

Land seismic: needs and answers

Denis Mougenot, chief geophysicist of Sercel, the French-based manufacturer of seismic acquisition systems, provides examples of how his company is tackling needed improvements in land seismic acquisition technology.

The geophysical industry has been struggling to achieve profitability for some time (IAGC, 2003). In such a market, some seismic acquisition system manufacturers realize that contractors will only spend their precious capital on equipment for which they can get a near term return. This has led these manufacturers to focus their development effort on system improvements that enable contractors to collect more seismic data per day, in other words to be more productive.

This article describes some of these specific productivity enhancements. Improvements are illustrated by the features in the Sercel SN388 system and by the revolutionary 408UL system introduced in late 1999. These two 24-bit recording systems are widely used by contractors and represent together about 750 000 channels and 600 central units. Changes that have contributed to faster acquisition and better data quality are considered. Improvements in seismic acquisition productivity have contributed to reducing the cost of seismic data and have helped the industry reduce the cost of finding and recovering oil and gas. These improvements can give some insight into future evolutions.

Increased production demands/ lower costs

It is well known that an oversupply of crews within the seismic contracting industry and the demand for lower prices in new contracts have both contributed to an understanding that lower data acquisition cost is a survival need for contractors. At the same time geophysical demands have required higher fold as well as larger offsets and uniform azimuthal distributions. Together this means that while demand for lower costs increases, the density and number of traces produced is also on the increase. In this context of low cost per trace and high fold per survey, seismic crews must improve their productivity to be profitable.

Many factors can influence the productivity of seismic crews. Many of these factors are not influenced by the acquisition system, for example, geophysical planning, logistical planning, personnel choices, contractual issues, HSE, local culture, oil company requirements, to name just a few. But there are also many ways that the acquisition system can impact how much data is collected per day.

Productivity improvements can come from 1) shorter time to troubleshoot the line; 2) shorter lost time between records; 3) the ability to record more lines and channels; 4)

a new paradigm for acquisition field equipment, the use of a Link between multiple single channel units rather than the old technique of a fixed number of channels in boxes and cables; 5) automated QC so that the observer doesn't need to spend so much time visually inspecting records; 6) multi-fleet vibrator techniques that allow operating without a delay for vibrator move-up; 7) overlapping record techniques, such as Slip-Sweep that allow collection of multiple records simultaneously; 8) built-in redundancy to allow a system to continue operation even with the inevitable damaged cable; 9) high enough system uptime and reliability to allow 24-hour acquisition in some areas; 10) very low power operation to minimize battery handling and replacement; and 11) lighter weight field equipment..

All of these issues will be discussed further in this article.

More channels

The most obvious way to increase trace production is to increase the number of channels recorded per shot. This is one explanation for the large increase in seismic crew channel counts reported by Jack (2003). On average, SN388 systems were sold with 940 channels and the 408UL systems average 1860 channels. A few 3D crews are reported using 7000 active channels. With the onset of 3D/3C some crews equipped with 4000+ 3C digital sensors are even recording about 10 000 active channels.

More records

Another way to increase production is to record more shots per day. This requirement can be made possible by recording more quickly and by ensuring that the system is up and ready to record the highest percentage of the time. The number of Vibroseis sweeps recorded in a day has increased steadily benefiting from many improvements in technology including the use of several vibrator sets (up to four) and even overlapping between the sweeps to reduce cycle time (Slip-Sweep; Burger *et al.* 1999). In addition, the amount of time lost between sweeps needs to be as close to zero as possible. Geophysicists have been instrumental in implementing record productivity with vibrators operating in flat and wide-open areas. Considering the single sweep per shot point (about 12 s duration) that is often used for recording 3D in the Middle East, the reported records for shots per hour are: 95 sweeps/h (single fleet of vibrators); 145 sweeps/h (dual fleet of vibrators in

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alternate flip-flop mode); 215 sweeps/h (four fleets of vibrators in overlapping Slip-Sweep mode). Thus, using multiple fleets of vibrators makes it possible to record data close to continuously, and to increase shot point density.

