What's New in The Rapidly Changing Face of Land Seismic Instrumentation

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At the recent SEG Convention in San Antonio, Texas, there were half a dozen different land seismic instruments which claimed as one of their main benefits the ability to work without digital spread cables. There is nothing novel in the notion of a wireless seismic recorder but there is something special about these latest cable–free products, and some of them have already made an impact. They will certainly benefit the Indians exploration industry.

Most of these latest systems claim to be designed for a new-era of land acquisition in which there is a major trend to far lower costs, HSE exposure is much reduced and channel counts can easily sore to five or even six figures. At least one manufacturer seems to believe that by 2010, half of all land channels sold could be cable-free. However, neither exaggeration nor wishful thinking are new to seismic equipment marketing so, before there is a rush to discard all

Central America. Drilling on the first ever discovery of a new-era cable-free system.

Central Europe. Side-by-side use of new-era cable-free system and land cable system.

existing cabled hardware, we should take a closer look at what actually is happening.

Cable land seismic systems

Digital cable telemetry systems first hit the market in 1979. We are now almost thirty years on so no one can deny the long run of success enjoyed by this technology; in many ways it is what made 3D acquisition viable on land. But most technologies do not survive three decades without giving way to new ways of doing things, at least at some level, and cabled systems look like being no exception. Cable-free hardware is already being used in anger so, even if cable telemetry dominates another five years, no one can claim that cable did not get a good run for its money. It should receive our eternal gratitude for how far it brought onshore exploration before we pass the batten of land geophysics on to something more up-to-date.

So what has made this most conservative of industries reconsider its acquisition options? In my view, responsibility (blame or credit, depending on your position) for the move to "newera cable-free" rests mostly with the oil companies themselves. In the past, I feel that system producers rather than the data end-users have mostly been responsible for development decisions in acquisition hardware, with some manufacturers apparently paying little more than lip service to what oil companies wanted. In some respects this is quite reasonable because no hardware company that I know of operates as a charity. Therefore, design choices are, more often than not, made of course with profits in mind rather than what may necessarily allow progress in acquisition geophysics - an industry where it has long been safer to create a minor variation on an established theme than to write a whole new symphony. For some while there has only been very little variety on Central Europe. Side-by-side use of new-era cable-free system and land cable system. offer as to the way we acquire land data - there seems to have been much greater choice in margarine than options in land instrumentation. It was not a situation which could persevere for ever.

In the mid-late nineties, data end-users at workshops and conventions, started to exercise their collective muscle and suggested that recording hardware needed to experience a quantum leap. In-the-know oil company geophysicists, slowly at first, then more vocally, demanded to know why the technology we regularly take for granted in digital cameras and mobile phones should not be used to help us record land seismic data at much lower cost, with very many more channels and less harm to the environment. There was a feeling that land instrumentation should be more Wallmart than Wall Street, the sort of thing you might even find one day on eBay.

Cable systems were never going to be able to take such a giant leap for seismic-kind because some considered

Deploying new-era cable-free equipment in rain forest.

them already almost as perfected as they are going to get after thirty years. As Hamlet put it, they were "hoist by their own petar"; the very ubiquity of cables demonstrated its shortcomings better than alternative technologies had been successful in pointing out its weaknesses when cable systems are sometimes stretched inappropriately into the modern acquisition era. One major cable technology short-coming Deploying new-era cable-free equipment in rain forest. is the problem as channel counts rise to many thousands.

Historically, it was of course digital cable telemetry which started to make possible the transport of very much more data down one twisted pair than analog transmission permitted. Products such as Texas Instruments' DFS5 used a couple of conductors to pass data from only one geophone trace, a data rate in modern terms we may think of in round figures as 10 kbits/second. The latest cable systems send one thousand times this much data down one twisted pair - but that's the problem. The laws of physics in general, and transmission theory in particular, both elicit a price for this. This price is in terms of cables, forced to transfer very high frequency data, can become increasingly susceptible to small physical damage making problems for the flow of high rate digital information which, if the frequency had remained lower, would make no difference at all.

