SOURCE MANAGEMENT

IN THE MODERN ERA

How advances in digital technologies are delivering smarter and more productive vibroseis, with advanced signal data quality

SERCEL
A Viridien Business

Since the 1950s, vibroseis has been used as a reliable means of performing on-land seismic reflection data acquisition. Throughout that period, the principles of vibroseis have remained mostly consistent: a vibrator, often truck-mounted, is used to inject vibrations into the earth, generating a controlled wavetrain for a specific duration and comprising a sweep of frequencies. This data is then combined and compared with the source input signals to produce a seismic section which provides valuable information for processes like oil and gas exploration.

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INTRODUCTION

While vibroseis as a concept is well understood, recent advances in mechanical vibrators, digital recorders and correlator stackers, along with the advent of real-time satellite positioning (GPS), means that the technique can now deliver far better signal quality. It can also be performed at far higher levels of consistency and productivity during field operations. These advances are leading to the emergence of new approaches to land data acquisition, allowing geophysicists to identify subsurface anomalies and more accurately predict where oil and gas might be trapped.

Vibroseis, then, remains an important seismic method. This whitepaper provides a historical perspective of its development, before identifying several technological advances which have led to the refinement of the technique. It also takes a view of the future, looking at how automation of seismic sources might be applied as an enabler of higher productivity vibroseis.

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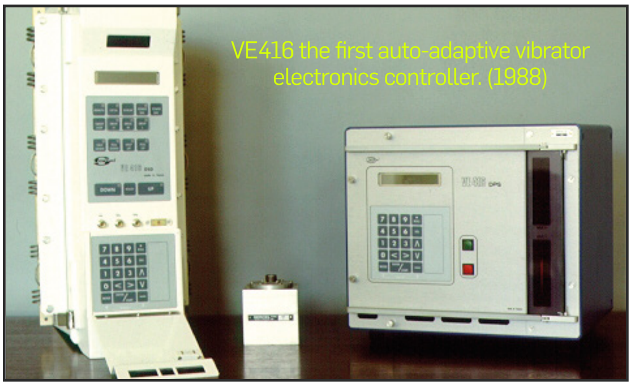
VIBROSEIS: **A HISTORICAL PERSPECTIVE**

Land vibroseis is widely recognised as a flexible and scalable method of land data acquisition. It is particularly suitable for use with simultaneous sources, with large numbers of vibrators being set to work in unison to provide the source input. From here, the emitted signals can be parameterized to allow for the completion of multiple sweeps as well as variable start times, making it possible to extract the contribution from each of the sources.



VE416 the first auto-adaptive vibrator electronics controller. (1988)

Correlation stacking unit, the first to give accurate real-time correlation. (1981)

This approach has proved highly scalable in recent years, with advances in digital technologies making it possible to operate multiple fleets of vibrators in real-time over vast distances. As a result, there has been a sharp increase in land seismic crew productivity, with crews operating as many as 50 vibrators simultaneously in open terrain. The number of Vibration Points (VPs) has subsequently risen dramatically, from around several hundred VPs/day to more than 32,000 VPs/day, in some cases.

However, development of such high productivity vibroseis methods has not happened overnight: it is, in fact, the result of numerous incremental advances in technology, achieved over several decades. For example, the early 1980s saw the introduction of simultaneous sweeping, built on the use of field correlator stackers comprising several hundred CPUs assembled into a large card for channel processing.

The mid-1980s-early 1990s, meanwhile, saw the introduction of digital vibrator electronics capable of phase and force control, leading to the first 3D acquisitions using phase-encoded high-production vibroseis. The capabilities of field correlator stackers continued to improve, thanks to the ability of processors to correlate in the frequency domain, making it possible to handle the increasing number of channels available.

In the late 1990s, GPS positioning was integrated for quality control purposes, and to allow the management of different fleets of vibrators in alternate or simultaneous modes. Real-time differential satellite positioning and reliable WiFi/radio communications meant networked vibrator fleets could be set up more quickly and accurately, and over longer distances.

More recently, the focus has been on the continued refinement of systems and technologies to improve productivity. This progression has seen the introduction of lighter and more intuitive recording systems which can be deployed and activated in shorter timeframes. Computational power and memory advances have seen a dramatic increase in channel count. Also, synchronization of the recorder and the vibrators by GPS timing has led to performance improvements. Radio transmission suddenly became digital, multiplexed and synchronous, and this had the effect of increasing the number of vibrator fleets that could be managed by a single radio frequency, boosting transmission range and flexibility.

