FROM DISRUPTIVE TECHNOLOGIES TO DISRUPTIVE BEHAVIOR: Process Change in the Oil Service Industry

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Introduction

During the period from the mid-eighties to the mid-nineties, dramatic changes occurred in the cost of Finding, Developing, and Lifting (FD&L) oil and gas. Initial gains were made by trimming organizational fat, both in oil companies and oil service companies, partly in response to plunging oil prices.

Today, FD&L costs hover in the mid-single digit area ($/barrel), significantly reducing the impact of the saw-tooth behavior of oil prices. This situation offers the hope that the boom and bust cycles of the past will not easily be repeated.

Discrete technologies have often been cited as being largely responsible for the improved economics of recovery. While this is certainly the case, we are suggesting that the major gains were made by process change in both the oil and service companies. This paper describes the concept of Disruptive Behavior as driving the process change, and it in turn being triggered at least in part by the onset of Disruptive Technologies (Bower and Christensen, 1995).

Disruptive Technologies

Bower and Christensen define a disruptive technology as one that may not initially appeal to the majority of customers, but after success in a niche market, the appeal broadens and eventually overwhelms the conventional product. They suggest that the technological change per se is not radical, but that the appeal is typically in the packaging of different attributes.

As a rule, mainstream customers are unwilling to use a disruptive product in applications they know and understand. At first, disruptive technologies tend to be used and valued only in new markets or applications. For example, Sony’s early transistor radios sacrificed sound fidelity but created a market for portable radios by offering a new and different package of attributes- small size, light-weight, and portability.

Bower and Christensen found that few companies, when confronted with disruptive technologies, have been able to overcome the handicaps of size and success. Industry leaders are rarely at the forefront of commercializing new technologies that don’t initially meet the functional demands of mainstream customers and appeal to small or emerging markets.

Disruptive technologies are often developed in independent organizations and commercialized by independent organizations. In the disk-drive industry, every company that tried to manage mainstream and disruptive businesses within a single organization failed. Conversely, most successes were in organizations that were isolated from mainstream organizations.

In the oil service business, typically, a disruptive technology is also a significant advance in science and/or engineering. Also, for it be truly effective, it must drive changes in processes through disruptive behavior.

Measurement While Drilling (MWD) is an example of a disruptive technology. Conventionally, the trajectory followed by an oil and gas well, and information on the strata penetrated, was determined after the well segment had been drilled, through the use of wire line deployed sensors. MWD allowed these measurements to be made while drilling, thus saving rig time, and, ultimately, permitting correction of the course of the well in response to the information, without pulling the drill string out of the hole.

The early practice of MWD supplied the measurement of drill string position in 3-D space, and, perhaps, did not fulfill all the criteria of a disruptive technology in part because of its somewhat ready acceptance.

Service companies in the business being cannibalized- surveying by conventional means- accepted versions of MWD in their structure. The measurements in the new technology were substantially of the same quality as the one being replaced.

Bower and Christensen observed that in the disk drive business, three waves of entrant companies led the changes. The first point was when hard disk drives (8") invaded the mini-computer market. The second wave was when 5.25" drives invaded the personal computer market. The third invasion was with 3.5" drives in the portable-computer market.

Similarly, in the MWD business, the first foray was in the directional business, the second in formation evaluation, and the third in horizontal drilling. Like hard disk drives, innovations in different MWD segments raised each technology's capabilities to such a great degree that they soon surpassed customer expectations in each of the established markets

For example, In the formation evaluation segment, the early MWD measurements were not readily accepted as a replacement for wire line measurements. However, they were recognized as being augmentative to the measurements made by wire line methods, and provided value through stratigraphic correlation. The resistivity measurements were in the realm of formation identification rather than evaluation. They did not represent a valid threat to the wire line industry.

Then, in 1983, NL Industries introduced EWR, the first truly quantitative Formation Evaluation MWD (FE MWD)

The EWR Story

EWR (Electromagnetic Wave Resistivity) opened the door to legitimizing MWD as a substitute for wire line logs in reservoir sections. Subsequent FE MWD measurements were not as accurate as their wire line counterparts. This rationalization of less accuracy being acceptable because of benefits in other areas (drilling related cost saving) may never have occurred had it not been for the extraordinary quality of the EWR measurement.