Total system weight is another issue regularly highlighted by oil companies as something which increases

the cost per channel of operations. The telemetry cable itself makes up perhaps three quarters of system-specific weight and this is very difficult to reduce since that would mean making the cable weaker or taking away some conductor pairs. Both of these are the opposite of what we need when thinking of improved HSE or large channel count acquisition. An extra nail in cable's coffin is that they have to be joined by digital connectors, all of which must work well for the spread to operate and, as channel counts try inexorably to increase, the issue of serial dependency then looms large too.

This is not to say that cable systems do not claim to be able to operate within range of some of the channel counts now being discussed. Specifications of some cable products claim that they will work with tens of thousand of channels - and well they may though no one has tried it. However, since some recent geophysical papers speak about the need for anything from fifty thousand to three million channels per crew, then almost by their own admission, cable systems will not solve these problems.

So given that there are now tried and tested alternatives, it is now reasonable to ask the question whether cable is any longer either the most appropriate or only way to grow in an industry otherwise much changed from the late seventies. When there was no technological alternative to cable, then one could understand the reticence to start the move away but with all the new cable-free products, then we may consider that cable may at least be reaching the autumn of its years for some applications. Not everyone will want tens or hundreds of thousands of channels on each crew, but if new technology can achieve this for an acceptable economic and environmental price, then think how much benefit it will also bring to smaller operations.

Cable-free variety

Modern cable-free hardware comes in two broad categories and, out of the six systems mentioned above, three fall into each camp. The first includes those which store all data in local memory for later harvesting - sending nothing at all back by radio, not even a status byte. This is a "shoot blind" approach but this characteristic endows such products with the massive advantage of being by far the lowest cost to buy and to operate. Secondly, there is hardware which sends something back over some period of time over some distance. Currently none in this latter category seem capable of high data-rate sustained throughput in all seismic environments from more than a rather limited number of channels, and then at relatively high cost. You will not yet find this in the text books on seismic instrumentation but given the recent arrival of this new-era philosophy to the industry, I would like to suggest a relationship which covers the current engineering and commercial issues in operating with any the cable-free technology.

When a value is assigned between 1 and 10 to each of the following five characteristics and then the product taken, you arrive at a figure between 1 and 100,000 which in some way represents the difficulty of getting any cable-free system to work in a particular acquisition environment. Strictly speaking, this derived value would have somewhat strange units but we may as well think of it in terms of cost, and the higher this value, the greater the cost.