Sercel announces the VE432, the 32-bit full digital vibrator control electronics. (1997)

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MODERN VIBROSEIS **TECHNOLOGY SOLUTIONS**

It is clear, then, that vibroseis techniques have undergone many advances over the past few decades, with the combination of vibrators and vibrator electronics resulting in better capability and productivity, which has reduced operational expenses while increasing the quality of the generated signal. But, where exactly do we stand now? What type of performance can the oil and gas sector expect from the most advanced systems on the market?

Firstly, it is worth looking at the vibrator, which has emerged as the primary source of choice for large land seismic surveys, when the terrain will permit. This equipment is used to transmit energy into the ground via a baseplate held in place by the weight of the vehicle and decoupled from it by airbags. Above the baseplate a reaction mass, typically between 3500 and 7000 kg, is hydraulically driven up and down, transmitting a signal into the earth.

Only about half of the seismic crews worldwide are equipped with vibrators, but it is estimated that these crews produce more than three-quarters of the seismic records. Such performance is related to the high source productivity made possible by using several fleets of vibrators sweeping alternatively and/or simultaneously. More than often these fleets are composed of a few large vibrators of 60,000 lbf or more hydraulic peak force like Sercel Nomad-65.

Indeed, the Nomad 65 has emerged as one of the most popular heavy vibrators in the world. Recently it has been enhanced with the launch of the Nomad 65 Neo - an all-terrain broadband version that features new mechanical and hydraulic components and a shaker redesign, meaning it is capable of delivering stronger low-frequency content with full drive achieved from 5.4Hz. Another newly developed feature of the Nomad 65 Neo is an Intelligent Power Management system, which through optimized engine efficiency reduces fuel consumption by up to 15%. As well as getting smarter, vibrators have also been getting heavier. The super-heavy Nomad 90, for instance, has a highest peak force of 90,000 lbf, combined with an ultra-stiff baseplate to improve high-frequency signal fidelity. Main options across the Nomad range include a central tyre inflation system, rear cameras, soundproof cover, centralised greasing system and tracks.

While the vibrator provides the brawn, it is the vibrator electronics that acts as the brain when vibroseis is taking place. These systems are used to perform a variety of critical functions such as accurately controlling the amplitude and phase of the vibrator ground force along with harmonic distortion.
In recent years, vibrator electronics have become highly optimized to benefit from the latest developments in integration, radio transmission and servo-control. The latest digital control systems can deliver and control signals with higher accuracy and speed, allowing users to implement vibroseis quicker than ever before, with an emphasis on improving productivity and flexibility.
The Sercel VE464 digital control system, for instance, is an advance on the long-established VE416 and VE432 models, bringing several significant benefits to the market. It uses a fully auto-adaptive servomechanism, that enables the use of advanced techniques such as pseudo-random sweeps, multiple simultaneous sources in flip-flop or slip-modes, coded sweeps, cascaded sweeps and custom sweeps. Moreover, an even higher level of flexibility can be achieved through the use of dedicated sweeps by programming a different sweep per vibrator in a given fleet.
Other advantages have come to the fore. Stakeless operations can be achieved with the vibrator capable of being guided by acquisition systems from one pre-planned VP to the next by using the GPS guidance. Improved communication is delivered through the use of an advanced TDMA Radio capability instead of standard VHF transmission. This advance increases the capacities of the system, removing any chance of interference when using more than two fleets in navigation mode, and allowing the use of an increased number of fleets – to a maximum of 100.
Meanwhile, enhanced real-time quality control can be delivered by a complete QC database generated for real-time or post-processing analysis including phase, distortion and fundamental ground force. In addition, digital control identifies the ground viscosity and stiffness, which regularly provides information on the ground absorption model and can be used to enhance seismic data, for example to improve ground velocity model used in FWI processing. Other QC measurements can be sent to the acquisition system in real-time or stored on a local hard disk for further analysis and treatment requested by some acquisition methods.