Resistivity is arguably the single most important FE measurement. It serves to identify rock as being hydrocarbon bearing, but its key role is in estimating the relative proportion of oil and water in the fluid mix present in the formation. This fraction, known as Hydrocarbon Saturation, is a key to estimating the commercial viability of the reservoir. The other important measurement, porosity, estimates the fraction of total rock occupied by fluids.

While both properties are important in an exploratory well, in the bulk of wells drilled, development wells, resistivity is more valued. This is because porosity does not change over the life of the prospect, but resistivity does as the hydrocarbon is produced.

The developers of EWR recognized the key feature of EWR as being the vertical resolution, which is defined as the ability to accurately estimate the resistivity of a thin bed when bounded by beds of different character. This feature was recognized by Shell petrophysicists as a possible means to evaluate a relatively new class of extremely productive reservoirs known as Turbidites.

Conventional wire line methods, in some cases, could not even locate the reservoirs, and quantitative evaluation was out of the question because of the sequence of thin beds, each as narrow as a few inches. As a result, EWR made its name in a niche application, but the impact on FE MWD as a whole was more profound and broad scale.

As it has turned out, the niche is now the big game. Most of the prolific deep-water discoveries comprise turbiditic reservoirs, and these have transformed the Gulf of Mexico into a hive of activity.

Curiously, yet another leap in FE technology, that of Nuclear Magnetic Resonance tools, also has found unique applicability in this type of reservoir. Ironically, the key attractive feature of this technology is its inability to “see” the non-hydrocarbon bearing rock. As a further matter of interest, the threatened wire line industry did produce the Array Induction Tool, which matched or exceeded the features of EWR and its later improvements. But to misquote Mick Jagger, ”time is on our side” (or rather, MWD’s side). Earlier information, in the drilling process, means earlier decisions.

The Case for EWR Being a Disruptive Technology

EWR was the first commercial offering emanating from an elite group, named DST, formed by NL. This was a separate unit, dedicated to the development of MWD services. Up to that point MWD resistivity development had been conducted by companies performing MWD research in the mainstream of their business; the results, while unsatisfactory, provided a base line for NL to measure against.

In October 1985, two Shell petrophysicists presented a paper that caused a minor tremor (Greif and Koopersmith, 1985). They claimed to have used EWR to eliminate wire line logs on twelve of the twenty-four wells of the Cougar platform. Additionally, the use of EWR resulted in "recognition of commercial hydrocarbon intervals that otherwise would have been bypassed".

The following summer, either coincidentally or causally, Schlumberger set up a grouping of elite scientists and engineers, much as NL had done in forming the DST group. This group did not report to the developer and purveyor of MWD services- Anadrill. This entity was successful in developing FE MWD tools. Eventually, the commercialization was handed over to Anadrill. NL also initially commercialized the tools under a separate divisional banner, eventually folding this unit into the Sperry Sun division.

At this juncture it is useful to take stock of the criteria that Bower and Christensen (reference) lay down as indicative of disruptive technologies' success:

1) Often developed in an independent organization
2) Commercialized in independent organizations
3) Initially under perform in one or two dimensions important to customers
4) Tend to be used at first in new markets or applications.

The first three characteristics were in fact met, as described earlier. In point of fact, the fourth was as well, by EWR, in that the Shell petrophysicists took the risk they did because their application was unique. The turbidite deposits on Cougar were poorly evaluated by wire line techniques. EWR's shortcomings, the principal one being smaller investigative depth, were outweighed by the benefit of recognizing turbidite deposits. In fact a pervasive theme in the rise of use of MWD for formation evaluation has been the acceptance of somewhat less data quality for the greater good of well-cost savings. This transition, from the valuation of discrete services in isolation, into that of optimizing well cost was an important step that occurred in the late eighties, mediated in large part by MWD.

Transition from Cost per Foot to Cost per Well

Before MWD, well services, and drilling services in particular, were purchased on the basis of minimizing the cost per foot of well drilled. While this remains an important metric for the oil company, it has been increasingly re examined as the sole basis for the choice of services.

In the most simplistic analysis, MWD service charges caused the cost for the well segment to go up, but post-drilling costs were saved in the form of wire line deployed instrumentation. Initially the services replaced were those of wire line surveying, but later it also included formation evaluation services.

Increasing sophistication in the use of MWD allowed further savings brought about by, among other factors, the use of information obtained earlier than it would have been otherwise. Thus, the overall well cost was reduced despite higher costs incurred in particular segments. This total cost divided by the measured depth was still a useful metric but was decreasingly used for the purpose of choice of individual expenditures.

