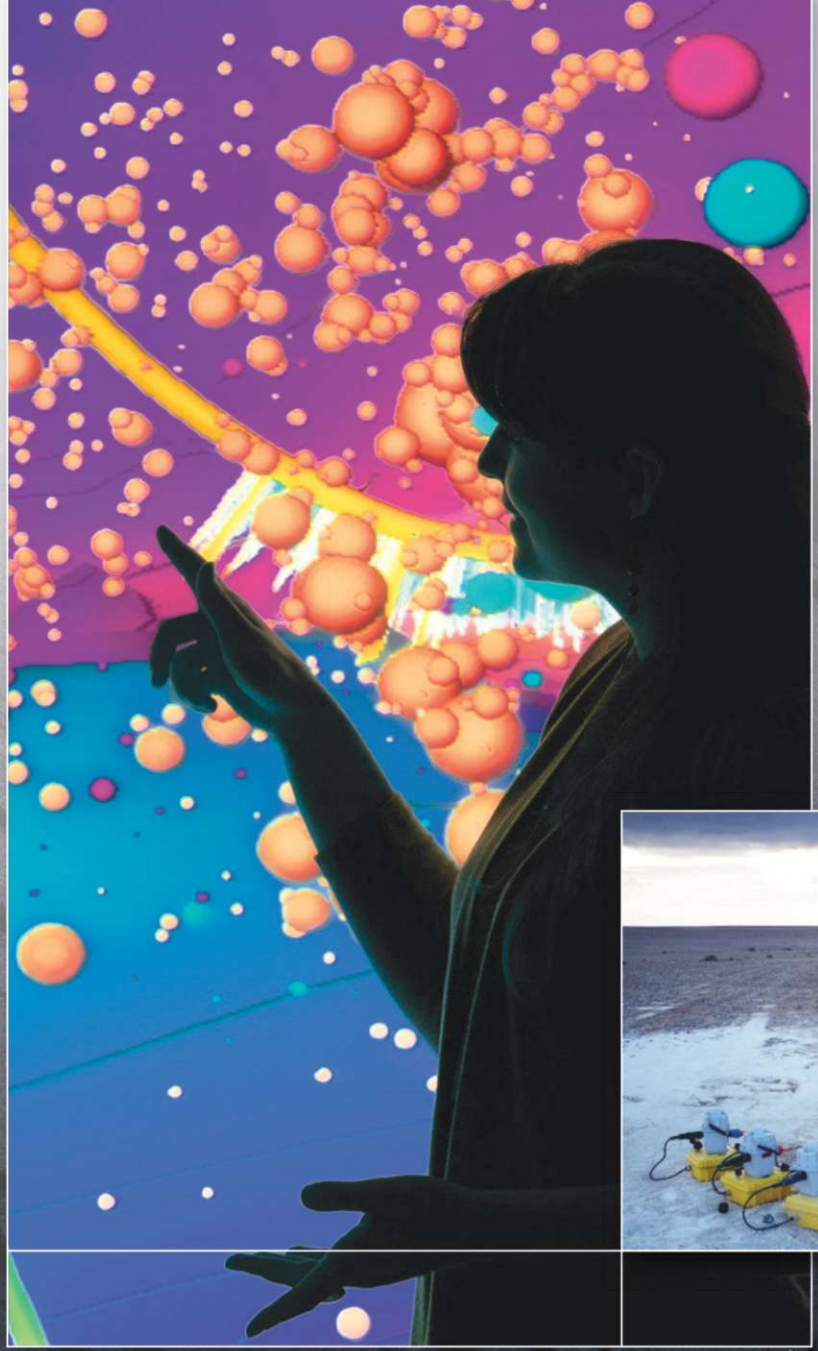
HARTENERGY

Eagle Ford Techbook

Drilling and Completions

A supplement to

E&P



Microseismic

HYDRAULIC FRACTURE
MAPPING SERVICES

Without an accurate map of your fracture network, you could be pumping money into the wrong place.

This year, an estimated USD 47.6 billion will be spent on hydraulic fracturing. Microseismic monitoring is one of the few measurements that helps evaluate the effectiveness of stimulation treatments. Combining real-time data processing and analysis with microseismic measurements from downhole or surface arrays enables optimizing completion treatments as they happen, reducing unnecessary costs. Since 2003, our field-proven microseismic services have helped customers evaluate their stimulation effectiveness and recovery in every active US shale play.

Learn more at
slb.com/microseismic

Schlumberger

E&P

Eagle Ford Techbook
Drilling and Completions

A supplement to *E&P*

HART ENERGY
1616 S. Voss, Suite 1000 | Houston, Texas 77057
Tel: +1 (713) 260-6400 | Fax: +1 (713) 840-8585
hartenergy.com

Editor in Chief **MARK THOMAS**
Group Managing Editor **JO ANN DAVY**
Executive Editor **RHONDA DUEY**
Senior Editor, Drilling **SCOTT WEEDEN**
Senior Editor, Offshore **JENNIFER PRESLEY**
Senior Editor, Production **AMY LOGAN**
Chief Technical Director **RICHARD MASON**

Contributing Editors **KELLY GILLELAND**
BRUCE NICHOLS
TRAVIS POLING

Associate Managing Editor **MARY HOGAN**
Associate Managing Editor, *E&P* **BETHANY POLLER**
Associate Online Editor **VELDA ADDISON**
Assistant Editor **ARIANA BENAVIDEZ**

Corporate Art Director **ALEXA SANDERS**
Senior Graphic Designer **NATASHA PITTMAN**
Production Director **JO LYNNE POOL**
Marketing Director **GREG SALERNO**
For additional copies of this publication, contact Customer Service +1 (713) 260-6442.

Vice President – Publishing **RUSSELL LAAS**
Vice President – Publishing **SHELLEY LAMB**
Director of Business Development **ERIC ROTH**

HARTENERGY
Editorial Director **PEGGY WILLIAMS**
President & Chief Operating Officer **KEVIN F. HIGGINS**
Chief Executive Officer **RICHARD A. EICHLER**

Hart Energy's Techbook Series

The 2014 Eagle Ford Techbook is the third in a series of techbooks in which Hart Energy provides comprehensive coverage of effective and emerging technologies in the oil and gas industry. Each techbook includes a market overview, a roster of the key technology providers, case studies of field applications, and exclusive analysis of industry trends relative to specific technologies.

To learn more about E&P technology trends, visit *EPmag.com*.

Table of Contents

Held aloft by a crane, a worker prepares to loosen the lubricator at one of four Gloria Wheeler wells during a zipper frac for Comstock Resources Inc. *(Photo by Tom Fox)*

The Eagle Ford Shale, Energy Titan of the Southwest

After a frenetic half decade, operators are settling into the resource harvest phase of the Eagle Ford shale.

By Richard Mason
Chief Technical Director, Upstream

Behold the mighty Eagle Ford shale, energy titan of the Southwest!

The play is one of two on the vanguard of creating an oil production renaissance in the US. With unofficial data (non-Texas Railroad Commission) indicating Eagle Ford production climbing toward 1 MMb/d of oil (and 1.5 MMboe/d including liquids and natural gas), the Eagle Ford is neck and neck with North Dakota's Bakken shale in claiming supremacy as the US region generating the largest contribution to rising domestic oil production, which is up more than 50% in the last four years to 7.7 MMb/d.

Today's Eagle Ford is all about transformation. The play has evolved beyond the growing pains of discovery and delineation in 2009 to 2011 and the infrastructure bottlenecks characteristic of the optimization phase in drilling and production practices in 2011 to 2012. In 2014, operators are "all in" when it comes to the resource harvest phase of unconventional development with its promise of free cash flow for those able to master the sizeable organizational and engineering challenges of economically coaxing oil and NGL from tight formation geology.

During the last two years, Eagle Ford operators have made extraordinary gains in drilling efficiency, reducing drilling time — and well cost — partly through the use of Tier I technology rigs well-suited to marry digital integration from the rig floor with a new generation of downhole tools and rotary steerables. Add in the ability to move quickly between multiple wells on a single location and lots of practice in the more than 5,000 horizontal wells drilled in the play, and it is harvest time in the Eagle Ford.

Since 1Q 2012, drill days have fallen 21% to an average of 18 per well, according to RBC Capital. Those gains were compounded in 2013 with the rapid evolution to pad drilling, which grew from less than 20% of horizontal wells in the Eagle Ford in 4Q 2012 to north of 70% of horizontal wells early in 2014. Individual companies, like Pioneer Natural Resources Co. or Marathon Oil Corp., have gone from less than 20% of horizontal drilling on pads in early 2013 to virtually 100% in early 2014. Few industries have witnessed such massive transformation in so little time.