The Cable-free Equation

Attach value between 0 and 10 for *i, ii, iii, iv and v.*

i = how much data to be transmitted

ii = how quickly

iii = from how far away

iv = weight per channel

v = serial reliability of any part of the process

Cost factor to buy and operate crew:-

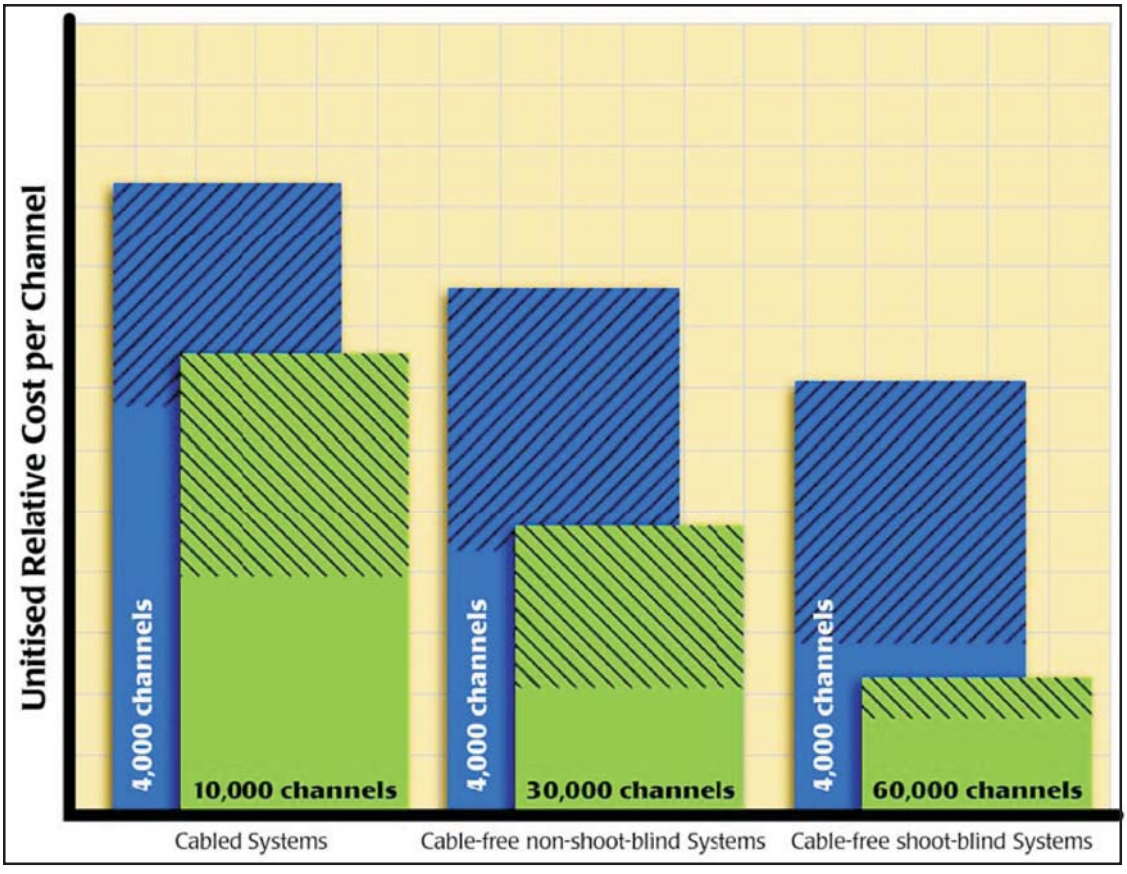
$$0 \leq i \bullet ii \bullet iii \bullet iv \bullet v \leq 100{,}000$$

The Cable-free Equation, showing relationship between cost and various features of new-era cable-free systems.

The five characteristics are: (i) how much data, i.e how many channels and whether the full record or just status, (ii) how quickly, i.e data rate, (iii) from how far away, i.e the farthest channels, (iv) the weight per channel for any particular operation and (v) the serial reliability of any part of the transmission process. They are multiplicative because they can each affect the other. The lower the product, the more channels it is likely to be able to afford to buy and to use.

Shoot-blind systems are easiest to deal with because their factor for characteristic (i) is zero, and thus the product zero too. Cable systems can also be partially considered in this equation and do well as long as the amount of data is not overstretched. In other words channel count, weight and serial reliability must be kept reasonable - as they are for crews with just a few thousand channels. For non-shootblind cable-free systems, even a small data packet or short range transmission poses problems because it means the introduction of some form of transmitter and associated circuitry inside each box. This in turn means greater complexity, power consumption and weight, which translates into higher cost to buy and to operate, and thus a high derived value - the exact opposite of what this industry wants cable-free to achieve. Nevertheless, even cable-free systems which do send something back (depending on technology) may well offer advantages over a cable system. In either case, nothing approaches the cost-to-use which shoot-blind cable-free offers.

One advantage which cable systems are still seen as having over cable-free is that they offer realtime data from the entire connected spread for purposes of data quality control. If this is just to provide a means of supporting instant quality



Incremental cost per channel to use any particular acquisition system type. It is now possible to mix technologies from both ends of this spectrum to get the best of all worlds for land exploration.

