Overall Source Effectiveness: Getting the most out of land source assets

Introduction

Densifying seismic acquisition surveys for a cost that is in line with the benefits expected in terms of improved imaging relies on a dual approach. On the receiver side, the average seismic sensors inventory available on a given project has remained roughly stable over the past decade. The densification relates to the number of recording channels: field digitizers are deployed in greater number and closer together but record individually less sensors. The economic balance behind survey densification relies heavily on the overall source strategy, which includes the number of vibroseis deployed on the project and advanced operating strategies. Large fleets of single, “super-heavy” 80,000 lb vibrators are increasingly being deployed to meet this target, in conjunction with high-productivity shooting methodologies. DS4 (Bouska 2010) and ISS-like (Howe 2008) methodologies have proven to be the most productive and are now common in the Middle East where they deliver 20 to 30 kVPs/day on average. But there is still room for improvement.

As a matter of fact, when an acquisition crew is in place, shooting additional VPs represents a marginal cost but requires extra time windows for shooting. The vibrators, however, remain subject to regular standby while an analysis of their operation demonstrates a clear margin for optimization.

Current technologies offer options for addressing these operational shortcomings: automation is progressively maturing and integrated to optimize seismic sources productivity. Advanced highly efficient shooting strategies which preserve imaging quality are regularly validated across various terrain conditions. Finally, with digitalization, source behavior can be monitored to identify availability and efficiency bottlenecks. In short, this abstract addresses the following question: how can productivity be improved for a given source inventory? The authors herein introduce innovative solutions and demonstrate that both source availability and efficiency can be optimized.

Automation

Agriculture and mining industries have already introduced a noticeable level of automation in field operations that are similar to seismic sources operations. The environment is, however, well known, characterized and controlled, and for larger scale applications than for seismic acquisition – although solutions are starting to emerge for the latter.

An automation quick-win can therefore be easily identified when analyzing a vibrator duty cycle. The operating cycle of seismic vibrators can be broken down into four stages. Once a vibration point n has been completed (VP_n), a cycle consists of 1) Raising the baseplate, 2) Travelling to the VPn+1 location, 3) Lowering baseplate and 4) Vibrating. With modern vibroseis equipment, stages 4) and 1) are usually automated: the vibration is started as soon as the baseplate is lowered and within positioning tolerances, and the baseplate is raised as soon as the sweep is completed (Figure 1).

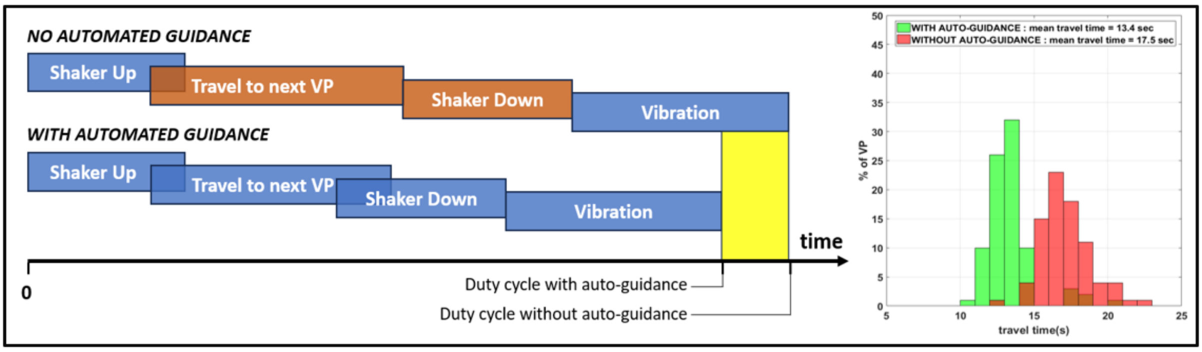

Figure 1 *Schematic view of the production duty cycle of an individual seismic vibrator, without (top left) and with (bottom left) vibrator auto-guidance. Blue stages are automated, orange stages manual. The yellow area represents the timing gain. Productivity gain measured during field test with 12.5 distance between source point (right)*