In today's Eagle Ford, operators seek to extend efficiency gains to completion practices, experimenting with tighter spacing between laterals, the

Facing page:
C.J. Gibbs and Scooter Lewis prep equipment on the Gloria Wheeler C4H for a stage frac in McMullen County, Texas. The four pad-drilled Gloria Wheeler wells in Eagleville field were undergoing a zipper-frac treatment involving alternating stage stimulation in parallel horizontal laterals. *(Photo by Tom Fox)*

use of zipper fracs to increase the volume of stimulated reservoir rock, and clustering stages at sweet spots along laterals to boost recoveries beyond the estimated 3% to 5% and estimated ultimate recoveries of 350,000 boe operators believe they are capturing. Operators also are experimenting with stacked laterals to exploit more reservoir rock at different depths within the formation and looking at additional targets including the Austin Chalk, the Buda Lime, and Pearsall formations both above and below the Eagle Ford.

It is still early on the completion side when it comes to efficiency gains, but progress appears to follow operator experiments with flow rates, sand volumes, and perforation spacing as hydraulic horsepower is focused closer to the wellbore, lessening interference between laterals even as well costs continue to decline.

A tour of pad drilling operations in the Eagle Ford looks more like a visit to an open-air well factory rather than a discrete oil and gas operation as the region sprouts retention ponds, central gas processing facilities, and clusters of pumpjacks or wellheads that follow the relentless march of walking rigs across the sere South Texas landscape. Those facilities are built in a just-in-time process as operators move forward on drilling, completion, gathering, processing, and takeaway infrastructure virtually simultaneously, accelerating the process that gets new flush hydrocarbon production into the price-favored Gulf Coast market place.

Getting here wasn't easy. As the play ramped up from 2010 to 2012, shortages of equipment and crews created tight market conditions and spiraling well costs. When natural gas prices collapsed in 2012, equipment rotated into the liquids-rich Eagle Ford from other US markets, creating an oversupply that resulted in deflating pricing for oil services. Fracture stimulation dropped on a per-stage basis from US $200,000 per stage in 2012 to well under $100,000 per stage in 2014. Subsequently, well costs fell from more than $9 million to less than $7.5 million, depending on depth and lateral length. In some cases, well costs are dropping below $7 million, though oil services pricing, always a major component of well cost, has stabilized and might move modestly to the upside in 2014 depending on macro factors in the natural gas market.

The Eagle Ford is highly concentrated among operators, particularly in the Karnes Trough sweet spot of DeWitt, Gonzales, and Karnes counties and in La Salle and McMullen counties directly south of San Antonio. Seven operators preside over 200,000 or more acres each, including EOG Resources with nearly 640,000 net acres under lease. A majority of top operators are majors, former majors, or the largest of public independents, a group that includes some of the most technically astute oil and gas companies in the world. One has to drop far down the acreage rankings to find private operators, though many are there, having nimbly carved out their own piece of the Eagle Ford pie.

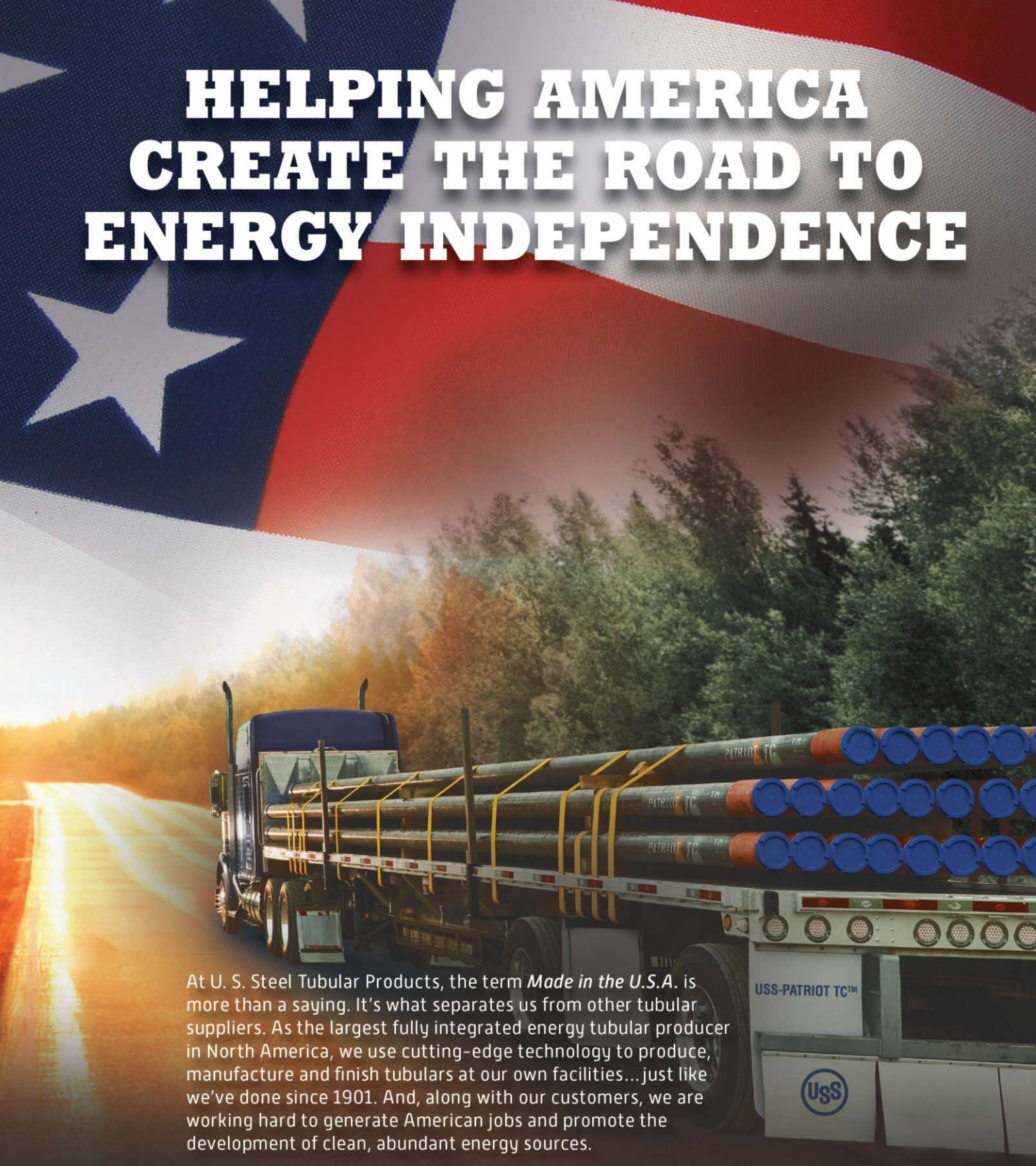
Leading Acreage Positions in the Eagle Ford

Company	Acres (x 1,000)
EOG	639
BP	400
Chesapeake	380
BHP	340
Shell	270
ConocoPhillips	227
Anadarko	200
Marathon	200
Newfield	185
Murphy Oil	159
SM Energy	145
Pioneer Natural Resources	118

Source: RBC Capital Markets and Hart Energy North American Shale Quarterly

Meanwhile, smaller public independents like Sanchez Energy Corp. ($635 million in 2014 capex, 70 net wells), SM Energy Co. ($650 million, 100 net

HELPING AMERICA CREATE THE ROAD TO ENERGY INDEPENDENCE



At U. S. Steel Tubular Products, the term *Made in the U.S.A.* is more than a saying. It's what separates us from other tubular suppliers. As the largest fully integrated energy tubular producer in North America, we use cutting-edge technology to produce, manufacture and finish tubulars at our own facilities... just like we've done since 1901. And, along with our customers, we are working hard to generate American jobs and promote the development of clean, abundant energy sources.

Call 877-893-9461 or visit www.usstubular.com and see how we are helping create the road to energy independence.

