Recording system enablers of large-scale onshore seismic with nodes

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Introduction

Seismic production on typical vibroseis crews is limited by receiver roll-rates, especially as high-productivity single-source and simultaneous sweeping techniques are increasingly employed. While the operational benefits of nodal acquisition have led to rapid adoption in most markets, nodes are not yet routinely used for large-scale surveys in desert environments, typically requiring 50,000 or more channels. To understand the factors limiting uptake of nodes for large-scale seismic surveys, we examine how nodal system design choices affect receiver throughput and crew resourcing requirements. We use a realistic scenario of a crew rolling ~10,000 nodes per day to assess the feasibility of various nodal system designs for land seismic production at scale.

Land Seismic Production Constraints

Seismic production, as the name suggests, can be likened to a manufacturing process where the raw materials are the source and receiver systems (both equipment and personnel), and the finished goods are the seismic deliverables to the processing centre. The theory of constraints (Goldratt and Cox, 1984) is commonly used to analyse and improve manufacturing processes by isolating and addressing the most significant bottleneck in a system so that, when applied iteratively, overall system throughput is maximized. For vibroseis operations, receiver-side productivity constraints must be addressed to improve overall production. It should be noted that receiver and source productivity are not independent, as the choice of receiver equipment impacts vibroseis operational speed (e.g. navigation to avoid cables vs unconstrained navigation with fully buried nodal receivers).

At a high level, all nodal systems follow a similar operational procedure (Figure 1). Nodal seismic operation can be separated into camp procedures, such as battery charging and data download, and field procedures, such as node planting, activation and retrieval. The efficiency of each can be analysed separately to assess overall constraints on system throughput and opportunities for improvement.

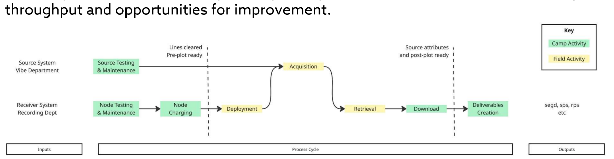

Figure 1: a simplified model of the seismic production process

References

Dean, T., 2024. A comparison of two land nodal seismic recording systems, *Exploration Geophysics, 55:3, 277-287,* *https://doi.org/10.1080/08123985.2024.2319283*
Goldratt, E. M., and J. Cox, 1984. : The Goal: A Process of Ongoing Improvement, North River Press
Goujon, N., A. Ourabah, Z. Song and C. Giersz, 2021. Which sensor for land nodal seismic: recording acceleration or velocity? *First International Meeting for Applied Geoscience & Energy Expanded Abstracts.* https://doi.org/10.1190/segam2021-3583516.1
Muijzert, E., 2022. Attenuation of Wind Noise by Seismic Surface Arrays and Nodes, *83rd EAGE Annual Conference & Exhibition.* *https://doi.org/10.3997/2214-4609.202210368*

Field Operations Efficiency

The primary determinant of field operational efficiency is in-field logistics. The weight and volume of equipment to be transported to the line controls the number and type of vehicles and field personnel required; the node weight and form factor have a strong influence on the time taken to deploy each receiver station. Consequently, a primary focus of instrument manufacturers has been node miniaturization. Node autonomy also impacts field operations efficiency, with long autonomy preferred to minimize or eliminate any need for battery management on the active spread. 50 days is increasingly requested as the node autonomy specification by seismic contractors, and miniaturization must not come at an excessive cost to autonomy.

Sensor choice fundamentally controls node weight and power consumption (Goujon et al., 2021). The average node weight has trended down over recent years (Figure 2a) due to growing acceptance of nodes with limited or no remote QC which require fewer battery cells. Further improvement in the weight of MEMS and geophone-based nodes will be challenging to achieve without sacrificing autonomy. Piezo nodes are in a class of their own in terms of weight while still achieving 50 days autonomy (Figure 2b).

