Building the Perfect Storm

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To be truly effective, a seismic operation must look beyond the initial technical parameters of subsurface imaging. With careful consideration, operational efficiencies, cost management and the technical requirements can be aligned effectively without sacrificing data quality. In short, the relationship between the technical, economical, operational, and program timing must be accepted and optimized. Without proper consideration, the operational logistics and the technical parameters may limit crew production, increase costs, or adversely affect the program timing.

To optimize acquisition performance, it is necessary to analyse previous crew performance and build mission-critical timelines. Without a comprehensive strategy, the project may never achieve optimum execution because design flaws are not recognized, and future projects may proceed with similar flaws.

Why is it so important to ensure the design does not restrict success? Now more than ever the oil and gas sector is expressing enormous concern that service sector costs are escalating out of control. The cost concerns – directed primarily at big rig drilling – have widespread repercussions that include geophysical exploration. Today's goal is to minimize rising costs and operating inefficiencies to maximize project returns. In times of economic restraint, it is important for management to create and consider alternate opportunities and the first step toward improvement is a comprehensive project review. This discussion looks beyond the technical parameters.

Standard technical parameters such as spatial sampling, program size, and so on, become the first set of limiting factors. Each project may be limited by a technical or operational aspect or by combinations of both that converge to reduce field operation efficiencies. The message here is that once the technical design is almost 'finalized' a practical test should be applied to identify potential design inefficiencies. In the simplest form, a meeting between the project manager, cat push, drill push, recording manager, crew supervisor, and designer provides the best opportunity to review the operational complexities associated with each parameter of the design.

Complexities can vary from equipment availability, line construction, survey, sources, receivers, instrumentation, timing and personnel to political and regulatory issues, often directly affecting economics and logistics. The team should anticipate the project timelines and key completion events, which then becomes the guiding operational document and part of the operational strategy.

To demonstrate some limitations, consider a large 3D dynamite seismic program in northeast British Columbia. Keep in mind most small surveys have many of the same issues at a smaller scale. An issue you can work through on a large program may be a showstopper on a smaller program. The sample survey is a rectangle area 12 km east/west and 15 km north/south. The receiver lines are in the east/west direction. The receiver and source station intervals are 60m and the lines are spaced 180m and 360m, respectively. The program has 83 receiver lines – each about 200 stations in length – resulting in 16434 receivers and 981 km of receiver line. There program has 34 source lines – each about 250 stations in length resulting in 8364 source locations and 500 km of source line.

Type	Int	Line Spc.	Number of Lines	Line Length	Sta/ Line	Total Sta.	Total km
Rec	60 m	180	83	11.82 km	198	16434	981
Src	60 m	360	34	14.70 km	246	8364	500

Assume a two-hole pattern with each hole 7 meters deep, the two holes 5 meters apart, with 0.5kg per hole. The recording patch is 18 lines of 60 channels per line, split spread, rolling on and off lines and channels. The initial timeline to complete the program in 83 days would look something like the following:

Line cutting	Jan 03 to Feb 21	(50 days)	30 km cut and cleaned per day
Survey	Jan 10 to Feb 28	(50 days)	30 km surveyed per day
Drilling	Jan 20 to Mar 02	(42 days)	200 source points per day
Recording	Feb 15 to Mar 25	(39 days)	500 ch up/ 500 ch down per day

Obviously to complete the acquisition during the winter season, the technical parameters have set the minimum production rates, which in turn have established the amount of equipment and personnel required. Production directs costs instead of production managed by costs. It is at this point other influences affecting the program come into play. In chronological order, here are some of the influences: the regulatory process, the political process, local influences, weather conditions, accommodation, crew and equipment availability, safety, industry demands, production rates, spring thaw…any of which can slow or bottleneck the process. Managing time – or the lack thereof -– is critical in adhering to the guiding operational document and strategy.