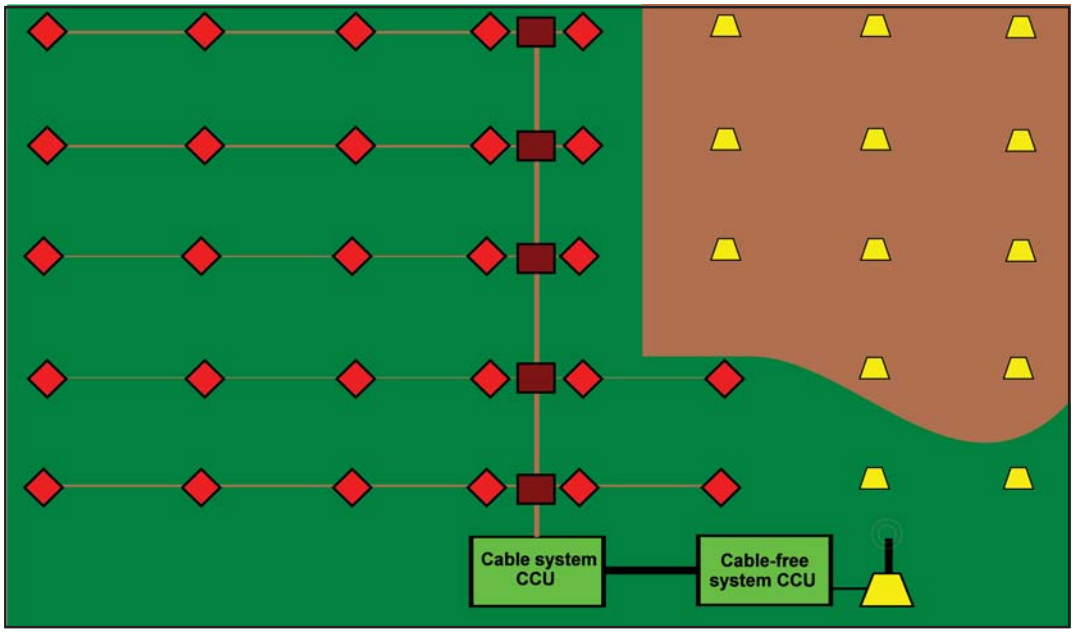
control checking of channels and sensors, then how important is this when such hardware nowadays tends to show incredible reliability? Another function provided by realtime checking is that it allows the observer to know quickly if sensors or ground units are not where and how they were deployed. But is laying 100 km of fragile and expensive cable still the best use of manpower to achieve this end? The real question to ask is: if the technology which lets us perform these QC feats automatically reduces the number of affordable channels - and thus increases HSE exposure and reduces the data quality of a final section - then are we now looking at a choice between data quality or data quality control? It cable-free shoot-blind channels really are now as low cost (to buy and to use) compared to all other technologies as the above equation indicates, then this is a discussion which the industry must undertake with some urgency.

However, no matter how one considers the necessity of realtime QC of each trace, where cable systems do still come out on top is their ability to monitor spread noise in real time, alerting the observer of when it may be necessary to stop acquisition. So does this mean that we have to stick with expensive systems after all, just to keep a noise monitoring function?

This is to make the situation too black and white because the reality is that we would like not to have to limit ourselves to a stark choice between high tec costly cabled hardware or simple low-cost cable-free. We ought to be able to choose functionality from both ends of the cost and technology spectra to suit any acquisition application. This would require shoot-blind cable-free systems to be able to work side-by-side cabled systems. And this is exactly what at least one of these new-era systems has been designed to do, permitting seamless integration of the two technologies enabling a sort of hybrid exploration to take place. So how did this new era start?

The birth of new-era cable-free acquisition technology.