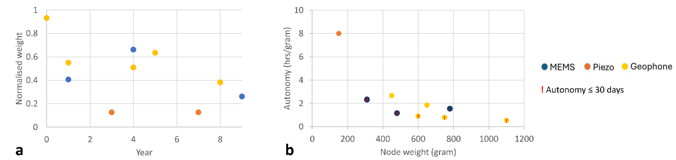

Figure 2: (a) Nodes have become slimmer over time. (b) Sensor technology controls node weight and autonomy

The time to deploy each receiver station is also critical for the viability of large-scale land seismic acquisition, and contractors must balance deployment time with quality. Building a seismic vault at each station is clearly unfeasible, but nodes with compact and streamlined form factors can be quickly buried to mitigate the most important receiver-related signal perturbations (see Figure 3) by ensuring good coupling and verticality combined with surface-wave noise attenuation (Muijzert, 2022). In contrast, nodes designed to sit on the ground surface rely on friction for coupling, are easily tilted, quickly pick up wind noise and are unshielded from surface-wave noise. A further benefit of burial is unobstructed source operations with minimized risk of theft and interference. Table 1 shows typical deployment cycle times using modern nodes for various scenarios.

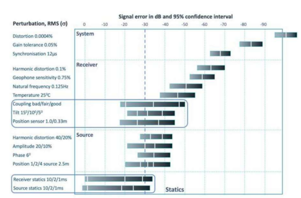

Figure 3: relative importance of land seismic perturbations (Dean, 2024)

Terrain	RP Increment	Cycle Time	RP per hour
Flat desert	8.33 m	11 s	327
Flat desert	12.5 m	13 s	276
Rocky desert w offsets	7.5 m	15 s	240
Flat, hard, gravel	25 m	16 s	225
Dunes	25 m	25 s	144

Table 1: typical deployment cycle times in different terrain conditions for modern, lightweight, compact nodes

Camp Operations Efficiency

Node battery charging is the rate-limiting step when preparing nodes in camp. Nodal systems can be separated into three types based on their approach to battery charging: i) batch-handling of nodes using a motorized lifting aid with simultaneous charging and data download in high-capacity racks (Figure 4); ii) individual handling of nodes with combined charging and data download hardware; iii) individual handling of nodes with separate charging and download hardware.

Charging time is similar between systems, so rack capacity and loading/unloading efficiency controls overall throughput and crew resourcing requirements. Table 2 summarises charging and download hardware and staffing to roll 10,000 nodes per day for the three different system archetypes. High-capacity racks with batch, motorized, handling of nodes significantly reduce charging/download infrastructure and personnel requirements (and costs) when compared to systems that rely entirely on manual handling of individual nodes. The most efficient systems maximize the batch size and charging/download rack capacity, which reduces the number of handling operations to a minimum.

Various other aspects of recording system design also become increasing important as channel counts and roll-rate increase including: reliability of charging technology (e.g., wired vs wireless), reliability and scalability of data download (e.g., radio vs optical), node testing methodology (manual vs automated).

Figure 4: mechanized loading of modular, high-capacity, charge/download racks (left) and automated node tester (right) enables scalable camp operations

Handling	Charging & Download	Capacity & Throughput	Racks	Handling Operations	Crew
Batch, motorized	Combined	540 nodes/rack 3,240 nodes/day/rack 19,440 nodes/day/container	4 racks 3 linear m	223	2
Individual, manual	Combined	36–108 nodes/rack 144–432 nodes/day/rack ~5,376 nodes/day/container	35–70 racks 14–42 linear m	20,000	16
Individual, manual	Separate	32–48 nodes/rack 220–355 nodes/day	56–90 racks 70–120 linear m	40,000	32

Table 2: Comparison of recording department hardware and personnel requirements to roll 10,000 nodes per day (containing 28 days of data) for different types of nodal recording system

Conclusions

The technical and operational scalability of nodal receiver systems is a function of inter-related choices between node and charging/download hardware design. As such, systems must be designed holistically with high-channel-count seismic in mind, rather than evolved from existing systems that were not conceived for such applications. Efforts focussed on addressing field operational bottlenecks, such as reducing the size and weight of a node, shift the system throughput constraint onto node charging in camp and do not, by themselves, make the overall system more suitable or cost-effective for large-scale nodal seismic operations. Receiver system architectures that rely entirely on manual handling of individual nodes in camp inherently require recording department headcount to increase in proportion to channel count and roll-rate, making them impractical and uneconomic for large-scale seismic operations, as evidenced by the lack of large-scale deployments (50,000+ channels) using such systems. In contrast, systems built from the ground up with scalability in mind, incorporating motorized batch handling and high-capacity charging and download racks, have already been proven at very large scale (165,000 channels, 10,000+ daily roll) with minimal camp recording crew. True scalability is not theoretical but is achievable in practice, opening the door for wider adoption of nodes for large-scale land seismic acquisition.