The Vibrator Auto-Guidance solution addresses the two remaining steps. When the vibrator approaches a VP position, control is taken over its speed and the deceleration is optimized to reduce the travel time between VPs. Baseplate lowering is also managed automatically and activated before the VP location is reached: this action can therefore not only be mainly performed in masked time, but also allows the "full-up" option to be used rather than the "half-up" option, reducing the likelihood of actuator damage due to obstacles in the way. When automated, these two steps offer constant and optimized productivity improvements, as the uncertainties associated with variable driver performance (for example, owing to their experience) are removed. Vibrator positioning accuracy is also improved and lies within a 1-m radius, paving the way for a potential reduction in the typical 3-m radius acceptance criterion. Driver fatigue is reduced, and their skills are mainly required for the most hazardous phases, such as accelerating or turning.

Another powerful way to benefit from automation for seismic sources lies in optimizing their production paths. Progressing "manually" along a predefined path is not only inefficient in terms of productivity, it also implies significant fatigue for drivers when repeating low-value tasks, and hidden OPEX associated with longer-than-necessary vibrator journeys. Figure 2 illustrates an example of vibrator path automation. The terrain is initially surveyed and modelled to account for topography, obstacles, and any exclusion or special regime zone. It is then classified by areas to account for the ability of sources to progress more or less easily. When compared to a conventional guidance, vibrator path optimization enables a source travel time reduction of up to 20 percent in a constrained environment.

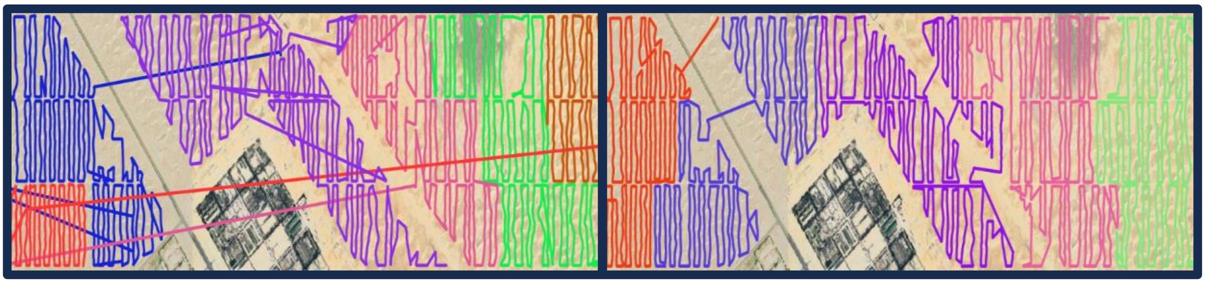

Figure 2 *Vibrator path optimization: shot point distribution of fleets operating on a terrain with obstacles: (Left) Manual progression (Right) Vibrator path optimization with limited detour and travel time.*

Shooting strategies

Progressive seismic source automation offers a powerful way to smooth shooting operations, by leveling out most variations in performance linked to varying terrain and driver skills. Another way of accelerating program completion with similar source assets is to move from standard and widespread shooting methodologies (DS4 & ISS) to new methodologies that enable source asset optimization while preserving seismic data quality.

The first is xDSS (Tellier 2022), which has been developed to optimize the source cycle by reducing overall radio communications. The xDSS, like the ISS, is a decentralized source control management method, which means that transmission of source-ready messages and firing orders are suppressed with a potential gain of multiple seconds in the cycle time. Removing radio dependency also removes several minutes of production standby time that is required daily to maintain functional radio coverage. Unconstrained acquisition methodologies have demonstrated their ability to break productivity records achieved in test environments (Pecholcs 2010) or in production mode: for example, 45000 VPs per day achieved with 35 single vibrators. The xDSS solution offers the possibility of attaining such records by enhancing dataset quality compared to conventional unconstrained methodologies by integrating time/distance management into vibrator electronics. This additional control over time/distance limits shots contamination and facilitates seismic data processing respecting the deblending golden rules: randomness in time and space, and sparseness in the frequency – wavenumber domain.

