A business case for seismic data transmission by satellite

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Summary
How can we still further reduce costs for oil field services without degrading data quality? This is question of paramount interest to the entire oil exploration and production industry. It has been estimated that fully 25% of oil exploration costs are associated with seismic services. A technology which has created much discussion and excitement in the seismic industry for the last several years has been satellite transmission of seismic data from acquisition vessels to onshore processing facilities. This paper will explore the issues surrounding the viability of seismic data transmission via satellite (SDT) and will show that this method adds $2 to 4 million of value per 3-D survey to the oil company employing it.

The value of 3-D seismic - an update
One of the ways SDT adds value to E&P operations is by delivering seismic data to the decision-makers more quickly. This faster delivery is dependent on the underlying value of the 3-D surveys themselves. Aylor has carried out and published previous work that characterizes the present value of 3-D seismic to the oil industry.[1-3] This work has documented the value of an average exploration 3-D seismic survey acquired between 1990 and 1994, conducted across an area previously explored using 2-D techniques.

Figures 1-2 demonstrate how variable discount rates and oil prices influence the value of this average 1990-94 exploration 3-D survey. Figure 1 shows that depending on the discount rate applicable, the incremental value added by a 3-D survey compared to exploring the same area with a 2-D survey can vary between $30 and $104 million. Because these are positive cash flows and due to the effects of the time value of money, the present value of these 3-D surveys is affected by how quickly they are delivered to the oil company. The value of the 3-D survey is reduced when it is delayed because decisions on where to drill development wells and on the size of facilities depend on this data. These delays translate into later production of hydrocarbons and later realization of the revenue stream to the oil company, taxing authorities and those involved in field drill-out and operations. The right side of the figure shows that the value of delivering a 3-D survey one month early varies between $1.4 million and 1.9 million, depending on the discount rate appropriate for a company. Figure 2 shows that this average 3-D survey's incremental value added also varies depending on the price of oil. Here the 3-D survey value varies between $15 and $77 million and the value of a month earlier delivery of the survey varies between $0.9 and $2.7 million, depending on the oil price (which has been held constant over the life of the field for each modeled oil price).

Current processes
Figure 3 is a flowchart that characterizes how 3-D surveys are handled in the field as they make their way from data production to final processing. The figure compares four options for acquiring, cataloging and processing seismic data, namely: stand alone onboard processing with no further main processing center work; stand alone hand carrying of data to a main center for processing; onboard processing followed by hand carrying data to a main onshore processing facility; and satellite data transmission to the main onshore processing facility. The figure shows

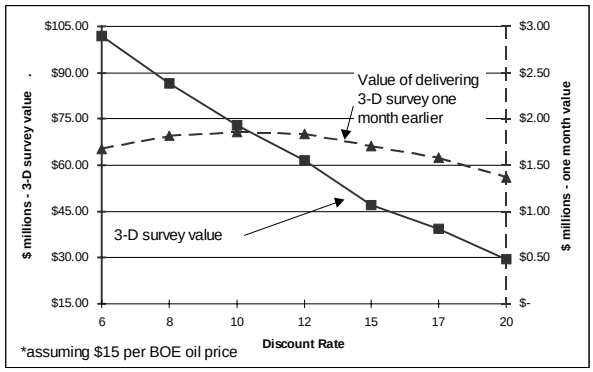

Figure 1 – 3-D survey value and one month of early delivery value as a function of discount rate, using 1994 3-D survey performance assumptions.

