve currently serves as the Director of Upstream Oil and Gas Ventures.

Kees Ruitenbeek holds a degree in Electrical Engineering (1981) and a PhD in Technical Sciences (1985), both from Delft University of Technology. He joined Royal Dutch/Shell in 1985 as a Research Geophysicist with KSEPL. After various assignments in Libya, Angola and Gabon, Kees joined Petroleum Development Oman in November 1996 as Geophysical Manager. On 1 January, 1998, he took over from Peter Nederlof as Secretary General of GEO '98 and as a member of the Editorial Advisory Board of GeoArabia. Since 1998, he is PDO's Asset Manager GeoSolutions.

Jan Wams graduated in 1975 from the University of Delft in Medical Acoustics. He was drafted into the Dutch Army in early 1976 where he researched laser- and night-vision equipment. Jan joined Shell in 1978 and shortly after was transferred to the UK to take up a position in seismic data processing, followed by postings in Thailand and Brunei as a Seismic Interpreter. Jan was transferred back to Holland in 1988 to head the Land Acquisition group, followed by a posting to Yemen as Chief Geophysicist. After a further year in Holland as an Advisor on acquisition matters, he joined PDO in 1993 to head the geophysical operations department. In November 1998, he was transferred to Argentina in order to coordinate Shell Capsa's Geophysical activities.

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