Thus, while early MWD was justified solely on the basis of service cost it replaced, increasingly, the justification shifted to impact upon the well cost by improved decision making. This behavior by young engineers was not encouraged by the departmental structure of oil companies, nor by the formal measures of success. Nevertheless, this shift in behavior commenced, and, several years later, the reorganization of oil companies into asset units strongly facilitated it and, in fact, formally legitimized it.

Disruptive behavior is created and propagated when different disciplines of an enterprise work together, in a coordinated fashion, towards a common goal. FE MWD and EWR created a tight, real time interaction and promoted integration between the Geoscientists (petrophysicists and geologists) and Drilling Engineers during, not after, the drilling process.

The transition to cost per barrel could not have taken place if they did not work together, accommodate each other, and change practices. And over time, a common goal evolved- the organizational perspective of $ per barrel prevailing over a department's compartmentalized goal of $ per foot.

Disruptive Behavior

True disruptive behavior is that which results in significant changes in business practice, to the point of becoming the new norm at some juncture. Resistance to change is likely greater than in the case of disruptive technologies, thus making the transition to a new norm longer and more significant.

The oil services case study underscores this point. But first it is instructive to examine the criteria that often describe such behavior. The impetus of a disruptive technology is greatly facilitative in creating disruptive behavior. It emboldens decision-makers to push the behavior envelope because of the economic promise of the technology. This was indeed the case in the EWR case cited above, and MWD in general.

The second requirement is that the disruptive behavior be mirrored in the service company, albeit in a modified form. A one off success does not require this, but sustained broad scale change does. In this case the need was that service companies shift their behavior from being mere fillers of orders to becoming more of collaborators.

Eventually, when oil companies moved to asset units, serving their needs required an even higher degree of interaction bordering on partner status. The behavioral changes required for this were enormous and were facilitated by other events, as described later. This shift in service company behavior would be in clear recognition of a shift in what the buyer now considered to be higher value. This shift is known as the phenomenon of Value Migration, also described in greater detail in a later section.

A third criterion for success is that the disruptive behavior originates in bell-weather customers, making it more difficult to ignore. In this aspect, there may well be a departure from disruptive technologies. Oil related companies, being more steeped in convention than most, are more likely to change when bellwether companies act as beacons and show the way.

The corresponding change in service companies is easier for companies in the forefront of new technologies, which have already experienced the need to have more of a collaborator status in order to market these technologies. Institutional memory is a severe detriment.

The Cost Per Well to Cost Per Barrel Transition

In order to discuss the disruptive behavior that occurred in the late eighties, we need to first examine the technologies and economic considerations that triggered that behavior. First, we should be clear on the point that these transitions, being related to human behavior, are gradual. Even the statement that a given behavior is the norm, carries with it the understanding that at best we can expect a Gaussian, or Normal, distribution, with mavericks stretching the concept at one end, and traditionalists sticking with the previous norm at the other.

Horizontal wells comprise one of the single greatest productivity advances ever in the oil and gas business. The concept centers around the fact that the majority of the reservoirs of the world are horizontally placed, because sediment deposition occurs in that manner. The exceptions are when beds get uplifted by other geological phenomena, but in these instances, the basic concept of drilling horizontal wells still applies, which is that the well follows the slope of the producing formation. This dramatically increases the footage of the well in direct contact with the reservoir fluids, thus increasing the production rates over those in a conventionally angled well. This is particularly advantageous when the producing interval of interest is narrow.

The key enabling technology is that of steerable systems, a technique that allows the drilling assembly to be 'steered' in 3-D space without having to pull the drill string out of the hole. The counter-intuitive means for accomplishing this was born out of practical problem solving in the field, most likely during drilling operations in Alaska. A crucial facilitator was the ability to measure position on the fly using MWD.

Reservoir engineers had always known that better drainage would be achieved with such a well geometry, but drilling had not been able to deliver. Now that a well could be drilled in this manner, the next hurdle was that the early horizontal wells cost as much as 2.7 times vertical wells. The cost per well dictum had to be sacrificed against the delivery of fluids more effectively.

In other words, a coordinated engineering decision spanning at least three disciplines: drilling, geology and petrophysics, and reservoir engineering. It became acceptable for the well to cost more if it delivered more. This spurred the shift towards a *cost per barrel* thinking. Again, departmental structures were not facilitative of this type of decision making, and therefore, this shift in fact represented disruptive behavior.