Made in the U.S.A.
for more than 100 years™

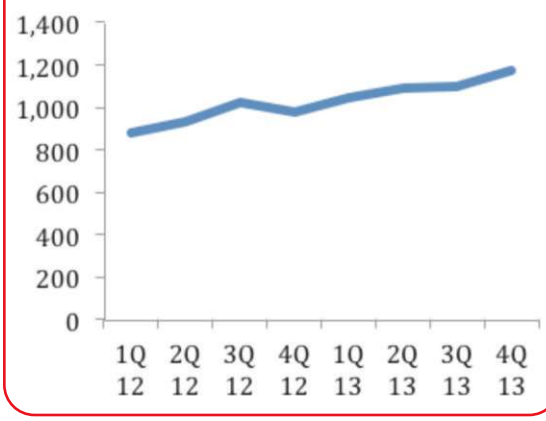
USS U. S. Steel Tubular Products

Right: Drilling mud tests are underway at Halcón Resources' Bumble Bee 1H well in Brazos County, Texas. *(Photo by Mieko Mahi)*

wells), Cabot Oil & Gas Corp. ($350 million, 45 net wells), Penn Virginia Co. ($525 million, 52 net wells), and Carrizo Oil & Gas Inc. ($440 million, 47 net wells) combine savvy bolt-on acquisitions and technological expertise to either extend the boundaries of the play outside the core or capture ever greater yields by applying learnings gained through the manufacturing analog that characterizes pad drilling and batch completions in the oil patch.

While Eagle Ford rig count, at roughly 220 units, has plateaued — it was actually 10% off the peak in 2Q 2012 — quarterly well count continues to grow and topped 1,170 in 4Q 2013, according to Baker Hughes. Despite a lower average rig count, Eagle Ford operators drilled 16% more wells in 2013 than they did in 2012.

Eagle Ford Well Count



Source: Baker Hughes

Buying in

Operators continue to position themselves in the Eagle Ford as they use acquisitions to add liquids and oil production to existing portfolios. The play has been the sole focus for $20 billion in announced transactions since January 2011. When Eagle Ford acreage is broken out of larger transaction packages, such as the BHP Billiton/Petrohawk $15.1 billion deal in July 2011, combined transaction value in the Eagle Ford easily exceeds $25 billion, putting the play on par with both the rejuvenating Permian basin and the consolidating Gulf of Mexico in domestic transaction valuation. In all, the Eagle Ford shale accounts for 14% of announced domestic transaction volume during the last three years, and those transactions continue.

In November 2013, Devon Energy Corp. acquired GeoSouthern Energy Inc.'s Eagle Ford assets for $6 billion, constituting the largest single Eagle Ford transaction to date. That deal was followed in February 2014 when Canada's Baytex Energy Corp. purchased Australia-based Aurora Oil & Gas Inc., including prime acreage in the Sugarkane field in the heart of the Karnes Trough for $2.35 billion, clearly the most prolific portion of the play. That transaction valued Aurora's 22,100 acres at roughly $50,000 per acre, on par with what Marathon Oil Corp. paid for the best parts of the Hilcorp package it acquired in a June 2011 $3 billion deal.

Devon, Baytex, and Marathon were looking for prime acreage position in the heart of the play and were ready to pay up for the privilege. Another entrant by purchase is EXCO Resources Inc., which picked up 55,000 acres in the oil window from Chesapeake Energy Corp. for $685 million in July 2013.

CLEANER. FASTER. SMARTER.

The Evolution® high-performance, water-based fluids system is so clean, fast and smart, you'll be done with your well and on to the next in no time. Faster penetration rates, greater cost savings and compliance with environmental standards all enhance the value we deliver to our customers. Helping you evolve in unexpected ways is what we do best.
Learn more at **www.newparkdf.com/evolution.**

EVOLUTION®
THE HIGH-PERFORMANCE,
WATER-BASED FLUIDS SYSTEM

NEWPARK
DRILLING FLUIDS

Eagle Ford Acquisitions and Divestitures

Buyer	Seller	Date	Value ($MM)
Devon Energy Corp.	GeoSouthern Energy Corp.	11/20/13	$6,000
Marathon Oil Corp.	Hilcorp Energy Co.	6/1/11	$3,500
Baytex Energy Corp.	Aurora Oil & Gas Ltd.	2/6/14	$2,350
Korea National Oil Corp.	Anadarko Petroleum Corp.	3/21/11	$1,550
Marubeni Corp.	Hunt Oil Co.	1/6/12	$1,300
Mitsui & Co. Ltd.	SM Energy Co.	6/29/11	$750
Marathon Oil Corp.	Paloma Partners II LLC	5/9/12	$750
EXCO Resources	Chesapeake Energy Corp.	7/3/13	$685
Penn Virginia Corp.	Magnum Hunter Resources Corp.	4/3/13	$401
Other			$2,746
Total			$20,032

Source: Hart Energy A&D Database

Acquisitions also enable companies to extend Eagle Ford acreage. Penn Virginia Corp. expanded its Eagle Ford holdings in the northern part of the play in Lavaca and Gonzales counties in April 2013, buying out Magnum Hunter Corp.'s 19,000 Eagle Ford acres for $401 million. Penn Virginia has subsequently pushed the Eagle Ford sweet spot to the north and east of the original Karnes Trough core following the acquisition.

Private equity, which financed the earliest development in the play, continues to both enter and exit the Eagle Ford, signaling healthy deal flow in an otherwise stable market. Kohlberg Kravis Roberts & Co. LP (KKR) initially exited the Eagle Ford in June 2011 with the $3.5 billion Hilcorp sale to Marathon, but then it came back a year later with $200 million in joint venture (JV) financing for Comstock Resources Inc. to accelerate development in its McMullen County Eagle Ford sweet spot. KKR's portion of the JV was valued at $25,000 per acre.

Meanwhile, JVs with buyers from around the globe have contributed more than $7.7 billion in developmental capital to the Eagle Ford — second only to the Marcellus and Utica shales. JVs also account for roughly one-third of transaction values in the South Texas play.

A $35 billion oil services market

The Eagle Ford represents an $8 billion drilling and completion market characterized by more than 80,000 stages annually. At $7.5 million per well, estimated expenditures will top $35 billion in 2014. Figures from the University of Texas at San Antonio Institute for Economic Development suggest the Eagle Ford contributes more than $61 billion in gross domestic product and 116,000 jobs statewide directly and indirectly.

While those headlines are impressive, it is the work in the field that makes the Eagle Ford go. As an unconventional play, the Eagle Ford features the greatest concentration of Tier I rigs in the domestic market with more than 160 units classified as higher-end technology rigs or roughly 71% of Eagle Ford rig count. Only the Permian basin features more rigs drilling horizontally, and no region features as high of a Tier I technology rig market share as the Eagle Ford.

Technology and engineering will play an important role in 2014 as operators transition to tighter downspacing and solve issues surrounding how to coax greater recoveries out of tight formation reservoirs. While maturity is the first word that comes to mind when viewing today's Eagle Ford, the technical staffs at a majority of operating companies readily admit it is still early days in the mighty Eagle Ford shale. ■

Calfrac leads the way in extracting oil and gas from some of the toughest reservoirs in the world. We're proud to announce our new home in **San Antonio, Texas** which allows us to better serve customers. As a top-tier pressure pumping company, we pioneer innovative hydraulic fracturing and completions solutions that help our customers grow and yield maximum production—even in the most challenging unconventional plays.

Welcome to Calfrac. Welcome to the future of oil and gas production.

CALFRAC WELL SERVICES

www.calfrac.com

Pad Drilling Productivity

The Eagle Ford shale played a crucial role in the application of pad drilling to exploitation of tight-formation oil and gas.

By Richard Mason
Chief Technical Director, Upstream

After the dust settled from a whirlwind 2013, it rapidly became apparent that the oil and gas industry had passed through a significant inflection point. That inflection point involved the wholesale transition to pad drilling and batch completions as the major component in how field operations were conducted in tight-formation development.

Pad drilling, which involves boring multiple wells from a single surface location, and its companion process, batch completions, now characterize nearly three of four horizontal wells in the domestic market. The transition was swift and thorough. In 4Q 2012, less than 20% of horizontal wells were drilled on pads domestically. At year-end 2013, the number was closer to two-thirds of horizontal wells, according to Hart Energy industry surveys.

The move to pad drilling in 2013 revitalized new rig construction as operators sought Tier I technology rigs with self-moving packages either on skids or walking systems to adapt to the new environment. Tier I rigs serve as a platform to leverage the capabilities of modern downhole tools and directional steering systems to develop better wellbores.

"Once you move into that level of technology on the drilling rig itself, you have finer control over everything that is happening at the surface that affects your downhole environment," said Andy Hendricks, CEO for Patterson-UTI Energy Inc. "By doing so, you can use other high-end technologies to maximize that, like PDC [polycrystalline diamond compact] drillbits and advanced directional drilling systems. Having that high-spec rig out there improves the performance and reliability of the other components that you bring to the table while you are drilling."