Source-driven recording

To implement fleet management, vibrator electronics must be carefully integrated within the central unit to get the recording started by the vibrators as soon as one fleet has reached the next shot point. In this source driven operation mode, the recorder must not delay the source. With the introduction of a very large spread (> 4000 channels), line forming (i.e. the selection of the active channels to be recorded by one set of vibrator) has been the main cause of dead time (up to 6 s between records with SN388). With the concept of super-spread implemented in the 408UL, all the channels available into a large template are recorded (Figure 1). Using the SPS relation file, the workstation will then select the active channels of the spread for data processing, formatting and storage on the cartridge. A 15% improvement of productivity in flip-flop mode has been reported due to this software implementation.

New concept ground equipment

For generations of seismic recording systems, the equipment consisted of recording boxes, cables, geophones and batteries. The same configuration was used for truck-based operations as in the desert, helicopter operations and man-portable operations. It was simply a case of the crew adapt-

ing to the equipment the best they could. With the introduction of a new concept in ground equipment called a Link, the 408UL offered equipment that could adapt to the operation, helping to increase the efficiency of a specific crew on a specific job. The Link is a single handleable unit including cable and a user defined number of single station recording electronics units which can be designed for the operation including the distance between stations and the number of stations per handling unit. In this way the most efficient amounts of equipment for the particular logistical environment can be moved as one unit.

The weight of the equipment deployed in the field can cause logistical and safety problems. It can slow productivity and is one of the main sources of operational costs. Some high channel count, high productive crews in the Middle East with large geophone arrays may have to handle about 35 tons of equipment daily. With the rising number of channels, lighter field equipment becomes mandatory. One 408UL channel, including cable, field electronics and battery, is 3 Kg for 55 m cable length. This is a reduction of 50% with respect to the previous SN388 system. This improvement is related to more integrated electronics with fewer components which are lighter, more reliable and require less power. From the SN388 to the 408UL, the per channel power consumption has decreased from 240 mW to 140 mW. Lower power needs translate into fewer batteries and less weight, as well as higher reliability and longer electronics life.

Improved reliability of the system once it is laid out is another factor that contributes to decreased downtime/cost.

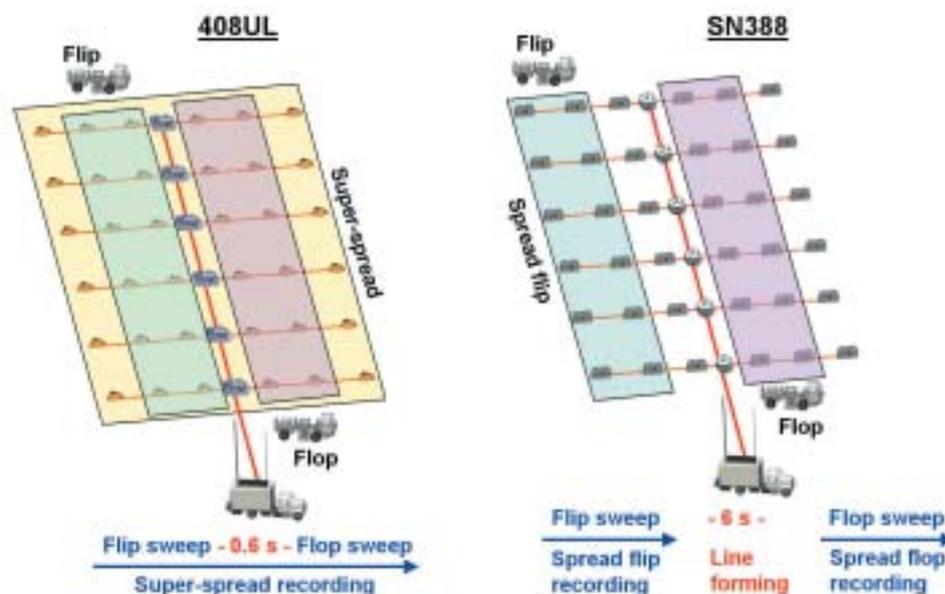


Figure 1 408UL super-spread in flip-flop operations prevents dead time due to line forming. All channels of the super-spread (a large template) are transmitted at once. Then the SPS relation file is used for sorting the lines corresponding to the active spreads flip and flop. With the SN388 line, forming of spread flop after recording of spread flip introduces a delay.