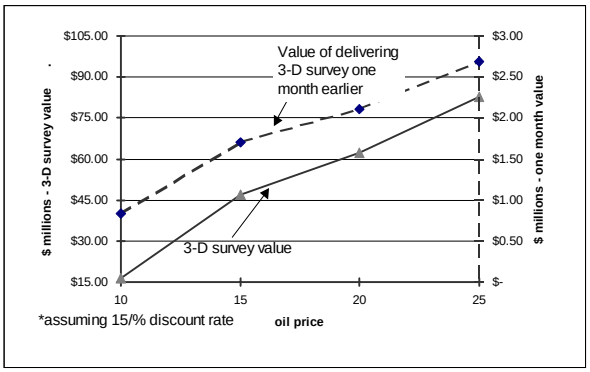

Figure 2 – 3-D survey value and one month of early delivery value as a function of oil price, using 1994 3-D survey performance assumptions.

the elapsed time for each step and the number of full time equivalent (FTE) people needed to execute the step, taking into account other responsibilities of people and those on shore leave who are also on the payroll. Figure 4 summarizes the positive and negative characteristics of each of these options.

Option 1-Stand alone onboard processing.
This method only uses onboard processing, 75% of the time with a conventional computer, and 25% of the time with a supercomputer. This method of processing relies on installing a computing system on the vessel, keeping its hardware maintained and operational, keeping its software up to date, and manning it with qualified processors. If the client wishes to oversee the processing, staff must be provided on the vessel for either the entire or partial duration of the acquisition operations. This option is generally more risky than others and is chosen only when speed of delivery is the most important consideration and when predetermined processing steps and parameters are thought to be sufficient. Since most 3D surveys encounter unique problems, requiring experienced processors and experts to solve them, this option is not a particularly attractive one in most cases.

Option 2-Stand alone onshore processing.
This method hand carries the magnetic tape copies of the data to the main onshore processing facility, without out any onboard processing. In the best conditions, every 2 to 4 weeks this process involves hand-carrying data (possibly using crew on normal crew rotations) from the vessel to a shore base. About 20% of the time however there is no opportunity to hand carry interim segments of the data to the processing facility, and it is only at the end of the survey that the entire data set is offloaded. The offloaded data is cleared through customs, which causes a delay, and then is shipped to the onshore processing center, again delaying the data. Once the tapes arrive at the main onshore processing center, it is cataloged, archived, and then made available for processing. Tapes must then be read to disk before interim sections and 3D volumes of offload increments can be produced. Because of the 3-6 week delay

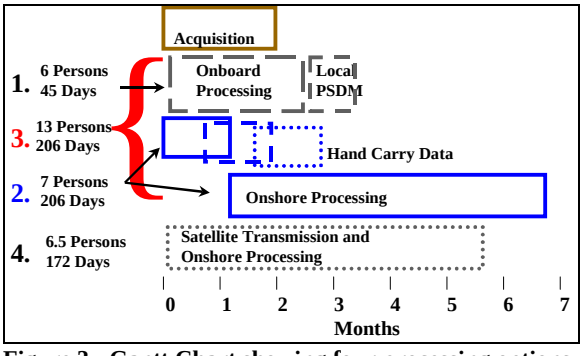

Figure 3 - Gantt Chart showing four processing options

in delivery of the data, it is common for the goal of this phase of the processing to be data assembly, pre-stack testing and pre-stack processing. After the full volume has been assembled, processing progresses in earnest, with concentration on dmo, pre-stack velocity model building, and depth migration. As is shown in figure 3, the final depth migrated data volume is available 206 days after the last shot point and 7.3 FTE people are needed.

Option 3-Onboard followed by onshore processing.
This option is a combination of options 1 and 2, and indeed, many, if not most 3-D surveys have some degree of onboard processing performed on them prior to being sent to the main onshore processing center. As discussed above, when onboard processing is carried out, it has been estimated that about 75% of 3-D projects use a less than full fold data set, deliver only a post stack migration as the final product, and often leave out compute or time intensive steps. Local onshore processing is needed to deliver prestack depth migration of the decimated, onboard processed data set, and complete reprocessing at the main onshore processing center is needed to deliver a full fold, fully tested and processed data volume.