The contract drilling industry will add between 80 and 100 new rigs in 2014 with nearly 70% of those units from the three largest domestic land drillers.

Although the Eagle Ford shale was not the first basin to make the transition to pad drilling, it was the first to do so specifically for economic advantage and serves as a model for how tight-formation oil and gas operations will evolve.

Operators began pursuing pad drilling in dry gas basins in the Rockies a decade ago, initially to overcome land use and wildlife regulatory issues. Pad drilling became an important part of the Barnett shale development after 2007 because so much of the formation underlay an urban environment. Regulatory and terrain issues also played a role in expansion of the technique to the Marcellus shale in 2011. Up until this point pad drilling was a niche solution in the operator's arsenal for exploiting tight-formation oil and gas.

However, the process took an important step forward in the Eagle Ford. There were few land use restrictions or regulatory issues facing operators in the Eagle Ford. Instead, operators determined that they could use larger surface locations in rural and mostly flat South Texas to add more wells to facilitate the economic potential of developing the Eagle Ford shale.

The major move to pad development occurred in late 2012 after large publicly held companies had

Facing page:
Natural gas flaring illuminates the night sky as two new pumpjacks are installed on pad-drilled wells for Comstock Resources Inc. on the Gloria Wheeler lease in McMullen County, Texas. *(Photo by Tom Fox)*

acquired substantial acreage blocks, in the case of Marathon Oil Corp., or sold joint venture interests in large existing acreage blocks to finance rapid development, in the case of Pioneer Natural Resources. Pad drilling became the quickest way to pursue simultaneous development and the concurrent infrastructure buildout to get growing volumes of hydrocarbons to market quickly.

In doing so, the Eagle Ford became the pilot through which the process of pad drilling and batch completions became the predominant way to develop tight-formation resources domestically.

Tight-formation development cycle

Pad drilling and batch completions are ideally suited to the resource harvest portion of the tight-formation oil and gas development cycle. The cycle evolves in stages from discovery and delineation in a new play, usually in the first two years, into optimization as operators and service companies work out the formula to properly exploit tight-formation hydrocarbons in an economic manner. It takes operators about two to four years to solve engineering challenges unique to each play. Afterward, the development effort transitions into a resource harvest phase, typically within four years of discovery. The best analog for the resource harvest effort is a manufacturing operation as operators employ batch processes and supply chain management in a just-in-time setting to capture economies of scale. In an ideal world, operators transition from outspending cash flow in the delineation and optimization phases into a net positive free cash environment following years of intensive capital investment.

The discovery and delineation portion of the cycle might require 100 horizontal wells to effectively define the parameters of a new tight-formation play. During the optimization phase, operators eventually move well count up to 1,000 as they investigate what works in exploiting the geology. As the cycle progresses into the resource harvest phase, operators methodically work their way through acreage sweet spots. The total well count in the resource harvest phase can exceed 10,000 or more in the largest basins.

Consequently, the rise of the Eagle Ford is among the more fascinating stories in modern oil and gas. From Petrohawk's commercial discovery well in October 2008, Eagle Ford rig count rose faster, and ultimately higher, than any other tight-formation play in US history.

Several factors differentiated the Eagle Ford from other tight-formation plays. Forty years of oil and gas development in South Texas created a treasure trove of preexisting well logs, enabling operators to quickly define potential sweet spots across the 6.7 million acres of the play. The presence of an existing midstream infrastructure for liquids processing and hydrocarbon transport with access to the Gulf Coast petrochemical complex reduced the cycle time to get hydrocarbons to market. Operators found the Eagle Ford an ideal place to do business with a local population comfortable with leasing and oil and gas development. Finally, the Eagle Ford offered operators access to crude oil at a time when the industry was making the transition from dry gas to liquids-rich portfolios in the wake of weakened natural gas prices. Those factors allowed the Eagle Ford to develop at a faster rate than any prior tight-formation play.

The progression to resource harvest in the Eagle Ford accelerated in 2013. Horizontal well count grew from 1,041 in 2010 to 4,177 at year-end 2013, according to a February 2014 RBC Capital Markets report, and the total of horizontal wells placed in production in the Eagle Ford and ancillary regional horizontal targets topped 11,500 at year-end 2013.

The Eagle Ford is the most intensively drilled horizontal tight formation play in the US. The 4,177 horizontal wells drilled for the Eagle Ford in 2013 outpace the 2,760 horizontal wells recorded in the Williston basin, which ranked second, or the Marcellus/Utica, which ranked third at 2,653 wells — just a few dozen more than the fourth-place Permian basin.

Pad drilling productivity gains

Furthermore, the Eagle Ford witnessed the greatest percentage gains in efficiency in drilling times during the last three years when compared to other unconventional plays. Therein lies the story. It appears that a major reason for drilling efficiency improvement involves the rapid transition to pad drilling with the trend well advanced inside the core of the Eagle Ford.

Oil and gas operators estimate 85% of horizontal wells in the Eagle Ford core will be drilled on pads

19 manufacturing plants throughout North America.

- U.S. owned and operated for over 50 years
- ASME Stamp Code Vessels and API 12F Monogrammed Production Tanks
- State-of-the-art, in-door steel grit blasting, painting and coating booths
- Experienced personnel and committed Health, Safety and Environmental Staff

Add up Dragon's more than 50 years of building high quality oil field equipment, a workforce currently 2,500 strong and growing; plus its 19 manufacturing sites; 25 rental and service centers—all family-owned and operated from the Beaumont, Texas corporate office—and you have a formula that succeeds. This is what you get with Dragon. This is why so many companies in the energy industry choose to do business with Dragon.

The company's expansive inventory and product offering includes a comprehensive line of exploration and production equipment including, tanks, trailers, pumps, and rigs and all the parts that go with them. Dragon equipment delivers exceptional durability under the harshest conditions and in a variety of applications— including well servicing, bulk storage, liquid and solids hauling and many pumping solutions.

DRAGON

Make it happen.

E&P-TBOOK 4/14

www.dragonproductsltd.com • 1-877-231-8198

U.S owned and operated for over 50 years.

in 2014, up from less than 50% at the beginning of 2013. Pads typically host a range of wells from two to six, depending on lease configurations, with an average 4.3 wells per pad. The tendency in late 2013 was to increase the number of wells per pad from two or three to four to six.

A representative batch drilling process involves operators drilling the surface section of each well with a single rig. Then the rig returns to the first well to finish the intermediate portion of the well and repeats the process across all the wells in the pad. The final stage begins when the rig drills each horizontal lateral sequentially. The technique compresses cycle time by shortening nonproductive time between wells from the four to seven days it takes to move a rig on a single-well program to 12 hours to move to the next well site on a multiwell pad.

The most obvious savings involve a sharp reduction in move days per well. Other efficiencies include using the same fluid systems for all the vertical holes before converting to a fluid system better suited for the horizontal lateral. The fluid changeover process is done once for all wells rather than multiple times for each well. Additionally, crews capture efficiency as they become more familiar with a play — a process that pad drilling enhances.

Pad drilling provides ancillary benefits as well. The process reduces truck traffic at the well site and generates less surface disturbance with fewer roads and pads. Multiwell pads provide efficiencies by allowing operators to arrange support facilities such as water for fracturing or pods for processing oil and gas from individual wells on the pad into a centralized facility that services multiple pads.

Pad drilling, which involves boring multiple wells from a single surface location, and its companion process, batch completions, now characterize nearly three of four horizontal wells in the domestic market.

In some cases, operators use spudder rigs to drill and set surface casing before a walking rig comes onsite to drill the remainder of the well.

"Whenever possible we used a lot of those walking rigs to further reduce rig release to spud cycle time and smaller spudder rigs to preset surface casing on multiwell pads," said John Brooks, COO for Penn Virginia Corp. (PVA) during the company's 4Q 2013 earnings call. "We're able to combine the preset surface casing with the walking rigs and can save up to US $70,000 per well and more than 50 hours of cycle time with the big rig," Brooks said.

PVA cites an 18% reduction in cost per foot in Gonzales County and 24% in Lavaca County at the northern extension of the Karnes Trough in 2013 despite deeper wells and longer laterals. Those savings are compounded by use of rotary steerable directional tools to deliver a smoother wellbore and increased ROP, producing further savings of about $200,000 per well.