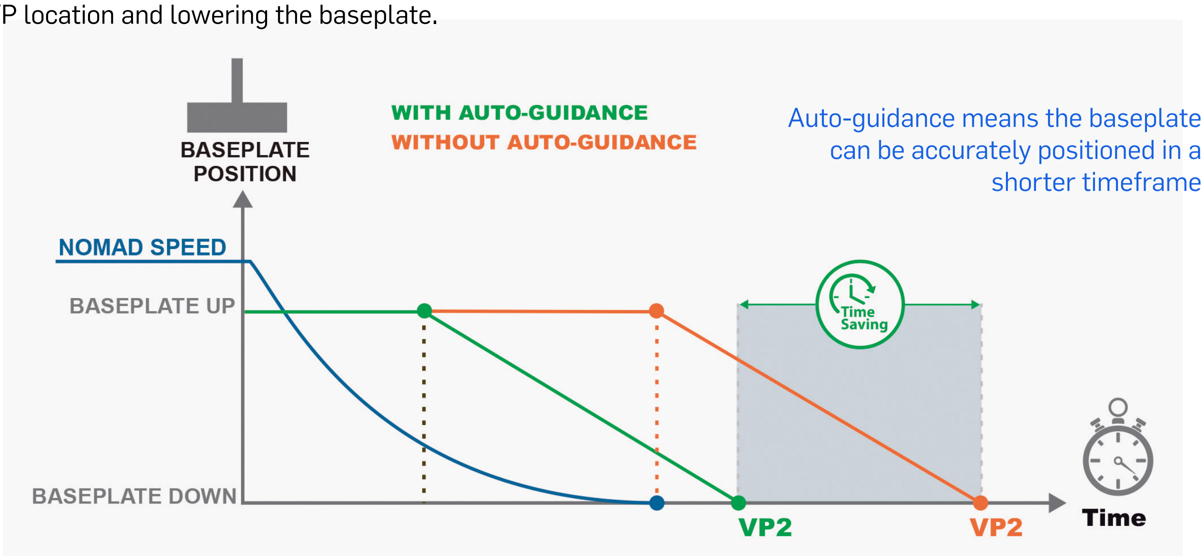
VE464 digital control system

Vibrator autoguidance results in more productive operations

4 TECHNOLOGY DELIVERS IMPROVED PRODUCTIVITY

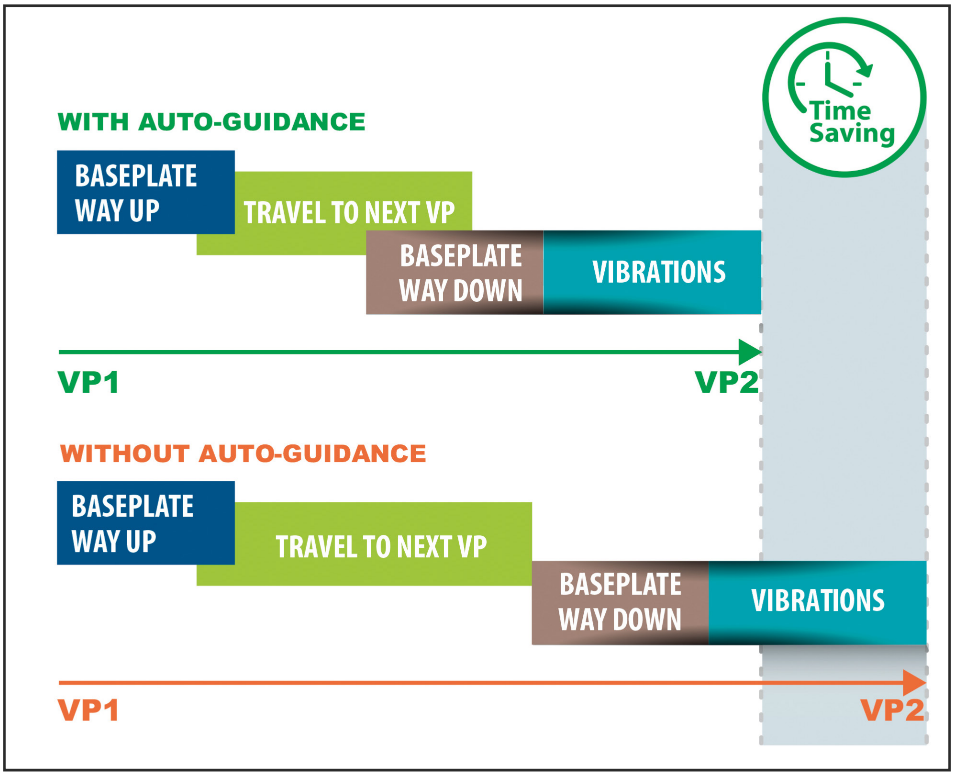
Now let us look in greater detail at some of the latest developments that are delivering significant advances in vibroseis capability, particularly in the areas of higher productivity and smarter management of operational fleets. Recent land acquisition projects are characterized by a trend towards higher trace densities, now recognized as the critical parameter for efficient reservoir analysis. On the source side, higher trace densities are achieved by single vibrators operating with advanced productivity techniques, such as blended shooting. Source productivity is a cost-enabler for these advanced projects, and increased automation is widely considered by many as a solution to meet the productivity objectives and scale down operational expenses.