During acquisition and onboard processing, data is accumulated on tape and offloaded at intervals for manual transport to the main processing center. It is by far the most costly of the 3options, but because it achieves both early delivery of the data through onboard processing and completeness through fully tested onshore processing, it is the option most used in the industry today. The completed job including interim and quick look 3D volumes and the final prestack 3D volume is delivered by 13.3 FTEs in 206 days after the final shot point is acquired.

Option 4- Seismic transmission of seismic data followed by onshore processing.
An alternative to the previous three cases that will allow replacement of both onboard processing and hand carrying of data is proposed. Satellites, transmitters and receivers are currently capable of burst mode transmission of digital data at very high transmission rates. These systems use NASA owned “TDRSS” satellites that currently retrieve data from and communicate with the Hubble space telescope and other scientific satellites. Each of the six currently operational TDRSS satellites is capable of transmitting digital data at rates of 311 million bits per second, or 39 million bytes (Mbytes) per second, or 3,359 billion bytes (Gbytes) per day. As a point of reference, an IBM 3590 tape cartridge system, with about 10 Gbytes of capacity per tape, writes data to tape at a rate of 5-9 Mbytes per second. In addition, modern 3-D capable seismic vessels are configured with 10-streamers and dual air gun sources, with 240 channels per cable. These vessels will generate about 165 Gbytes of seismic data per day, and the TDRSS

satellite system described below is capable of transmitting the daily seismic production from the vessel to a receiving station in about 81 minutes. It should be noted that no compression methods are used to achieve these transmission rates, and systems are in design to halve this transmission time.

Numerous operational scenarios are feasible, but for the purposes of discussion, we will refer to a system and processes similar to those described below. A seismic vessel is been equipped with a 2.4-meter, motion stabilized, wide-band dish with an interface to a cache system for interim onboard storage of nav/merged seismic data. Approximately daily the cache is up-linked to the TDRSS satellite and simultaneously transmitted to very high bandwidth receiver dishes at White Sands, NM. The data is then transmitted via fiber-optic cable first to a satellite operations center in Las Cruses, New Mexico and then to a seismic operations center in Houston, Texas, where the data is received, cataloged and robotically archived. This data is then made available via either internet, or via remote terminal to seismic data processors in Houston who stand ready to conduct acquisition QC testing and initial processing testing. Though it is not currently part of the system design, hardware data encryption and decryption, as well as "non-lossy" data compression, could be provided if needed to protect data during its transmission from the vessel to the operations center and to reduce costs even further than is described below.

The seismic operations center is manned around the clock and has facilities for telephone and internet communications with the recording vessel, allowing for real time transmission of processed sections and video clips to the vessel. In addition, the center is capable of robotic tape cartridge archival of 10 or more seismic vessels simultaneously, with facilities for onsite data processing teams if needed. Due to the need for close coordination between navigation processors and acquisition crews, navigation processing occurs on the vessel with nav/merge seismic data being transmitted and stored on disk at the satellite operations center. As techniques are refined, it may be possible to perform navigation processing at the onshore facility as well, with raw seismic and navigation data being transmitted to the center. At first, raw nav/merge seismic data will also be cataloged and stored on the vessel, but as confidence in the system improves, there should be no need for this redundancy.

The availability of seismic data only hours from its initial

	1. Onboard Processing	2. Hand carry to onshore processing	3. Onboard then onshore processing	4. Satellite transmis-sion to onshore proc.
Desirable Characteristics				
Processing keeps up with acq'n	√		∗3	√
HQ staff, including geologists, managers and engineers, involved in parameter selection				√
Full processing testing can be carried out		√	∗2	√
Qualified, experienced processors more readily available		√	∗2	√
Process specific experts available		√	∗2	√
Quick look and interim sections available	√		∗3	√
All the data processed; All steps available	∗1	√	∗2	√
Easier to find acq'n related problems	√		∗3	√
Final stacked and time migrated volume	√	√	√	√
PSDM volume		√	∗2	√
Processing hardware already purchased		√		√
Software up to date, maintained and ready		√		√
Undesirable Characteristics				
Processing delay to read in tape data		√	∗2	
Extra cost for onboard processing	√		∗3	
Very costly and slow: paying to do job twice			√	
Final results delayed by time to deliver data		√	∗2	
Canned processing flows; one shot only	√			
Unable to complete all processing steps before next job	√			
Possible incompatibility with onshore processing	√		√	
Onshore processors work conventional hours		√	∗2	
Non-captive onshore processors		√	∗2	
Handoff from QC to production processing			√	
Lack of sense of urgency for routine jobs		√	√	