There are several ways to measure efficiency improvements. The simplest is the addition of daily oil production per day per rig, generally viewed as the volume each new well contributes to the overall play. According to projections from the US Energy Information Administration (EIA) in its monthly Drilling Productivity Report, that figure for the Eagle Ford grew an average of 14 b/d of oil month-over-month in March 2014, rising from 438 b/d for each new well in February 2014 to a projected 452 b/d of oil in March 2014.

Similarly, natural gas production from the Eagle Ford, which the EIA pegged at 6.26 MMcf/d in February 2014, grew 369 MMcf/d, offsetting depletion of 246 MMcf/d for a net gain of 123 MMcf/d.

According to the EIA, the Eagle Ford saw the largest net change in new well oil production per rig of all regions in March 2014 and is growing at almost twice the rate of the Bakken, though each

When unconventional production requires

Real Solutions!

Automated Performance Intelligent Chokes

Fully-Integrated Solutions

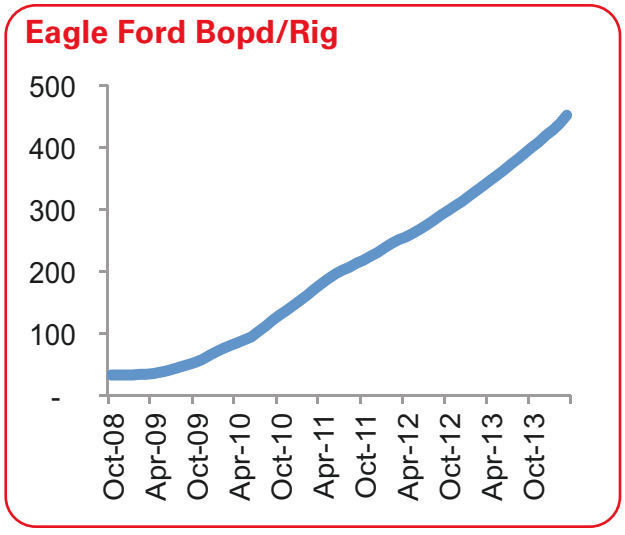
- ✓ Repeatable and stable controllability
- ✓ Superior performance in erosion conditions
- ✓ Improved production control
- ✓ Low power consumption design
- ✓ Wide range of available control protocols

MASTER FLO

The leader in choke technology ™

masterflo.com

new Bakken well will add roughly 486 b/d in March 2014 vs. 452 in the Eagle Ford. The EIA's Eagle Ford numbers include production in the Austin Chalk, the Eaglebine, and other East Texas plays.



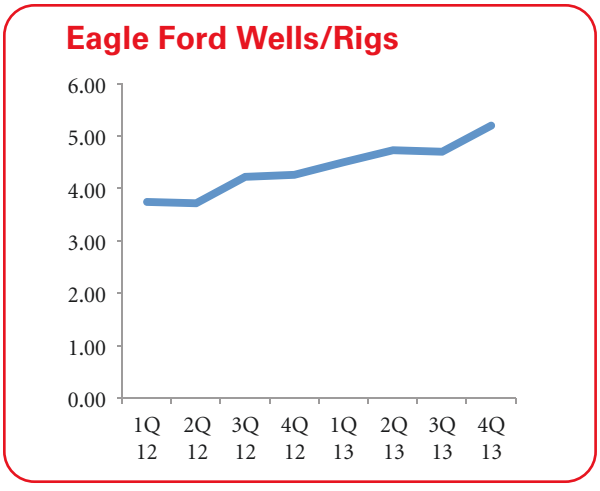
Source: US EIA and Hart Energy

Efficiency gains also are evident in the number of wells per rig. That metric has been marching steadily upward since early 2012, though it should plateau in the second half of 2014. Operators realized 5.2 wells per active rig in 4Q 2013, up nearly one full well per quarter from 4Q 2012, according to Baker Hughes. The 22% gain essentially means four more wells annually per rig. Think of it as 21 wells per year currently for each active Eagle Ford rig vs. 17 at year-end 2012. Consequently, well count can continue to grow in 2014 even if rig count stays flat.

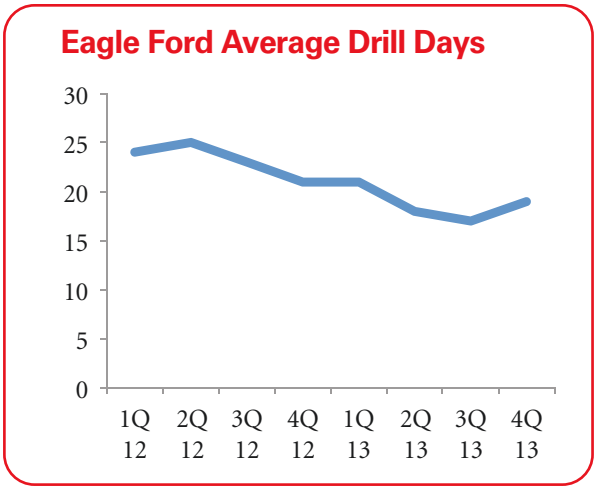
In fact, Eagle Ford rig count is generally projected to remain flat during the next half decade, though additional newbuild Tier I technology rigs are expected to displace the older Tier II electric units. RBC Capital Markets, for example, forecasts the addition of 45 Tier I rigs through the end of the decade, which will largely replace the existing active Tier II fleet component.

Though not necessarily a measure of drilling efficiency, Eagle Ford production should continue its upward climb at the same rate for another two to three years while operators drill out high-quality acreage in the play's core on multiwell pads using batch completion techniques. Ultimate Eagle Ford production could top 3.5 MMboe either late this decade or early in the next, depending on the forecaster. That production forecast is split between an estimated 700,000 bbl of NGL, 1.9 MMbbl of oil and condensate, and 4.8 Bcf/d of natural gas.

Drilling efficiency also is evident in the steady decline in drill days for a representative Eagle Ford well. According to a December 2013 RBC Capital Markets report, the average number of days to drill an Eagle Ford well fell from 24 in 1Q 2012 to 19 in 4Q 2013, representing a nominal drop of 25%. Combining the sharp reduction in rig moves from batch drilling across multiple wells on the same pad further shrinks well cycle time. Depending on rig configuration, it can take upward of seven days to move between wells on separate pads. Pad drilling reduces those trip times between wells to half a day or less.



Source: Baker Hughes



Source: RBC Capital Markets

ENHANCED QUIKRIG® COILED TUBING SYSTEM

Faster Rig-ups and Safer Operations, from the Industry Pioneers.

Faster and safer rig-ups equate to efficient well interventions. Halliburton's Boots & Coots service line– the coiled tubing experts – introduce their next-generation Enhanced QuikRig® (EQR) system. Suitable for work in new and mature fields and ideal for unconventional markets, this system can be rigged up in half the time of a conventional unit. Plus, the QuikRig system's unique design featuring pre-assembled well control equipment—capable of deploying extended bottom hole assemblies, and coupled with a latching mast design—helps provide safer operations by significantly reducing the risk of working under suspended loads.

Faster rig-up.
Safer operations with fully supported loads.

What's *your* well intervention challenge?
Boots & Coots is ready to go.

Solving challenges.™

HALLIBURTON

Boots & Coots

halliburton.com/boots-coots

Other ways to measure productivity include spud-to-spud cycle times. For Chesapeake Energy Corp., spud cycle time dropped from 29 days on average in 2011 to 21 days in 2012 and to 18 days in 2013. At the same time, the percentage of pad-drilled wells grew from 28% in 2011 to 59% in 2013. Chesapeake expects spud-to-spud cycle time to drop from 18 days to 14 days in 2014 as the percent of wells drilled on pads moves from 59% to 97%, management said at the company's 4Q 2013 earnings call.

Another example of the transition to pad drilling involves Pioneer Natural Resources. The company will move from 80% of wells drilled on pads in its core Eagle Ford holdings in 2013 to 100% in 2014. Well numbers per pad vary from three to four. According to Pioneer's 4Q 2013 earnings investor presentation, cycle time to place pad-drilled wells online averages 90 days to 120 days for three well pads and 120 days to 150 days for four well pads.

The question is whether the industry has captured all the efficiency opportunities available on the drilling side.

"Well, the savings are slowing down," Tony Best, CEO for SM Energy Co., said at the company's 4Q 2013 earnings call. "We probably reduced cost 20% the year before last and 14% last year." Best forecasts those savings in the single digits in 2014, although SM was tweaking changes in well design that could provide additional gains. "We haven't drilled the perfect well yet, but we have made substantial progress," he said.