All acquisition methodologies, even optimized ones, can still achieve production gains by applying Compressive Seismic Imaging (CSI) grid designs which have already been studied and published for many years (Herrmann 2011). This article focuses on the source aspect of the solution and the potential gain in program completion that can be achieved with a CSI source grid design without increasing source assets. The CSI concept, by generation of optimal randomness source and receiver grids, offers the ability to reconstruct signal and preserve image quality with potentially less source efforts compared to conventional grids. Application of CSI requires a specific workflow and strong equipment integration to be smoothly applied in the field and ultimately improve acquisition efficiency. The first step in the workflow is to define the optimal random distribution of the source points taking into account the terrain and imaging objectives: Figure 3 illustrates a simple example with a source effort reduced by a factor of 4 compared to a 25m*25m source point grid. Once the random source grid is available, it has to be applied by the driver and the vibrator without generating drawbacks that can cancel out the expected productivity gains obtained by reducing source points. Moving around a random source point grid is not as intuitive as the square source grid. Drivers need help to follow the optimized path that will reduce their fatigue, avoid U-turns and respect vibrator turning capabilities. These workflow steps are illustrated in steps 3 and 4 in Figure 3. Smooth deployment of CSI methodology can be facilitated thanks to a specific offering including CSI grid designs, optimized vibrator paths taking into account vibrator displacement constraints and fully integrated management by the recorder, vibrator electronics and guidance systems.

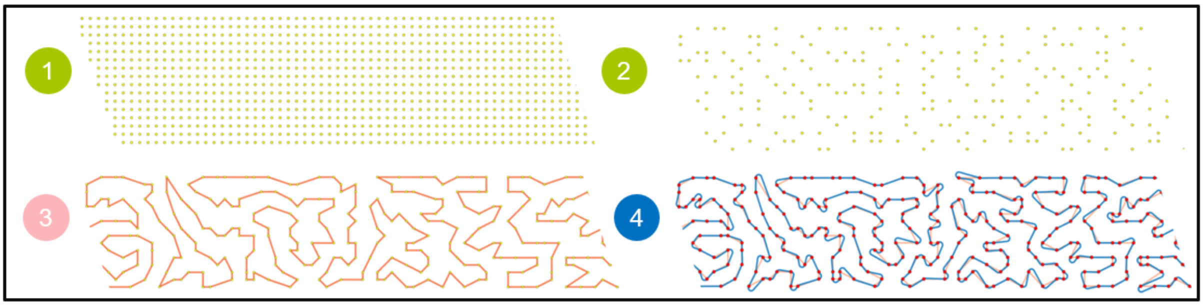

Figure 3 *(1) conventional grid, (2) CSI random grid with one quarter of the original source points (3) optimum vibrator path (4) smooth trajectory adapted to the turning capabilities of the vibrator*

Monitoring / Digitalization

As described above, operational solutions exist to get the most out of land source assets. New digitization solutions based on source metadata analysis, advanced monitoring tools and strong connectivity offer the possibility to go further in terms of source asset optimization. Digitization solutions, widely deployed in mining or agriculture industries, can have a big impact on source asset management : it streamlines processes and uses metrics analysis to enhance vibrator maintenance and performance.

Although some metrics of seismic sources (such as vibration QC, cycle time, etc.) are well known and used in the seismic industry, other source information (e.g., hydraulic and air pressure) are available at the source level only. Displayed in the vibrator cabin, they are taken into account - or not - by vibrator drivers, despite potential criticality. When required, for example, to troubleshoot a given issue, more data is collected and analyzed from the vibrator. In addition, much more data about vibrator behavior transits through the vibrator electrical backbone. This data is essential for instantaneous control of the seismic source, but so far has not been given more attention. Significant value, however, lies in due exploitation of this data. Vibrators frequently operating outside their mechanical and hydraulic limits will sooner or later exhibit technical issues. These issues can be detected as soon as they appear to mitigate their actual impact (prevention instead of recovery measures) and therefore preserve the vibrator's productive capability. Bespoke solutions have been developed for this purpose (Figure 4). By collecting and processing large amounts of otherwise hidden data, remote monitoring of source health can be achieved in near real time, making it possible to access and monitor the vital functions of each vibrator to take the necessary corrective action and monitor the progress of each vibrator's health. This monitoring is available either at the base camp or anywhere in the world through a secured and dedicated Cloud platform, to support operators' expectations for less staffed crews. By monitoring and connecting sources, failures are identified and dealt with in due time. Their consequences are mitigated, vibrator signal quality is preserved, breakdown time is reduced and source availability increases.