The Regulatory Process

There are an incredible array of issues associated with the geophysical approval process. The approval is necessary to commence the field operations and the approval may include conditions that directly affect the success of the project…economics, surface restrictions, and a myriad of

Continued on Page 26

Building the Perfect Storm

Continued from Page 25

issues. Suffice to say a comprehensive program pre scout, that includes a preview of all available material, is encouraged prior to the application submission.

Additionally contractor requirements, such as the new regulation/standard for tree fallers will prove challenging for the 2006/2007 season and, unless the market adapts, this situation will be problematic for 2008 and potentially disastrous by 2009.

The Political Process and Local Influences

The complexities of these issues are beyond the scope of this article.

Line Construction

The amount and type of line construction required each day is another potential bottleneck. In the aforementioned example, the operation needs to cut and clean (the cleaning includes bucking the slash piles, falling danger trees, removing pokers, etc.) 30 km per day to allow the sequential phases of the project to dovetail into the operation. If the line construction progresses too slowly, it can cause several adverse effects…the most adverse of which is to push the recording window to later in the season when the ground conditions oscillate between freezing and thawing. This seasonal fluctuation can create even more delays (replanting) and may severely degrade data quality. Delays are often directly correlated to increased costs.

The receiver and source line spacings and line widths are critical parameters and it is imperative the final approved design achieves a balance between disturbance, opportunity, and concerns about cumulative impact. (Line spacing is a technical parameter; line width is an operational parameter.) The Regulators may reduce the maximum allowable line width, which can have a significant effect. In rougher terrain, narrow line widths are the norm whereas in gentle open terrain lines are often wider. A narrower corridor will limit the equipment types available to traverse the line and, with many areas restricted to limited access windows, it is essential to have the right type and amount of equipment available for the project.

Social, economic, and political factors can have a direct influence on line construction. In an area where there is a strong slasher contractor base, mulchers may receive great local political resistance and may not be an option for cutting the receiver lines. With the current re-engineering of mulchers our industry has realized significant benefits. Most notably is efficiency, which has translated into reduced costs, increased daily production, and a safer worksite. However, it is often necessary to balance the slashing work opportunities with the mechanical cutting.

A mulching team comprised of one mulcher and three slashers can cut and clean the equivalent of what four fallers and nine slashers could do in one day. In the example, cutting 30 km of source and receiver line per day with mulchers and slashers requires 50 men; using slashers exclusively on the receiver lines would require upwards of 100 men. Given that mulcher cut and clean up generally costs the same as full handcutting, the extra 50 men for 50 days could cost an additional $450K in accommodation, which is often at a premium in remote locations. This example illustrates the importance of understanding local resources.

Perhaps the most interesting aspect of the line construction phase is the timing. The normal cycle for winter line construction is from late December to late February with the recording operations continuing into late March. At precisely the time the cutting crews achieve a rhythm and become operationally efficient, we release them…coincidentally the same time the daylight hours increase and conditions are most favourable to line construction. This is the time of year where we should begin cutting some of *next year's* program! Imagine the following winter already having 25 percent of the program cut. This would enable a quicker start, a reduced intensity level, and several economic benefits to the local economy and next year's budget.

Survey

The survey must keep pace with the line construction. Technological improvements have helped to increase efficiency but there is still a great deal of manual labour required. Continuing with the example, the surveyors must travel all 1500 km of line to locate and mark each station and securing sufficient survey services to meet the timelines can be difficult. With the modern cutting techniques (meandering avoidance), Global Positioning Survey (GPS) has become the norm. In some cases, chaining crews mark the stations followed by a GPS rover. In the 3D example, about six GPS crews and three support staff would be required to survey 30 km per day. To avoid extra costs associated with relocating stations (skids and offsets) and retraversing the lines, the chainers and GPS rovers require some basic geophysical training. Generally where skidding and offsetting is required, the terrain is more difficult, which tends to increase costs and slow production. If Light Detection and Ranging (LiDAR) is available, the GPS operator can accept a lesser vertical solution (fix) provided an acceptable horizontal fix is recorded because the LiDAR data can provide the vertical value. If LiDAR data is not available, the GPS operators must wait longer at each station to obtain an acceptable solution. Many of our narrow lines, with limited skyview (ratio of sky visible to sky obstructed), require the GPS rovers to wait much longer to achieve an acceptable solution. GPS technology requires a sufficient configuration of satellites and limited solar interference to provide adequate solutions. This is just one other issue that has to be managed, especially during the winter months.