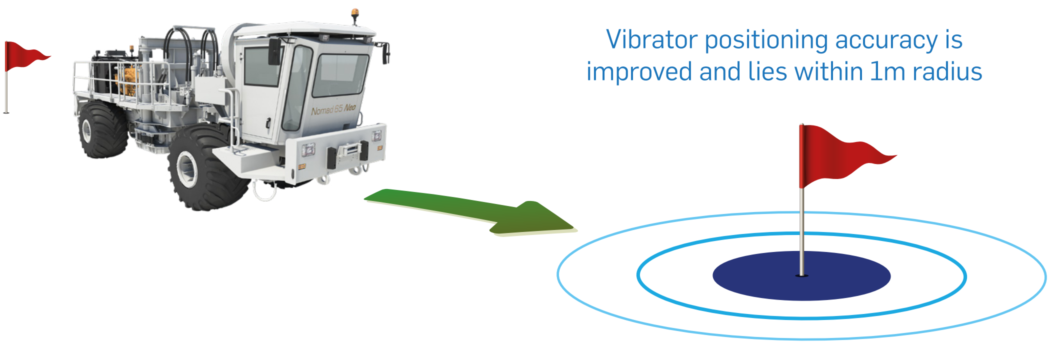
The operation of seismic vibrators can be broken down in four stages. Once a vibration point is completed, a cycle consists of raising the baseplate; travelling to the next VP location; lowering the baseplate; and vibrating. With modern vibroseis equipment, the raising of the baseplate and vibration itself usually have some automation: the vibration is started as soon as the baseplate is down and within positioning tolerances, and the baseplate is raised as soon as the sweep is complete. Now, though, vibrator auto-guidance solutions are addressing the two remaining steps – travelling to the VP location and lowering the baseplate.



When approaching a VP's surveyed position, control is taken over vibrator speed, and the deceleration is optimized to reduce the travel time between VPs. Baseplate lowering is also managed automatically and is activated before the VP location is reached: it can therefore not only be mainly performed in otherwise redundant time, but also allows the "full-up" option to be used rather than the "half-up" option, which reduces the probability of actuator damage due to obstacles. When automated, these two steps offer constant and optimized productivity improvements, as the uncertainties associated with variations in driver performance are removed. The vibrator positioning accuracy is also improved and lies within a 1-m radius, paving the way for a potential reduction of the typical 3-m radius acceptance criterion. The solution has been designed as an add-on, installable in less than an hour on a broad range of vibrators without prior expertise for setup and operation.

Research shows that vibrator auto-guidance can deliver significant advantages. Productivity enhancements of up to 10 per cent have been recorded thanks to optimised travel time between two VPs. Consistent positioning can also deliver better data, while increased automation can also deliver health and safety improvements through speed management and reducing driver fatigue.





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SMART OPERATION **MANAGEMENT**

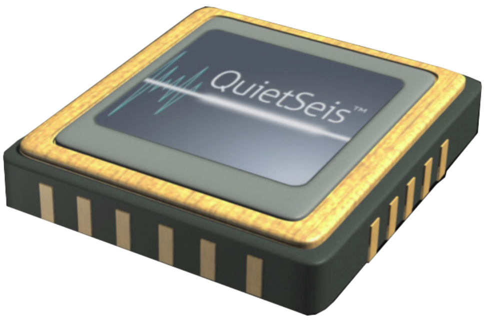
Technology development has also delivered advances in other areas – particularly around smart operation management. These advancements are centred on improving ease-of-use for operators out in the field, with capabilities such as quick/easy set up for single operators, more intuitive user interfaces, improved ergonomics, lighter configuration for smaller surveys and enhanced navigation systems using the latest GPS systems.

The latest generation of data harvesters, for instance, can manage highly effective data exchange between vibrators and recorders, improving the operational efficiency of seismic crews. Designed as mobile solutions delivered on an ergonomic tablet PC, these devices can wirelessly transfer SPS and SEG-D without any production interruption. They come with a Wi-Fi bridge allowing automatic data upload and download up to a distance of 30m. Data can be transferred to servers using a direct connection or, in the case of a 508^{XT} system, through the acquisition line to save time.

IN CONCLUSION

ANALOG TO DIGITAL TREND IS GATHERING PACE

So, then, after almost 15 years on the market, it is fair to say that digital sensors have proven their technical and geophysical effectiveness for seismic applications. This development has led to the introduction of recorders that have been fully optimized for seismic land operations.



For example, a new digital sensor featuring a second-generation QuietSeis MEMS accelerometer – providing a noise level of 15ng/√Hz, some three times lower than previous systems – has been integrated into the DSU1-508, making it the best recorder that Sercel has ever made. This unit is capable of high-density, high-resolution acquisition, and comes with a totally scalable nodal architecture called X-Tech, making it the first system capable of acquiring 1 million channels, with full immunity to statics.

This kind of performance means MEMS-based sensors now exhibit many desirable characteristics that make them the technology of choice across numerous seismic applications. While there's no doubt that, historically, the shift from analog to digital technology has been slow to take place, it is increasingly clear that the momentum behind MEMS deployment is now rapidly gathering pace.

Want to know more?

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