The world's first new-era cable-free system was brought to life by the mid-size US oil company Aspect Energy in 2001. Unhappy with the cost and risk of cable-based acquisition, Aspect put their money where their mouth was, and through the subsidiary Ascend Geo, started work on a new type of seismic system. From the beginning, Aspect had various needs in mind but they can be summed up with thoughts of: many more affordable channels, much lower operating costs, greater flexibility and less environmental exposure. They came to the conclusion that shoot-blind cable-free hardware, appropriately deployed, would be the only one able to fit the bill.



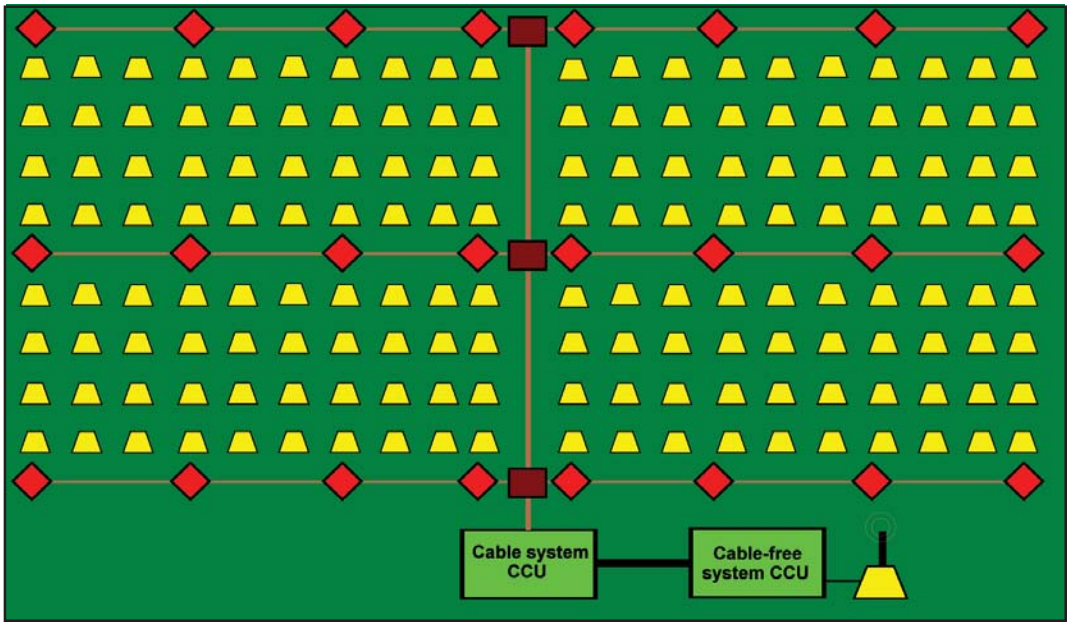
Side-by-side use of cable-free and cable systems.

After a few versions of systems which only saw life in the workshop, the third generation "Ultra" system was sent to Central America in 2004 to replace a cable instrument. Operators found that this cable-free hardware could be deployed at twice the spatial density of the cable system for around the same crew effort. Since the system had not been in the field before and considering the rainy season of this area, this was definitely being thrown in at the deep end. Nevertheless, the use of this revolutionary technology resulted in the first oil discovery in that country after 50 dry holes suffered by some of the majors.

This was also first ever exploration success for a new-era, shoot-blind, cable-free system. Since then, further generations of the same cable-free system in stand-alone mode have been deployed in various countries including Belize, resulting in six more discovery wells and an expanded programme reaching into Guatemala is planned. It has also been used side-by-side cabled systems in North America and Europe, for 2D, 3D and 3C/9C. As the system enjoys wider spread use, it evolves further with the introduction of new features specific to this type of acquisition.