Expanding through downspacing

As drilling efficiencies decline, the industry turns to completion efficiencies or the challenge of gaining greater recoveries from each horizontal lateral. These efficiencies are not so much about time savings since the time spent completing a well is far shorter than the time spent drilling. Time savings on the completion side generally originate from the move to 24-hour operations and the employment of zipper fracs that allow for simultaneous operations in parallel laterals. Rather, operators move from reducing cycle time in the drilling process to increasing the level of downhole performance.

The trend in the Eagle Ford as well as other horizontal basins is downspacing of horizontal laterals or shortening the distance separating parallel laterals. This is a delicate balancing act that seeks a Goldilocks solution in well placement. If laterals are placed too far apart, they leave resource behind. If laterals are placed too close together, they interfere, creating waste in capital investment. In the Goldilocks environment, recovery might decline for individual laterals vs. wider spacing, but overall hydrocarbon recovery in a unit rises based on synergies from greater stimulated rock volume.

Spacing between laterals varies across the Eagle Ford production window from 100 acres for deeper, gassier wells to experiments with 40-acre spacing in the eastern oil window. Representative Eagle Ford well spacing appeared to be about 80 acres per well in mid-2013. However, operators were focused on hitting the sweet spot in downspacing and by early 2014 began touting optimum placement at somewhere between 40 acres and 60 acres, depending on the location within the play.

Pioneer initially downspaced from 1,000 ft to 500 ft between wells in the liquids-rich portion of the Eagle Ford in the second half of 2013, according to an investor presentation accompanying its 4Q 2013 earnings release. The downspacing effort added 300 additional net locations to the company's portfolio, or a little less than three years of drilling inventory. In 2014 Pioneer will further test downspacing 300-ft intervals offset by staggered laterals with 45 ft of vertical spacing between upper and lower laterals. Pioneer is testing the staggered lateral approach in the lower Eagle Ford shale in three areas but plans to move the pilot to the upper Eagle Ford interval in 2014. Approximately 25% of Pioneer's Eagle Ford acreage is prospective for the upper Eagle Ford marl, and Pioneer is targeting 45 wells in the upper Eagle Ford as part of the 2014 downspacing pilot. Doing so successfully could add 400 new locations to inventory.

Similarly, EOG Resources Inc. increased its Eagle Ford recoverable estimate to 3.2 Bbbl of oil, up 45% on the basis of recent success in downspacing.

"We moved beyond an assembly line of operation to a high-precision manufacturing mode of delivering top-quality individual wells," EOG chairman and CEO Bill Thomas said at the company's 4Q 2013 earnings call.

Total skid packages
from start to finish

FMC Technologies, your measurement solutions provider, now offers complete fabricated skids for the upstream and downstream markets. The same experienced engineers that design the world-renowned Smith Meter® equipment can design and build skids to your specifications. Our direct offices provide immediate support, and inventory close to your operation to maximize your operations efficiency. For more information on how FMC Technologies has you covered from start to finish, visit www.fmctechnologies.com/midst

www.fmctechnologies.com

FMC Technologies

We put you first.
And keep you ahead.

The company focused on two goals for the Eagle Ford in 2013, including improving well productivity from its acreage in the western portion of the play. EOG considers the western portion equal to the eastern portion sweet spot in productivity and yield. The second focal area was on downspacing.

"While the optimum distance between wells will vary across the field depending on various geologic considerations, on average the wells will be drilled on 40-acre spacing," Thomas said. The change boosts EOG's inventory to 7,200 net locations, of which 1,200 have been drilled. The remaining 6,000 locations constitute a 12-year inventory with each well providing a potential 12% performance improvement over existing wells in the volume of recoverable reserves. EOG moved estimated ultimate recoveries (EURs) from 400,000 boe to 450,000 boe in early 2014.

In 2013, and largely on the basis of its Eagle Ford holdings, EOG became the largest oil producer in Texas.

Concentration in the Eagle Ford

As the Eagle Ford enters the resource harvest phase of unconventional development, concentration is a dominant characteristic. The top seven operators, employing 10 or more rigs, represent a combined 102 rigs and 45% of the Eagle Ford rig count.

For the oil services side, the top six contractors deploy 11 or more rigs and represent 77% of the play's rig count. A majority of those rigs are pad-capable and feature walking or skid packages that enable rigs to move between multiple wells on a single location.

Tulsa, Okla.-based drilling contractor Helmerich & Payne International Drilling Co. (HP) dominates the play with 80 rigs. South Texas has been a core region for HP since the mid-1990s. More newbuild pad-capable rigs are on the way. HP is manufacturing 36 rigs in 2014, including several for customers like Devon Energy Corp. that recently established a significant beachhead in the Eagle Ford following the $6 billion GeoSouthern Energy Corp. acquisition in November 2013. Devon plans to spend $1.1 billion in the Eagle Ford in 2014 as it transitions its portfolio from natural gas to oil.

Devon is ready to deploy the experience gained in other tight formation plays, including pad drilling, to its Eagle Ford sweet spot.

"I think the one thing in particular that we're going to bring to the table is our ability to execute what you might want to call 'the machine,'" said David Hager, COO for Devon. "The ability to manage the large number of rigs and bring those wells on production in a

Patterson UTI Energy's Rig 246 drills ahead on the Riedesel 01-02H pad site for Pioneer Natural Resources Co. in the Eagle Ford shale play near Yorktown, Texas. *(Photo by Tom Fox)*

COILED TUBING | HYDRAULIC FRACTURING | PRESSURE PUMPING | PERFORATING | WIRELINE LOGGING | THRU TUBING | PIPE RECOVERY

EFFICIENCY

where you most expect it.

C&J brings truly extraordinary service, operational efficiencies and technical expertise.

Known for always taking a highly customized job design approach, C&J Energy Services delivers a full line of advanced, value-added completion services for even your most complex and challenging wells.

Together with our Casedhole Solutions group, we combine high-specification equipment, operational efficiencies and technical expertise to produce the most effective completions in the least amount of time—resulting in lower overall costs.

C&J is committed to continually enhancing operator investment while protecting the people, the environment and the communities in which we operate. *What can we accomplish for you?*

Visit **www.cjenergy.com** for more details.

WINNER
OIL & GAS
AWARDS
WELL COMPLETION COMPANY OF THE YEAR 2013
Midcontinent

C&J Energy Services

very timely manner, that's something we're very good at. We had 35 plus rigs running in the Barnett at one point, and we've been very active in unconventional plays for a long time. It's a skill set, and I think that's something that we're going to bring to the table."

In its 4Q 2013 earnings call, HP said that two of the 13 rigs it added to its newbuild order book in January 2014 are headed to the Eagle Ford.

Domestic drillers Patterson-UTI Energy Inc. and Nabors Industries have a combined 60 rigs active in the play, while Chesapeake drilling subsidiary NOMAC has 16 units.

However, rig numbers only tell part of the story. The Eagle Ford is home to the largest concentration of Tier I drilling rigs in the US. The play sports more than 160 alternating current variable frequency drives, 1,500-hp rigs, many with self-moving packages. A majority of the remaining 65 rigs are older technology Tier II rigs, likely targets for replacement during the next half decade.

In terms of operator drilling programs, EOG carries the leaders' baton with more than 24 rigs active in early 2014, followed by Marathon Oil with 18 and Australian mining conglomerate BHP-Billiton with 15. EOG plans 525 wells in 2014, leading all operators in the intensity of its drilling program.

Operators are drilling wells at the rate of nearly 390 per month in the Eagle Ford.

Recently operators have gone to batch completions in which laterals are stimulated in tandem, usually as part of a methodology referred to as zipper fracs. EURs per well appear to be rising with the advent of the zipper frac methodology. A study of more than 1,000 Eagle Ford wells through early 2012 found average EURs in the 200,000-boe range. More recent studies find current average EURs at greater than 450,000 boe with a little less than 60% of that as crude oil or other liquids. Estimates put the recoverable resource at 15 Bboe, assuming $80/bbl, with acreage in the hands of 24 mostly publicly held companies.

