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Onshore Future-Seismic Here Today.

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Summary

In future, geophysicists involved in land exploration will regard this era as one of the most exciting in the whole history of the science. They will see how the challenge of ever more difficult to locate hydrocarbons was met with a new explosion in imagination and techniques. The period will be regarded as an example to other practical fields of physics in how to use advances in technology for the betterment of all mankind. It will be seen as a renaissance in the science and engineering of one of the world's most important endeavours - the search for energy.

Thus, science historians of future decades will not only focus on the increase in tangible reserves initiated by this era but also on how it was made possible by better use of developments often made in other branches of endeavour. But more than anything, this period will be identified as one when the industry was placed on a more secure footing - when it demonstrated its ability and commitment to adopt practices which would help to meet the world's hydrocarbon requirements of many more decades.

Introduction

Given the importance of the commodity for which this industry explores, its record in making use of new technologies to improve performance and success rate has been rather poor. From time to time, almost every business finds it necessary to make compromises to get the job done but in exploration, too often we have had to compromise too much.

We undertake 2D surveys where we could have done - and ought to have done - 3Ds. We limit offset and azimuth ranges where it is inappropriate. We take HSE risks where we should not. We deliberately plan under-sampled and aliased 3Ds instead of appropriately sampled 3Ds - and so on. We do it in the name of cost or equipment limitations but much of the blame for our poor performance often simply lies with our not having kept up with new technological capabilities which, if used, would have meant the such drastic compromises would not have to have been made.

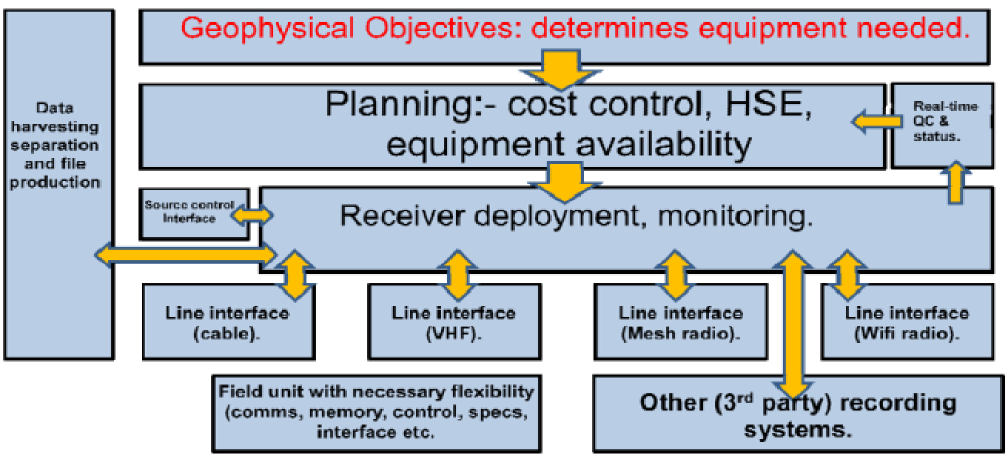

Figure 1. General purpose recording system architecture suited to wavefield recording.

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Geobody average velocity estimation

The background velocity was estimated during preSDM iterative velocity model update, and the velocity associated with the low-velocity geobody was estimated in

For example, the exploration business was rather slow to adopt the use of PC technology in the 1980's, in many cases thinking them little more than toys, yet they brought new flexibility to the field allowing better exploration decisions to be made there and then. They allowed data quality to improve.

And we do not need just to look at larger pieces of hardware to see where this industry has been slow on the uptake; at the level of making better use of individual electronics subsystems and components, such as analogue to digital convertors and chip-sized wireless communication capabilities, whereas other industries are quick to change, our industry has lagged behind. Even at the level of entire sets of crew equipment, 25 years ago explorationists stated that they thought seismic cables were a major hindrance. Now a quarter century on, still more than 80% of all exploration is undertaken with cables.