Seamless integration

If the undisputed raison d'etre of cabled systems is now just their ability to look at noise in real time while shoot-blind cable-free systems offer the lowest cost to buy and to



Seamlessly integrated cable-free and cable channels in ratio of about 10:1 to provide best of al worlds approach for oil companies.

operate, then these are the natural technologies to integrate together. Cable-free can be used on parts of the survey where it would be difficult or impossible to use cabled systems. We can also combine these different types of hardware across the entire spread at some ratio of channels which enables enough noise monitoring to take place, while simultaneously acquiring better spatial sampled data than could ever be afforded with cable systems alone. In some places, such as the Middle East, this ratio of cable-free to cabled may be 20:1 whereas in others it may just be 2:1.

This integration philosophy also gives rise to the idea that we should not only look at the cost of a specific crew but also the incremental cost of adding cable-free channels to it. Perhaps mathematically we could say that a cabled system of x channels may cost $y to operate. With 2x cable channels is may be $z (z > y), but with x cabled channels and x cablefree channels the cost would be less than $z, and possibly by a large figure.

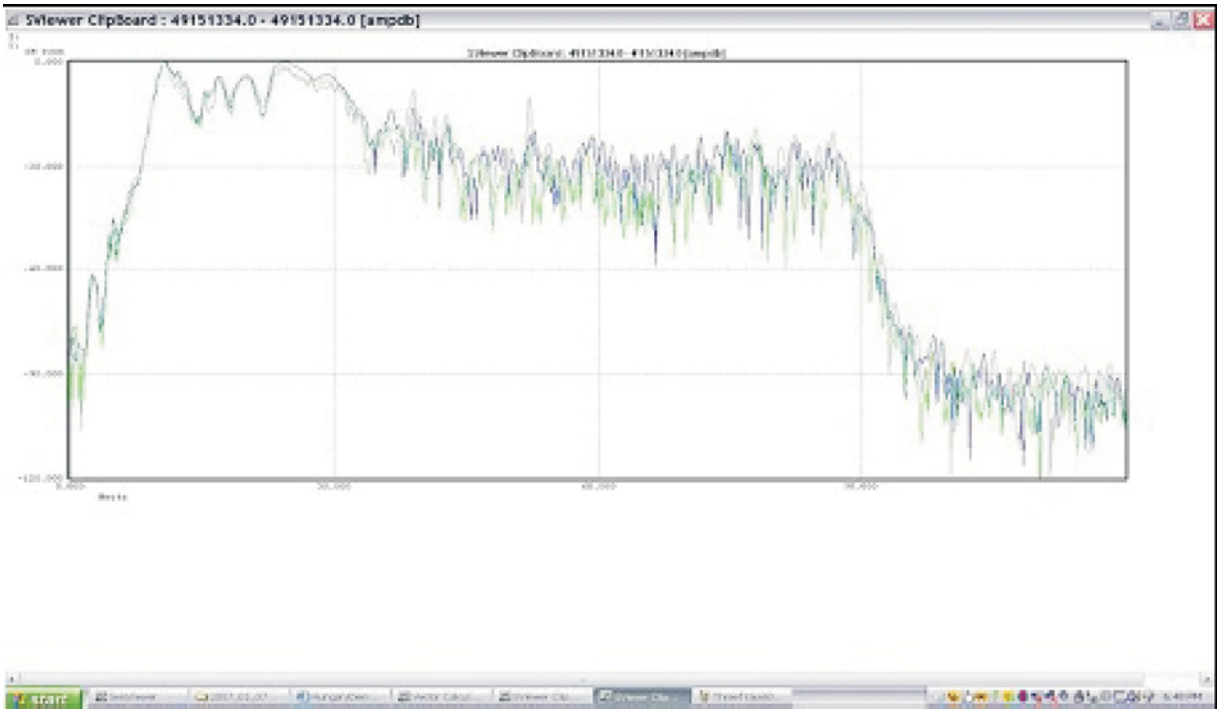
Cable-free is also breathing new life in to analog geophones, saving significant costs to crew operations at the same time as providing higher quality data. Deployed as smaller arrays connected to many more cable-free channels than was affordable in the past, crews are deploying a higher number of actual seismic traces but using no more geophones since strings can be half the length and with half the elements used previously. This gives the benefit of better spatial sampling along with the advantages of a hardwired array, perhaps at no increase in operational cost.