The Shift to NPV of Asset Thinking

The next major advance in draining reservoirs occurred with the advent of multilateral wells. These wells permit multiple laterally displaced drainage arms emanating from a single stem. The first commercial emplacement transformed the economics of that heavy oil reservoir (Smith et al, 1995). Improvements to this technique offer the promise of draining multiple zones in a sequence that maximizes early production and increases net recoverability (Cheatham and Rao, 1998), which is the fraction of total hydrocarbon in place that is recovered.

The means for accomplishing this are variously referred to in the industry as Intelligent Completion, Smart Wells (a term coined by Shell), and Active Reservoir Management ™. The availability, and to some extent, simply the promise of, these technologies, permitted the shift from *Cost per Barrel* thinking to *NPV of Asset* thinking, where NPV stands for Net Present Value, and, in fact, is cost per barrel thinking, with time value of money being added as a variable.

A few years before the invention of multilaterals, in the early nineties, it became clear to many oil companies that the departmental structure militated against cost per barrel type of thinking, and the concept of asset units was born.

BP was the first company to reorganize based upon independent assets. Shell introduced the concept of integrated services in its Drilling in the Nineties initiative, wherein drilling contractors led an outsourced package. Although it has similar underlying philosophies, it is not to be confused with the concept of asset units. The asset unit concept has been enduring, and is gathering momentum.

The Case for Disruptive Behavior Driving the Improvements in Oil and Gas Economics in the Nineties

We postulate that the disruptive behavior in question is the shift in the thinking of decision makers- away from minimizing cost of portions or compartments of the endeavor, to optimizing the overall economics of reservoir fluids delivery. This was a shift from the cost world to the value world.

A key factor in the disruptive behavior taking hold was the confluence of three major circumstances (Figure 1):

1) The evolution of disruptive technologies like MWD and others (like 3D Seismic, 3D Visualization, and Computing Technologies) that required and enabled an integrated approach, across disciplines, to effective FD&L of oil and gas.

2) Evolutionary psychologists claim that human behavior is hardwired (Nicholson, 1998). The general human tendency is to avoid loss when comfortable but to scramble when threatened. The instinct is to take risks as soon as losses start to mount, and to fight furiously for survival when threatened. The unusually harsh economic circumstances of low oil prices coupled with the relatively high FD&L costs created a sense of urgency that sought aggressive measures, and promoted an environment of risk taking during the last decade.

3) Industry leaders and bellwether companies led the way in being more accepting of technology and risk taking, and, thereby, organizational behavior, as the key to changing FD&L processes.

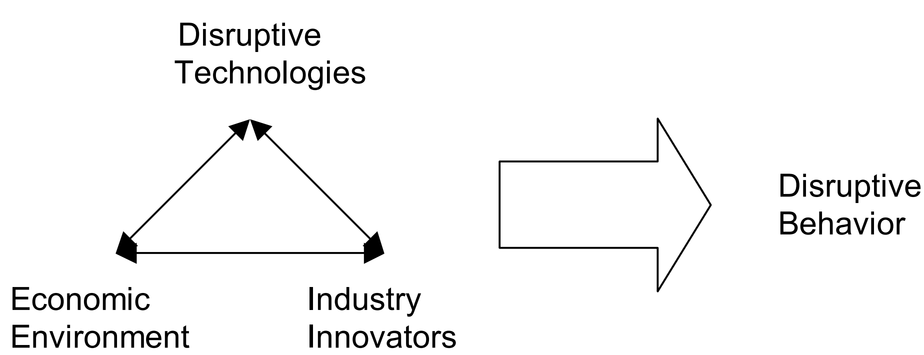

Figure 1

The corresponding behavior change required of service providers was even more profound, in part because it required them to better understand the evolving objectives of their clients. The transition from order taker to collaborator was alien and bordering on the presumptive.

Early practitioners were considered arrogant by sister divisions for whom the conventional mores were still working. Best positioned were divisions offering the disruptive technologies of the time, to the right customers, and therefore, party to the value migration process.

The Shift to NPV Based Decision Making- A Study in Value Migration

Value migration is a fascinating concept originated by Adrian Slywotzky, and best described in the book, Value Migration (Slywotzky, 1996). It comes into play in all walks of commercial life, and involves a shift in what attributes of a service the customer values. For the migration to occur requires both changes in the value beliefs of the customer *and* a service provider capable of delivering.