In exploration, where innovations come from large companies, adoption tends to be quick. But the breakthroughs from smaller organisations take much longer to bring advantage to our industry, even though history indicates that most game- changing inventions come from smaller companies. This slow adoption of technologies which can improve our business is a waste of resources. This had to change and it is at last beginning to do so.

Method

Exploration geophysics is practical branch of science in which we perform "experiments" - taking measurements and making predictions. We may call this "seismic surveying" but just like most other branches of applied physics, our experiments are confined in one or more ways by the measuring apparatus which normally places limits on the accuracy or range of data we are able to record. A simple analogy well known to astrophysicists is that their recording equipment, perhaps an optical telescope, is strongly affected by the size and quality of its optics. But additionally, and independent of optical quality, the measurements a telescope can make are also limited by where it can be placed, which is why the best ones are sited on tops of mountains or even in Earth orbit. Some of these analogies apply to measuring equipment used in seismic surveying.

The most common experiments carried out in our field tend to be the acquisition of seismic data either from passive or active sources. Much attention is directed into making sure our transducers and recording equipment are able to capture many attributes of the signal of interest with minimal distortion, perhaps with most attention being applied to covering the necessary range of signal frequencies, phase and amplitudes. We would instantly understand that any piece of hardware which imposed severe limits on such attributes might be considered imperfect and a significant source of compromise to our experiments and their interpretation. And where we perform active exploration recording, we additionally need carefully to control and monitor the energy we put into the ground.

The progress of our science is thus greatly determined by the range, accuracy and flexibility of source control and recording equipment to perform the experiments we want undertake. The corollary to this is that when our hardware is not capable of providing the necessary functionality, then the geophysics we perform must suffer, as must the decisions we make based on our experiments' results.

Until recently, geophysicists have tended to be tempted into believing (perhaps sometimes subconsciously) that the recordings they needed to undertake revolved around the idea of attaining sufficient samples, called fold, about some locations of interest under the Earth's surface at some common points approximately midway between a controlled source and some appropriate receivers. Assuming the recording hardware accurately recorded a signal's frequency, phase and amplitude characteristics, then it was only a matter of gathering enough sample points for data quality to be good enough such that "successful experiments" can be claimed to have been undertaken. As equipment suppliers also perceived the science in these terms, they built hardware suited to this task, which became known as CMP recording.

However, recently geophysicists have realised that much more ought to be experimentally possible. Firstly, they have seen that it is very desirable and advantageous to be able to change and then monitor the way in which sources put energy into the ground, in other words to control the injected wavefield. Next, they also have started to appreciate that CMP fold acquisition may be how commonly available seismic instruments force their recording to be considered, but working this way omits a lot of detail about the subsurface points which would be very helpful to acquire. They know that they would like also to gather information which is scattered off these points at a greater range of angles and distances. They also may want to record the injected wavefield reflections in much higher densities of receivers in all directions on the Earth's surface to avoid the contamination of data by noise or an "acquisition footprint". Some want to consider the recording of not just pressure waves but also shear waves, and so on.

In other words, knowing that no technology yet exists which can cost-effectively do it all, explorationists want to be able to decide which bits of information about the wavefield their recording systems should preferentially capture, recognising that each subset of available-to-record data carries something useful which the others may not. They know that one piece of information may have value suited to one type of experiment, whereas a different type of recorded data provides important detail relevant to some other part of the experiment. As our business does different types of experiments for different business purposes, it is useful to be able to adapt the hardware to the business purpose rather than having to have multiple sets of very different instrumentation.

Thus there is an understanding that it is not just a matter of recording frequencies, phases and amplitudes with sufficient precision but other characteristics of the wavefield too. However, given that instrumentation limits what can be done and imposes comprises in cost or safety, experiment designers (sometimes known as "geophysicists") want to be able to configure instrumentation for one or more specific wavefield-recording oriented purposes, rather than just be forced to use a device designed primarily for CMP recording.

Fortunately, the industry has developed and is now making available a wider range of hardware which has been designed around the idea of flexible wavefield generation and acquisition. Such systems, for the first time, are adaptable to the multitude of ways in which equipment must be deployed and deployable to cover such a disparate range of seismic experiments.