Finally, by doing away with the problems of laying easily damaged cable, cable-free systems also have found applications in passive acquisition. Going against policies which have been in place for twenty or more years, some oil companies are now so keen to reap the benefits of this new way of acquiring data that they are currently considering buying their own cable-free hardware to permit much lower cost 4D and other forms of on-shore permanent monitoring.

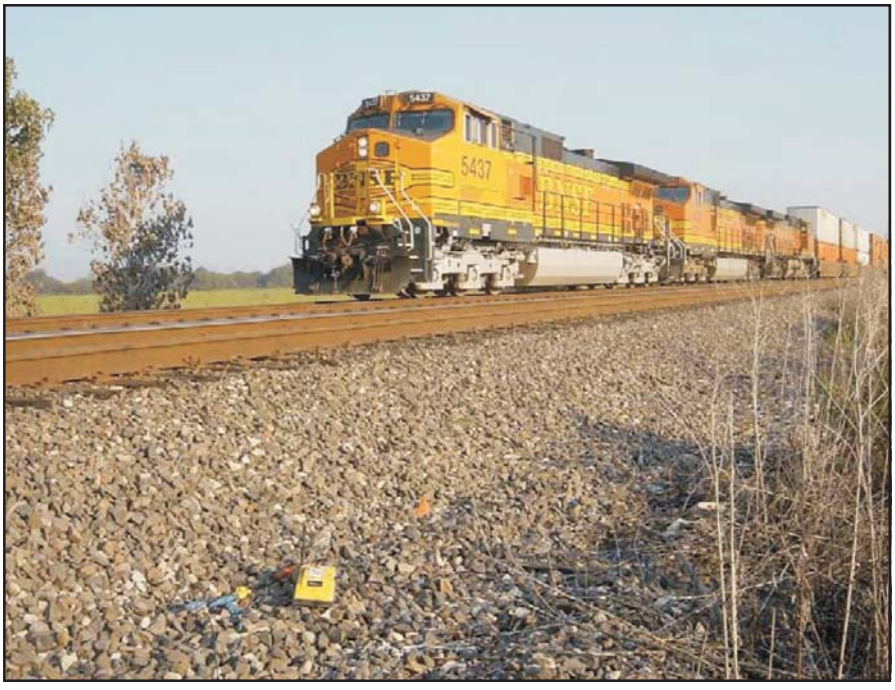
Conclusion

Cable-free systems, with or without oil at $100/barrel, have breathed new life into land seismic instrumentation and provide choices to end-users which they have not enjoyed before.

The idea that cable-free technology offers much better productivity has been tested by at least two of these new era systems, one with a large number of channels in a limited range of environments over a short period of time, and the other system occupying the other end of the employment spectrum by having been used with fewer channels but in many more locations and over a period of three years, for 2D, 3D and multi-component. Both systems report very significantly improved productivity rates - increases far



Data from Ultra cable-free and cabled systems seamlessly integrated. Blue trace: 18 geophones attached to cabled system making 50m array with 50m trace interval. Green trace: 12 phone array over 50m attached to cable-free system with 50m trace interval. Grey trace: 3 phone array of 4m length attached to cable-free system with 50m trace interval.



Ascend Geo Ultra G5 deployed for passive seismic profiling, using freight train as source.

beyond what it seems possible for cable systems to be able to offer on their own in the future.

But while cables offer functionality which we have not yet learnt to do without or which non-shootblind cable-free systems can only replicate at high cost, the next step for this industry will be to make more use of the simplest of technologies along with the most complex for the best of all worlds. In fact, this is not the future of land seismic, it has already begun.