Sources

Source logistics involve ensuring the correct number of drills, vibrators, or surface source generators are available. The drill complement required is dependant on the terrain, line width and subsurface drilling conditions. Currently there are two main limiting factors.

The first factor is securing enough drillers and helpers. Many of the drills are owner operated; therefore scheduling time off to manage fatigue and hours of service is difficult. The second factor is securing the appropriate number and size of drills. The terrain, which is directly related to line width, establishes which drill types are capable of the traversing the lines. Every year the drill contractors retool to bring the average drill widths down but industry continues to require a supply of larger inexpensive rigs. Hand drills are the smallest, followed in size by the heli rigs. Mechanical drills come mounted on wheels, floatation tyres,

Continued on Page 27

Building the Perfect Storm

Continued from Page 26

buggies, tracks, and/or heli skid mounts. The widths range from a few mini drills as narrow as 1.75m, a reasonable number of 2.5m rigs then increasing in width increments of about 0.5m to 4m. As the width increases so does the number of drills available.

A good rule of thumb is this: as the width of the drill increases the cost per meter of drilling decreases. Heli drills can range from $40 to $80 per meter, whereas a 4m wide flotation tyre rig can range from $2.5 to $4 per drilled meter. In our 3D example, the drilling could range from $600 a km to $14,000 per km. The source parameter listed the pattern holes at 5m apart; in NE BC no hole may be loaded within 6m of another loaded hole. To achieve compliance, the driller must drill both holes prior to loading either hole. This simple parameter limits production. If the source pattern separation were greater than 6m apart, drillers could operate more effectively.

The drilling precedes the recording crew and the drilling must be completed before the recording spread reaches the end of the program. Often the selected source parameters are based on 'what worked the last time' therefore it is advisable to conduct source tests on this year's work for next year. In good data areas, one may be able to reduce the source effort if the test data supports it. In bad data areas, one may increase the source effort.

Source /Receiver relationship

In the simplest form, the relationship between the receivers and sources is important and should be factored into all designs. Here is an example of a prescriptive regulatory requirement from the Alberta Oil Sands Tenure Guidelines that essentially restricts production and limits the creative process. The seismic requirements are: *"The fold, station, and group interval of the seismic program must be adequate to image both the bitumen reservoir and the Devonian subcrop. Seismic shooting parameters should be at least 15 fold, with a maximum group interval of 10 meters."* The first sentence sets the objective, whereas the second sentence attempts to prescribe the parameters, but does so rather poorly. No offset distance is specified for the 15-fold parameter, which renders the parameter useless. The maximum group interval, assuming this means receivers, of 10 meters actually restricts operations and creativity. Imagine a crew working this area where the maximum daily production, with 10m receiver intervals, is 5 km or 500 receivers moved per day. If the vibrator source interval is 40m then the vibrators would vibrate 125

Continued on Page 28

Building the Perfect Storm

Continued from Page 27

source points per day. If the vibrating time per source point is very short, then generally the vibrators would have to wait for equipment. When the vibrators are waiting for equipment, the crew is losing production. Reviewing the daily reports may not identify the amount of time lost waiting for receivers. The designer may never realize the crew was receiver-dependant with respect to production. The options to deal with receiver-dependency depend on the geophysical objective, operational strategy or both.