Digitalization can also be applied to monitor conventional seismic acquisition project metrics in real time: daily productivity, slip time, cycle, individual vibrator performance, time & geographic display (Figure 4). All these metrics can be completed with an Overall Equipment Effectiveness (OEE) indicator which has become the most widely used indicator in the manufacturing industry : the OEE indicator is a product of three rates : Availability * Performance * Quality. OEE can be applied for seismic exploration by managing sources as a factory, with each vibrator being an individual production line with vibrated point output. Its main advantage is that it represents the production efficiency of the source asset in a synthetic way: in this way, the added-value of all productivity solutions, production periods or seismic crews can be easily compared. All these metrics integrated into a modern and connected productivity dashboard aim to support crew performance faced with a growing number of assets (receivers and sources) and skills attrition. Seismic contractors are expecting support to identify weaknesses, bottlenecks and to take real-time corrective actions.

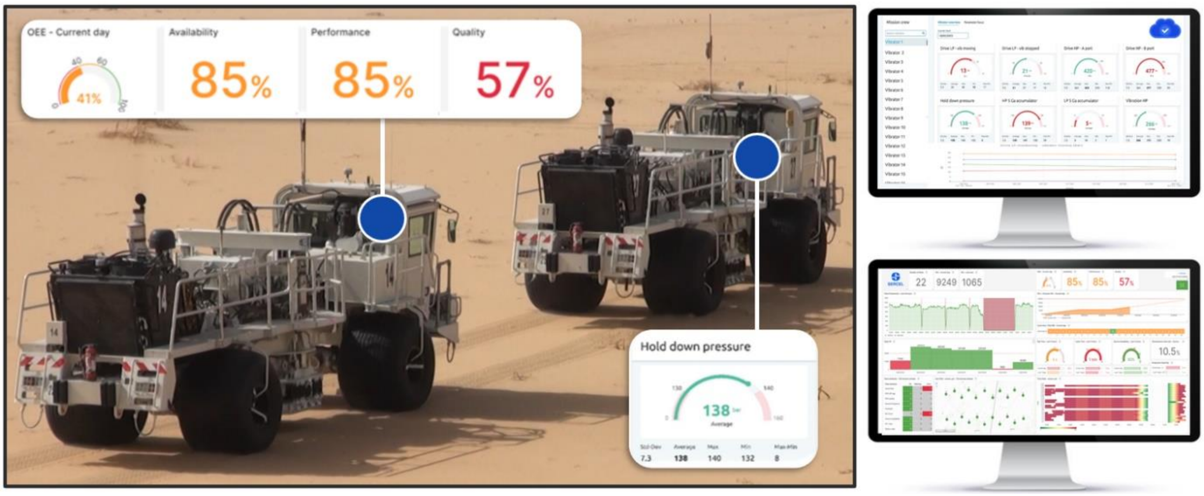

Figure 4 *Advanced dashboards for real-time monitoring of source key performance (bottom right) and maintenance (top right) indicators.*

Conclusions

Land source assets represent a significant investment for seismic contractors and deserve innovative solutions to maintain maximum performance and utilization rates for this equipment which is designed to last for decades. New solutions based on automation, acquisition strategy and digitalization have been developed to achieve significant gains in productivity while preserving smooth operations and optimum seismic imaging quality. In addition, novel cloud-connected dashboards simplify the maintenance and reliability of growing vibrator fleets. Deploying similar solutions for receiver assets will most likely be the next step to improve overall seismic crew performance.

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