The major change has been the need to develop equipment as a series of parts which can be configured and combined in different ways (so making it "general purpose") rather than the tightly integrated, immutable systems of the past which allowed good CMP-type acquisition but were much less suited to the varieties of recording needed when gathering data from some other aspect(s) of the wavefield. This also includes far more flexible source control equipment to cover ever better simultaneous source acquisition to multi-role cableless active and (occasionally combined) passive acquisition, for both shallow and deep targets.

Until recently there was insufficient choice in hardware to allow such variety. Now there is not only increasing choice, but just as important - willingness and a growing realisation of how to use it. Hardware is at last available which lets geophysicists indulge their imaginations to take on almost any survey type they can dream up. They only need to understand how each piece of equipment works and how it can be used with any other pieces of equipment. Thus, operators have the ability to customise their operations by picking and mixing the functionality they need for each survey. For those who learn to perform more than one "experiment" at a time, multiple sources and multiple acquisition systems on one operation will in future be the norm. This is future-seismic, it can change this industry and it has already begun to happen.

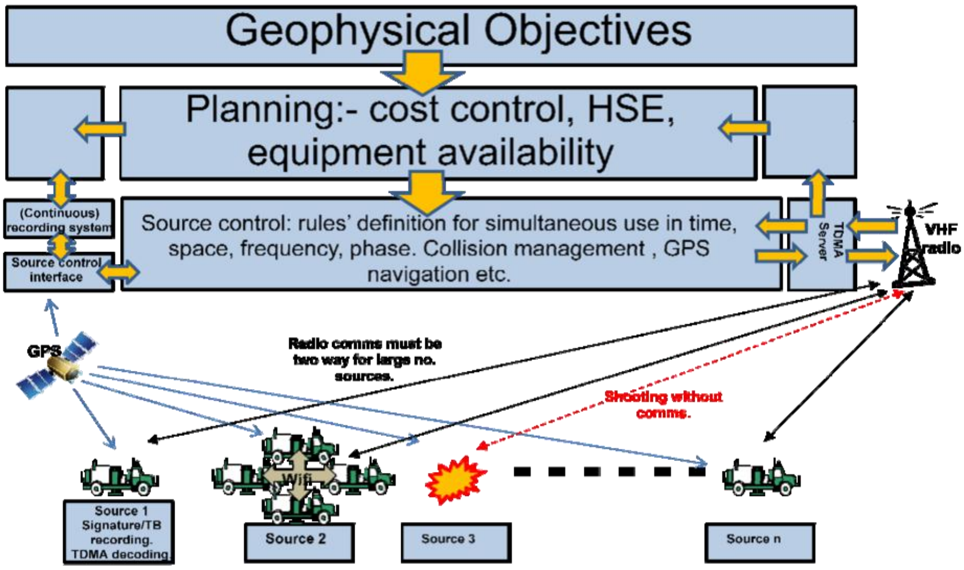

Figure 2: General purpose source control system architecture suited to wavefield recording.

Conclusions

As has always been the case, new hardware flexibility is vital if this industry is to progress. And equipment versatility is important to every country: India may not be considered the largest market for geophysical services globally but it can lay claim to being one with the widest range of requirements. This covers oil and gas traditional 2D/3D surveys, micro-seismics, gas injection, dam monitoring, mining, coal/CBM and passive work.

This paper considers what thinking, philosophies and engineering made these historic changes possible and concludes that the industry can now perform better "experiments" unrestricted by hardware limitations or design assumptions.

It looks at examples of how to switch from the idea of CMP fold recording to wavefield acquisition via the use of general purpose, universal "loose integration" systems and source controllers (Figures 1 & 2), and how this can translate into much improved hydrocarbon exploration success. It also covers some advice on how to make the best use of what is now becoming available.

Finally, this paper reviews what is now possible in terms of technology and technique, and the research scheduled for the next few years, describing how it could change the face of Indian exploration and increase tangible reserves.

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