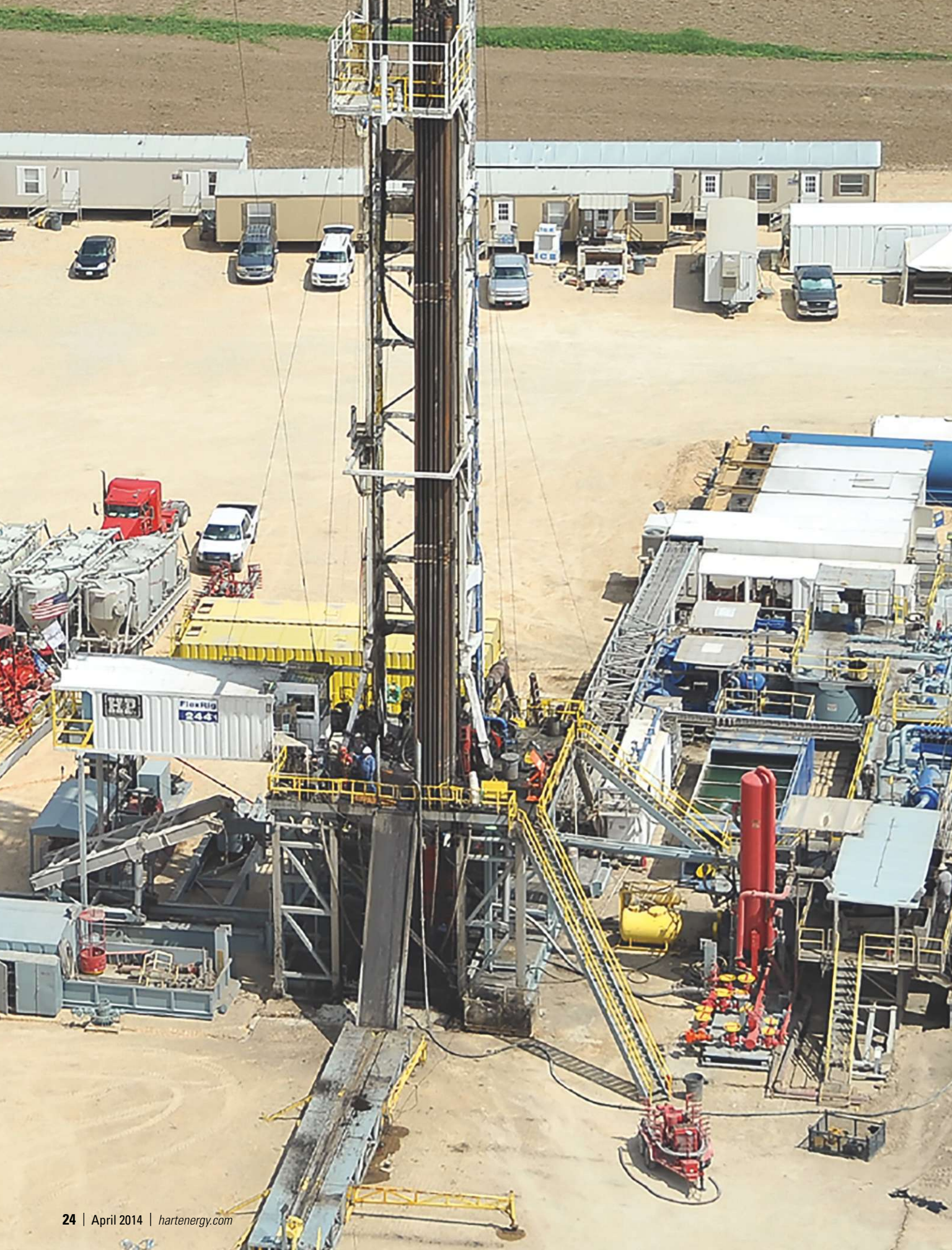
With the transition to pad drilling largely complete, operators are looking to push lateral lengths beyond the typical 4,500-ft to 5,000-ft approach used currently, when lease acreage patterns permit. Operators also are looking to move up and down the geologic column to explore prospectivity for the upper Eagle Ford shale, the Austin Chalk, the Buda Limestone, or deeper for the Pearsall shale.

Future downspacing efforts will not only include spacing between laterals but clustering stages along individual laterals to effectively stimulate the rock with the highest potential and avoid low productivity areas. ■

Eagle Ford Active Rig Counts February 2014

Contractors	Rigs	Operators	Rigs
Helmerich & Payne	79	EOG	24
Patterson-UTI	31	BHP-Billiton	18
Nabors	26	Marathon	15
Nomac	16	Chesapeake	14
Precision	11	ConocoPhillips	11
Trinidad	11	Anadarko	10
		Pioneer Natural Resources	10

Source: Company reports, Hart Energy


H2
FlexRig
244s

Facilitating Eagle Ford Success

Service and supply companies are providing technologies and strategies in the Eagle Ford that could prove useful in emerging unconventional plays around the world.

By Kelly Gilleland and Travis Poling
Contributing Editors

In every gold rush from California to the Yukon there was a chance at riches for the prospectors, but the smart money was on the merchants selling the picks, shovels, sluices, and services from assaying to milling.

The oil field has followed the same pattern, and while technology and a mature oil and gas exploration industry have taken much of the risk out of finding reserves, those selling the services and equipment to make it happen are reaping the benefits in unconventional plays like the Eagle Ford shale of South Texas.

In San Antonio, the closest major city to the Eagle Ford, and in small towns across 16 counties, oilfield service companies have opened up shop with field offices, regional headquarters, fleet maintenance facilities, manufacturing sites, laboratories, and sales offices.

Halliburton made a major statement in September 2013 when it built a 400,000-sq-ft administrative office and other service units on 150 acres in south San Antonio and hired 1,500 people. Other major players from Baker Hughes to Weatherford also have hired aggressively in the region.

Growth for some companies has been limited only by how fast they can hire. School districts in San Antonio and the rural communities south have lost hundreds of bus drivers to high-paying jobs in the Eagle Ford for anyone with a commercial driver's license and clean record. That bottleneck has brought in job seekers from out of state and put heavy pressure on affordable housing in the region.

Job fairs abound in the area, with service companies doing the lion's share of the hiring.

Crumbling roads also are an issue for well operators, transporters, and service companies. Last year the Texas Department of Transportation proposed replacing the pothole-strewn arteries with gravel roads, but the idea proved unpopular with companies and the locals.

There are proposals on the table to repave some of the roads with processed used tires as the base, because it keeps them out of landfills and could prove a cheaper alternative, the *San Antonio Express-News* reported in January.

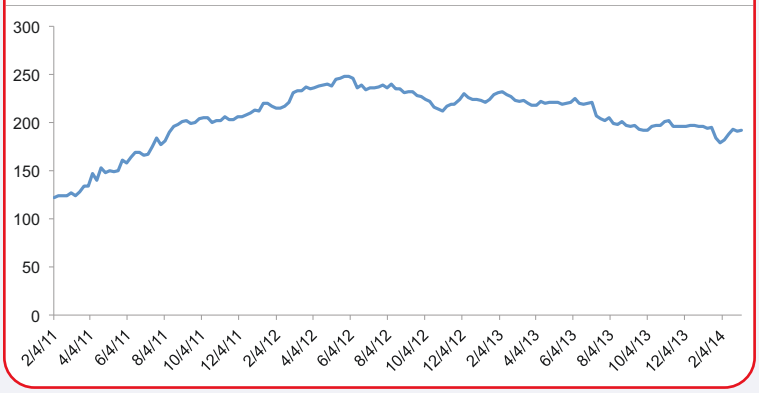
The other bottleneck that has emerged in the field is the water supply available for hydraulic fracturing in a region frequently stricken by drought. Most of the water that has been used in the early stages of the Eagle Ford development has been fresh groundwater.

A study from the US Environmental Protection Agency (EPA) determined it takes 90,000 bbl to 115,000 bbl of water to develop one well in the formation. The EPA estimates that if the rate of growth continues, the drilling process will use as much as 30,000-acre-ft of water each year, competing with municipalities, crop irrigation, and livestock for the limited resources.

Service companies, however, have risen to the challenge. Not only are methods of fracturing becoming more efficient from coiled tubing methods, cementing, and the introduction of longer-lasting replaceable tool parts, but challenges with reuse also are being addressed.

Facing page:
The Eagle Ford has been a testing ground for Halliburton's unconventional products and services. *(Image courtesy of Halliburton)*

Eagle Ford Rig Count



Source: Baker Hughes and Hart Energy

Holding ponds have been installed to start saving water after its first use, and service firms have developed new ways to strip it of damaging solids and microorganisms such as algae. New generations of environmentally friendly microbiocides are emerging to allow for the water to go down the hole again so less fresh water is used in the long run.

Other companies are employing new versions of remote, real-time monitoring and logging technologies to further remove the barriers to not having enough specialists in the field at any given time.