Footnotes:
1 - only about 25% of vessels are equipped with supercomputer class hardware that are more likely to have a full processing capability.
2 - only for *onshore* component of processing
3 - only for *onboard* component of processing

Figure 4 - Summary of characteristics of four processing options.

creation will produce a much different atmosphere at the onshore processing center compared to that now in place. Client oil companies will expect almost immediate display of record sections and rapid delivery of pre-stack testing, including fold, offset and azimuth distribution maps. Performance by processing teams will be measured by not only quality and completeness of test procedures but also by lag time from field production. Since the same group will be doing both QC acquisition and processing tests as well as final processing flows, there will be no lost time due to handoff between QC and final processing teams. As observations and questions arise regarding data quality, these can be discussed via telephone and internet link with the vessel. And importantly, because the QC data and tests will be located near the home office interpretation staff, more meaningful dialog will occur between client interpreters, industry experts, contractor processors and acquisition personnel.

As is shown in figure 3, there will be significant time and personnel savings associated with SDT. Because of the elimination of the need for onboard processing, four personnel will no longer be needed. The 45 days of onboard processing elapsed time will not be counted here because this elapsed time takes place in parallel with the other processes and does not delay the final processed section. Since data will be transmitted in real time to the satellite operations center, virtually all the steps in the hand carry case can be eliminated. Comparing the timing and manning requirements for SDT, 34 days and 6.8 FTEs can be eliminated.

Value of SDT.
The value of SDT is summarized in figure 5 below, showing the value to a client oil company, a seismic contractor and to a host government. In addition the value is viewed on a per 3-D survey, per sq. km. and per vessel year basis.

The following factors have been included in this valuation:

- Oil company value added due to the present value of receiving data and making decisions 34 days early
- Seismic contractor manpower and equipment savings associated with elimination of onboard processing
- Value to the host government is about 4 times that of the oil company [1]
- The present value of accelerated data availability for sale by a seismic contractor conducting a group shoot

	Value to Oil Company	*Value to Contractor*	*Value to Host Gov't*	*Estimated Cost*
Per 3-D Survey	**$2- 4 million**	**$359 thousand**	**$7.6 - $14.8 million**	**$300 - $480 thousand**
Per vessel year	**$12 – $24 million**	**$2.16 million**	**$45 - $89 million**	**$1.8 - $2.9 million**
Per Sq. Km	**$667 - $1333**	**$120**	**$2,520- $4,900**	**$100-$160**

Figure 5 – Summary of Value and Costs

Conclusions
Transmission of seismic data via satellite is a technology whose time is here. One contractor, SpaceData International, has demonstrated for at least one potential customer the transmission of a large seismic data set at 311Mbits per second, with no errors, using the TDRSS satellite. This company is actively marketing the product and is ready for contracts.

Transmission of seismic data via satellite represents the opportunity to revolutionize the manner in which seismic acquisition operations are carried out, providing *for the first time*, the ability for home office interpretation staff and technical management, industry processing experts, contractor processors and field based acquisition and navigation specialists to engage in dialog as data is being acquired. These systems provide very clear cost savings in terms of reduced staff and equipment, earlier delivery of processed data, elimination of redundant processing and survey optimization. These benefits make satellite transmission of seismic data an eagerly anticipated, quantum improvement in performance for the seismic industry.

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