Typically, therefore, this is more likely to happen in cases where the client and provider have a partnering relationship. Also, it is more likely to happen when a provider develops a unique service with a good understanding of the business of the client. True value migration is judged by whether the new set of beliefs is embraced by more than a few.

Service companies that recognize the migration in the early stages are able to move to improve their service mix to include higher value offerings. This is of particular importance because the services out of which value has migrated, usually, drift towards commodity status.

An example of this is shown in Figure 2. Drawn here is the sequence of service development starting with horizontal wells. The directional drilling technology for drilling these wells is widely available. The more recent advance of multilateral drilling is on the ascendancy to eventual maturity and commoditization.

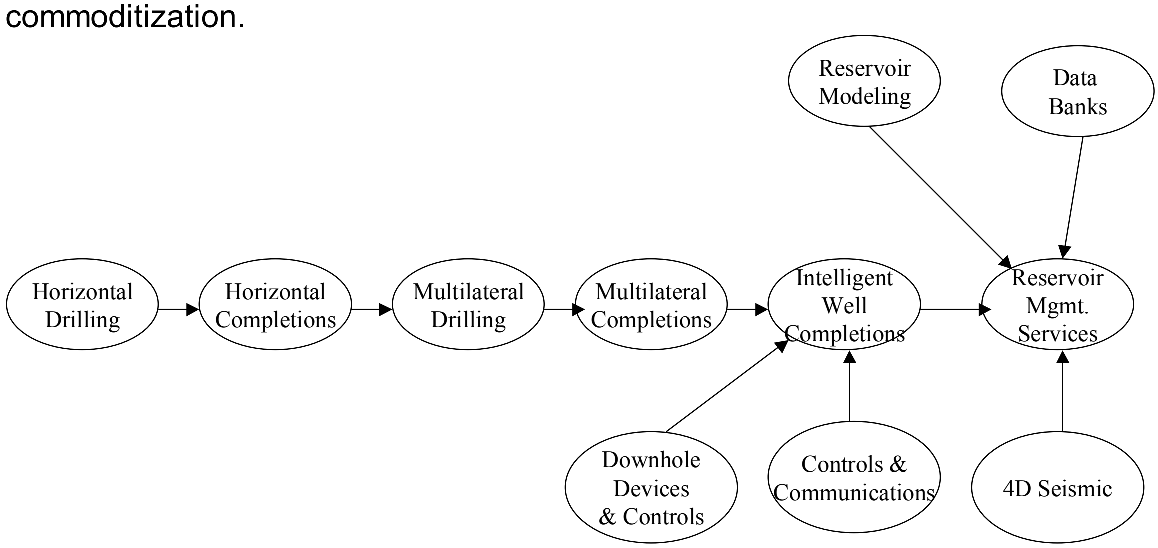

Figure 2

The recognition that in many reservoirs, proper completion techniques can make the difference in productivity has resulted in value migrating towards completions. Intelligent completion takes it to the next level of value, wherein with the aid of downhole sensors and flow control devices, production from the multiple legs can be maximized and net recoverability also increased. Finally, all the other measurements aiding this endeavor, such as 4D seismic, and the reservoir management software for decision making, take on importance.

As the vision gets progressively realized from left to right, the value migrates in that direction. Profit margins for the services on the left do not necessarily erode until there are multiple practitioners. Even then, quality of service will still remain a differentiator.

In the MWD service world, value is migrating away from individual tool attributes to interpreted results from them, most preferably integrated with other forms of data to permit the most timely decisions. This notwithstanding, because of the high cost of operating drilling rigs today, the reliability of the discrete downhole tools is still a major differentiator.

Conclusions

Disruptive behavior is defined as the actions of few which are in strong variance with the norms of behavior, and which provide a stimulus for change, such change causing a significant improvement to the business design over time.

We postulate that disruptive behavior is a means by which change is effected in the process of value migration (Slywotzky, 1996). The business design and process changes that occurred in the oil and gas drilling and production sector in the period mid-eighties to mid-nineties can be explained as a value migration phenomenon driven by disruptive behavior.

The behavior in turn was driven by the confluence of three factors: 1) The emergence of disruptive technologies, the key ones being MWD and 3D Seismic, 2) grave economic conditions, and 3) innovative personnel willing to drive change in behavior, including cross-disciplinary integration.

We suggest that successful service companies would be well served to have a corporate function dedicated to recognizing value migration, and the triggering disruptive technologies, in the early stages, in order to exploit the disruptive behavior likely to follow.

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