The goal could be increased data quality or increased production. If the preference were to increase data quality, while maintaining the same daily kilometre production, perhaps the designer could reduce the source interval or increase the source array time. If increased linear kilometre production were preferred, the designer could consider increasing the receiver interval to 20m and use source points at alternating 10 and 35m intervals. This allows a smaller natural bin size or binning similar to the base model with almost the equivalent fold. If the crew could vibrate 355 source points and move 400 receivers per day, the production would increase by 60% to 8 km and receivers moved per day would be reduced by 20%. If this area was caribou sensitive increased production helps support the early out concept of reducing potential conflict. If this were a dynamite program with relatively inexpensive drilling, perhaps the designer could apply for a variance and invert the source and parameter intervals to 40m receivers and 10m shots. Another option is to increase the crew size or channel counts but once these parameters hit a certain threshold, the gains are generally minor. The inverse relationship can happen where the crews are source-dependant. What source/receiver relationship did your last program have?

Zippers

Beyond crew and equipment is the whole consideration of program size and shape. The first question, is does the crew have sufficient equipment to work the program effectively or is there a better alternative?

In the same 3D example, recording the program without a zipper would require 4200 channels (18 full lines plus 3 lines of roll). Assume the crew cost is on a sliding scale: for example, 2100 channels are $1.30/channel per hour, 2700 channels are $1.15/channel per hour and 4200 channels are $1.00/channel per hour. As channel count increases, the hourly cost increases but the cost per channel actually decreases. If a crew is equipped with too many channels then the hourly cost may be excessive; alternatively if the crew does not have enough channels the shooters may have to wait for equipment.

The next question is how many channels the crew can move per day. We have already established that the crew needs to move roughly 500 channels up and 500 channels down per day with an additional 3 days to layout and 3 days to pick up for a total of 39 days…translating into approximately $2,130,000 (39*13*$4200).

If the crew opted for a receiver zipper then splitting the program in half would require 130 channels (an additional 30 channels per line for the zipper). The same 21-line capability requires 2730 channels with a crew cost of approximately $3140 per hour with a relay of approximately 5000 channels for a new total of 21,414 channels. Using the same production numbers the crew would take 49 days. The 49 days at the lesser channel count would cost $2,090,000 (49*13*$3140 + $90,000 in extra heli). Can you risk recording until April 1st with final pick up April 4th? What will the weather be like in April? Will the crews have to be airlifted to the field? Could the recording crew start sooner? How much more will it cost to construct the program in two halves?

Another zipper option is the redrill. With the double drill option, the receiver lines are 100 channels long (no relay). The same 21-line capability requires 2100 channels with a crew cost of approximately $2730 per hour. The drill option requires double drilling essentially nine source lines (or 2250 source points). Using the same production numbers the crew would take 39 days. The 39 days would cost $1,400,000 (39*13*$2730) plus another $300,000 (drilling $6/m, explosives, and processing) for a total of $1,700,000.

Have shots become cheaper than receivers? Perhaps at $6/m for the drilling they are. What if the holes were deeper, had double caps, and or more explosives? Can you secure enough drills and shooters to record an additional 2250 holes?

Zipper Type	Channels Required	Receivers	Shots	Days	Cost
none	4200	16434	8364	39	$2,130,000
receiver	2730	21414	8364	49	$2,090,000
drill	2100	16434	10614	39	$1,700,000

The next event is a budget cut and now the program shape changes. The east/west direction remains 12 km but the north/south direction is reduced to 8 km. Is it too late to change the orientation of the source and receiver lines so a smaller channel count is required? What are the options now? How much will this survey cost per sq km?

Brief conclusion

In essence, the seismic parameters are not the only parameters. The parameter process must be an iterative process or programs are doomed to the same evident and not so evident flaws. Again, the basics, review the following: last year's parameters, production, data quality, equipment availability, accommodation, political pressure, costs, timing, terrain, etc. Bring in the experts; the operations personnel, the geophysical contractor, and anyone else that can provide meaningful input. Now rebuild the parameters based on the technical and operational options. Then review again. Consider pre-planning somewhat for next year. Will next year's survey tie into this survey? Should source and receiver lines be cut now? Should receiver lines be cut and recorded off the end of the spread to reduce next years drilling? Have you incorporated operational realities with the technical parameters? Is it too late to review this year's plan?

Therefore, even if you are underway, review your operational plan, ask more questions, revise your project timelines, and at the end of the season…measure your success. R

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