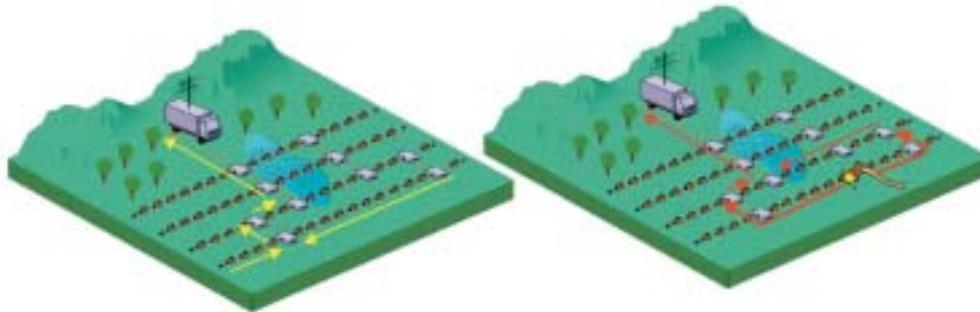


Figure 2 Multi-path telemetry thanks to multiple transverses. After a break of the receiver line, data are rerouted using another path. Recording can continue before repair of the receiver line.

Another real benefit of the Link configuration is the decrease in the number of connector and contacts on the line. The Link makes it possible to decrease the number of contacts to eight (two connectors x four wires) per Link for any number of channels. For a single SN388 unit using a seven pair telemetric cable the corresponding number of contacts is 28 (two connectors x 14 wires).

Increased layout flexibility/ better troubleshooting

As the seismic spread grows in size and complexity, the chance of something going wrong (from chewing animals, unfriendly machetes or any number of unforeseen causes) increases dramatically. Creative ways must be found to locate and deal with these problems immediately. In the 408UL the seismic spread has been transformed into a network capable of communications as well as data routing. It is called the Seismic Areal Network. This network supports a 'TCP/IP like' communication protocol close to the very robust one used for the Internet. It is created by linking servers (the field electronics) together. Each server gets the packets closest to their destination (the central unit). A packet may travel over many types of media (copper cable, optic fibre, laser, microwave, radio). The Seismic Areal Network offers more flexibility and redundancy for improved productivity. During layout of the spread, multiple telemetry support (radio, laser...) may be inserted anywhere in the spread to manage detours (plant...) and obstacles (river, highway...). In case of failure between two servers (leakage...) a new transmission may be required for the data stored in the buffers. Multi-path telemetry is also possible which corresponds to the definition by the central unit of a new route to transmit data using different receiver lines and transverses to go around a break in the network (Figure 2).

Better data

Beyond economic considerations, data quality requirements have increased the need for greater channel production on crews around the globe. Improved spatial sampling in both the shot and the receiver domains is a prerequisite for noise attenuation. Today's shot and receiver spacing used by most of the land 3D crews (50 m or 60 m along the corresponding shot

and receiver lines) is too large to avoid ground roll aliasing. This is the reason for a trend toward decreasing the receiver spacing to 25 m. Of course, not only noise benefits from better spatial sampling but also signal (Vermeer, 2002). The increase in fold coverage and related signal-to-noise ratio is one of the improvements. If the additional channels are used to increase sampling in the cross-line direction (i.e. to layout more receiver lines) this will provide wider azimuthal distribution. Such wide distribution should improve migration operations and multiple attenuation (Cordsen and Galbraith, 2002), and it is mandatory to define anisotropy.

To be able to record the large number of channels necessary to improve spatial sampling in the inline and/or crossline directions, the recording system should be able to collect, QC and record all the active lines on tape in real-time (i.e. with no dead time between shots). Downtime due to layout and maintaining the spread should be as low as possible. Multiple source management and source driven acquisition (i.e. recording as soon as one source is ready) should be available. Most of these capabilities have been implemented within SN388 and 408UL as well as by the other recording systems.

Real-time QC

Quality control of the field instruments, data and operations is a major factor contributing to increased crew productivity. QC in the 408UL has been improved by the real time capabilities of the Seismic Areal Network for data and commands. More and more, software is used to automate acquisition (for example, relating a given spread to a given shot) and to visually display QC results. From the recording truck, the spread is checked as soon as it is laid out. The observer gets a real time numerical (table) and graphical displays highlighting faults (for example, noise above threshold, sensor tilt error, cable leakage, or low batteries). By monitoring the parameters of each sweep (phase, distortion and force) for each vibrator, it is possible to identify trends and to ask for preventive vibrator maintenance. Geographical Information System (GIS) photos are used with the control displays to put QC data in their environmental context. Operator vehicles are not only tracked for safety, but also to optimize their movement on the spread. In

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the recording truck, the fold coverage is built up on each shot. If the decision to record a particular shot point is in question, the effect on the final fold coverage may be simulated to understand the impact of the decision.

For seismic data, real time automated QC has been also implemented. A dedicated workstation is connected by Ethernet to the central unit, in parallel with the SCSI tape drive. Since visual inspection of the increasing number of traces is impossible, quality is evaluated by means of seismic attributes computed trace-by-trace in real time. In the SQC-Pro software, a history panel displays attributes averaged on a

shot-by-shot basis (Figure 3). In addition to the faulty trace count evolution, the many reasons for which a trace may be in error are also on display, such as anomalous values of the geophone tilt, resistance or leakage, signal-to-noise or bandwidth below a predefined threshold. The source noise and the signal level, isolated by FK filtering, are also provided as a quick diagnostic. All these seismic QC results are not only useful for the observer. They are stored as ADS files (SEG format for attributes) for possible later use in processing.

Today, a recording truck is like a decision room, often with five or more large screens displaying data. With all this information, the observer should be able to anticipate situations and to be responsive for faster troubleshooting. However, two eyes may not be enough to take care of all QC situations. Addition of a specific QC observer is one solution. The extension of the acquisition network to a remote location, where more expertise is available, is another possibility. By adding a web server into a recording truck equipped with satellite data transmission, it is now possible to connect to the central unit any standard PC platform loaded with the eSQC-Pro software. With this remote access to seismic data (QC attributes and traces after lossy compression), any authorized person will be able to check the acquisition data quality with no delay, on the same system as the observer.

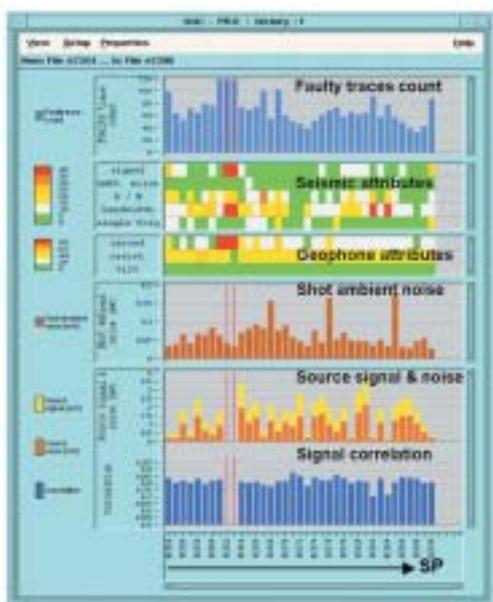


Figure 3 History view in seismic real time QC (SQC-Pro). Synthetic instrument and seismic data QC are displayed with respect to the successive shot points (SP). The observer is able to identify trends and anticipate troubles.

Full digital transmission

It took 30 years from the development of the first digital recorders to be able to move the analogue-to-digital converter from the central unit to the sensor (Figure 4). With the advent of digital sensor technology based on the MEMS accelerometer, full digital transmission becomes a reality. Suppression of the last segment for analogue transmission, the cable connecting the geophones to the station electronics, should remove all pick-up noise, cross-talk and sensitivity to leakage.

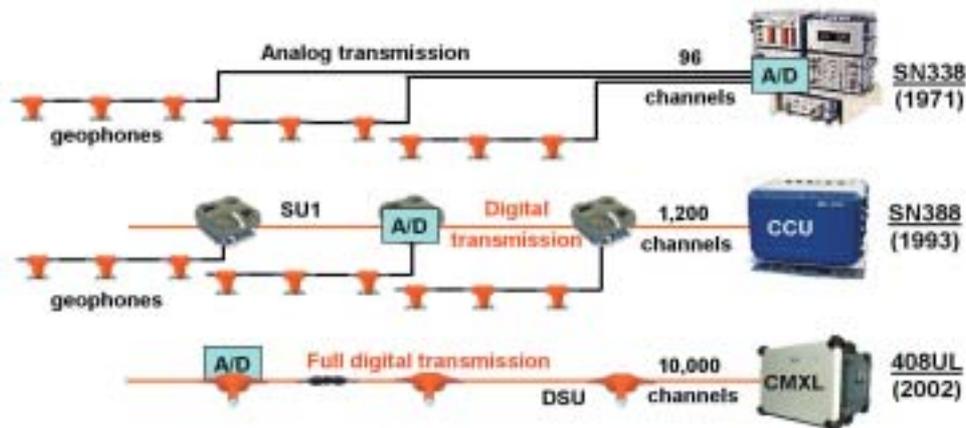


Figure 4 Towards the full digital transmission or 30 years of digital recorders. (A/D refers to analogue-to-digital converter; SU1 to station unit 1 channel; DSU to digital sensor unit; and CCU/CMXL to central units).

These MEMS accelerometers have been developed for the seismic industry by Input-Output (J. Tessman *et al.* 2002) and Sercel (M. Farine *et al.* 2003). In addition to a flat and broadband linear response in phase and amplitude, these new sensors combine low distortion (less than 90 dB) with the high dynamic range (above 110 dB) necessary to record quality seismic data. These digital sensors, being used as single sensors, provide the full benefit of point receiver recording: no high frequency attenuation and isotropic azimuthal recording. However, single sensors present some drawbacks: no random or organized noise attenuation, short spacing (i.e. more channels) to increase fold and avoid ground roll aliasing. For three-component recording, 3C digital sensors have a proven record of superior vector fidelity and better data, compared with strings of geophones (R.R Kendall *et al.* 2002).

What's next?

The seismic technique is a general tool that has grown in its' application as needs have dictated and technology has allowed. Energy reserves have generally become more difficult to define and generally hide in more difficult environments. As this technique has grown to fit the needs presented in the past, we very much feel it will continue in the same way. Fully exploiting existing reserves as well as locating new reserves will require data that penetrates geological conditions such as gas clouds, defines fracture production in tight sands, and locates subtle traps or residual and bypassed reserves. Describing reservoirs will ultimately provide energy where it had previously been overlooked. All of this will require better sampling, more channels and higher quality data.

Before a survey can be recorded it must be located and laid out on the ground. Front-end costs for surveys have grown right along with survey size and complexity. GPS systems and support equipment must develop to allow stakeless surveying, thereby reducing preparation time before the seismic survey starts while ensuring that the survey is located properly.

One trend is apparent. System channel counts will continue to rise. For better imaging of deep targets, fold and offset should increase. Wide azimuth 3D acquisition that improves imaging and anisotropy detection requires the recording of a swath with comparable inline and crossline offsets. Multi-component acquisition for full elastic parameters definition and single sensor recording for more accurate wave-field sampling will require the recording of more and more channels. As an example, a 3D survey that corresponds to a square swath of 8 x 8 km², with 25 m between single 1C sensors inline and crossline, would need 103 000 active channels and about 50 000 more for roll-on/roll-off. This figure would be multiplied by three for 3C, and it is at least one order of magnitude above the real time capabilities of today's recording systems.

The recording system of tomorrow will face a huge list of improved technologies:

- Higher telemetry rates - no matter what the medium
- Recording hardware technology with the capability to keep up with increased data rates
- Recording media technology which allows huge storage and small volume
- Lower power consumption
- Improved power sources
- Smaller, much smaller, higher reliability electronics technology
- Automated QC to keep up with the increased volumes of data

All of these are important issues but power management and telemetry bandwidth are two of the most difficult. Software and computer power will continue to replace hardware applications whenever possible as higher computer power in smaller packages become available.

The geophysical industry is a dynamic, technology-driven industry that continues to challenge our creativity and determination. Our future will continue to present adapt-or-die challenges, as it did in the past. In many ways our industry is not any different from many others, such as telecommunications or aerospace, we just get to work in places that others can only dream about.

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