Active R&D work on the part of numerous companies is expected to bring everything from better fishing tools to heat-resistant downhole parts. The Eagle Ford is looked at as the proving ground for some technologies that service companies hope to deploy in emerging unconventional plays around the world.

Baker Hughes Inc.

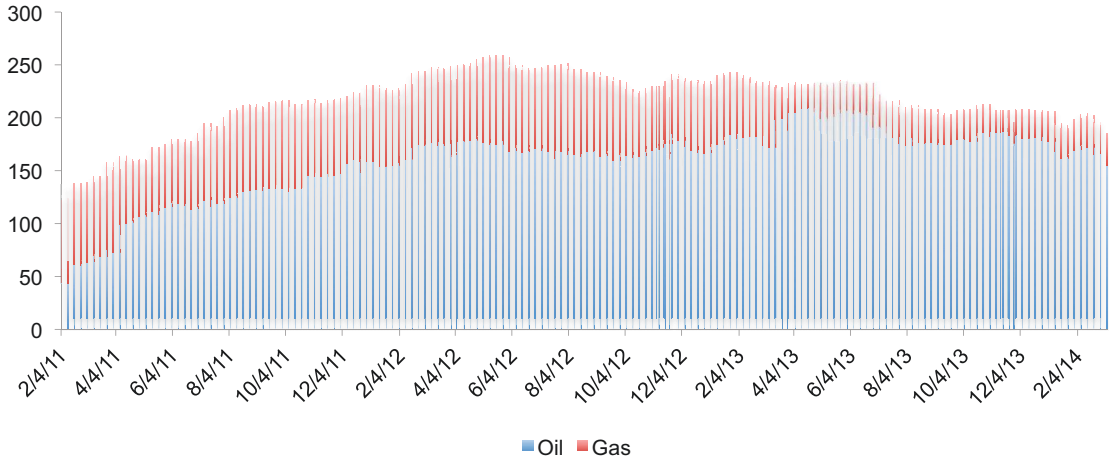
Houston-based Baker Hughes, with its size and range of services, boasts that it has participated in 97% of the wells drilled in the Eagle Ford shale.

The company expects a 4% to 5% rise in 2014 customer spending in North America "as customers demand robust technologies such as advanced directional drilling, complex completion systems, and pressure pumping to liquids-rich unconventional plays such as the Eagle Ford and Bakken," according to a management discussion of operations in a filing with the US Securities and Exchange Commission.

The average annual rig count, however, is likely to be flat due in part to improved efficiency in drilling performance, according to the firm.

Baker Hughes reported in its 3Q 2013 earnings report that the water management services business H2prO is gaining momentum in the Eagle Ford, Marcellus, and Permian basins and in September

Eagle Ford Rig Count By Commodity



Source: Baker Hughes and Hart Energy

EXPLORE OUR CAPABILITIES

Today's oil and gas fields present unique and dynamic challenges. At Cudd Energy Services (CES), we deliver specialized solutions that help our customers unleash the full potential of their assets, both onshore and offshore. With operations in major resource basins around the world, we have the proven technical expertise and operational experience to help you achieve your operational objectives in safe and efficient manner.

Discover our capabilities at www.cudd.com.

STIMULATION | COILED TUBING & E-COIL | HYDRAULIC WORKOVER
NITROGEN | INDUSTRIAL NITROGEN | SLICKLINE & BRAIDED LINE | SPECIAL SERVICES
WATER MANAGEMENT | WELL CONTROL

CUDD
ENERGY SERVICES

PROVEN EXPERIENCE. TRUSTED RESULTS.
WWW.CUDD.COM

reached a company record of treating 5 MMbbl of water from production in one month.

Other services in the Eagle Ford include providing drillbits, drilling fluids, and directional drilling.

The company has been hiring aggressively in the region with more than 400 new jobs at a recently constructed US $30 million facility just south of San Antonio. It also expanded its Corpus Christi, Texas, offices to accommodate the growing Eagle Ford business.

Basic Energy Services

Basic Energy Services, based in Fort Worth, Texas, has about 2,000 customers with a heavy concentration in liquids-rich basins, including the Eagle Ford and Permian.

From 157 offices in 15 states, the company offers well completion and remedial services, fluid services, rental tools and fishing tools, well servicing, and contract drilling. Completions and remedial services made up 40% of the revenue mix in 2013, according to Basic's annual financial statement filed with the US Securities and Exchange Commission.

Locations in the Eagle Ford area include Pearsall, Pleasanton, Kenedy, and numerous other service yards in South Texas. The company also maintains a maintenance facility in Beeville. Basic operates in the Eagle Ford as part of its Gulf Coast region.

Most of the 2013 capex went into new saltwater disposal facilities, executives said at a December presentation at the Capital One Securities Energy Conference.

Bico Drilling Tools Inc.

Houston-based Bico specializes in the manufacturing and servicing of downhole drilling motors, rotary steerable tools, drilling jars, and shock subs.

The company has a sales and service center in the Midland/Oddessa area in the Permian basin but works with customers in the Eagle Ford shale and throughout South Texas.

According to a recent Eagle Ford client case study on the company's website, Bico used a specialized system to clean and revitalize a well that had dropped off production to less than 10 b/d of oil. When the process using Bico-designed tools was completed, the well began producing at 135 b/d of oil.

Product lines from the 23-year-old company include SpiroStar thru-tubing and motors and the conventional drilling Flexdrill.

In a letter to customers, Bico President Samuel Claytor said the company is working on significant changes in motor design, rotary steerable technology, and advanced circulating tools.

Block Engineering Inc.

Block Engineering, the maker of the Quantum Cascade Laser, plays a role in national defense with the ability to detect chemical weapons and other weapons of mass destruction from up to 3 miles away. However, on the practical side, the lasers come in handy for several industries, including oil and gas.

For little cost, the sensors can measure natural gas for Btu content "to optimize drilling operations and the gas enrichment process," according to the Massachusetts company's website. Portable sensors can detect leaks in pumps, valves, and gear boxes. The early warning helps production companies save on downtime and avoid explosions. The devices also allow for quick field testing of the content of crude oil to improve drilling.

Block's Fourier Transform Infrared (FTIR) spectrometer measures gas content for mud-logging purposes to better determine what kind of hydrocarbons lie below.

In January, the company announced it had signed a long-term agreement to provide a miniaturized version of the FTIR to an unnamed supplier of systems to the drillers in the oil field.

BWA Water Additives

With limited supplies of fresh water in South Texas, water treatment solutions for reused or lower-quality water have become more important for Eagle Ford drillers. BWA Water Additives recently expanded its oil and gas additives business from primarily conventional on and offshore applications in the North Sea to hydraulic fracturing in the US.

The latest development from the Manchester, UK-based firm is the Environmental Protection Agency (EPA)-approved Bellacide 350, which prevents biofilm, sulfate-reducing bacteria, acid-producing bacteria,

INNOVATIVE SOLUTIONS TO OPTIMIZE YOUR PRODUCTION

FLOW EQUIPMENT LEADERSHIP

Cameron's Artificial Lift Solutions elevate linear lifting technology and wellbore performance to new levels.

Cameron's patented CAMLIFT™ linear lifting system requires no ground preparation at the site and may be installed in less than two hours. It is mounted directly to the wellhead, is ideal in tight spacing situations and can lift up to a 40,000 lb peak load – the same level as conventional beam units. Versatile and adaptable, Cameron's CAMLIFT has the ability to make real-time adjustments in stroke speed, length and downhole pump performance. Look to Cameron for top to bottom, complete artificial lift solutions that deliver higher efficiency and lower operating costs.

Learn more about ***Making the conventional unconventional***™ by calling 1 877 327 7898 or email Artificial.Lift@c-a-m.com

APPLICATIONS

- SHALE OIL
- SHALE GAS DELIQUIFICATION
- CONVENTIONAL OIL
- GAS WELL DEWATERING
- HIGH-SOLIDS PRODUCTION
- HEAVY OIL
- SAGD
- HORIZONTAL WELLS

AD00630ALS

RAISING PERFORMANCE. TOGETHER™

CAMERON

According to BWA Water Additives, operators needing to meet local or regional environmental requirements are using Bellasol S65, an HP/HT biodegradable scale inhibitor. *(Image courtesy of BWA Water Additives)*

and algae. The company also has launched Bellasol S65, a biodegradable substance that works on tough scale species even under HP/HT conditions, according to a BWA news release.

At the DUG Eagle Ford Conference in San Antonio in late 2013, a BWA executive said microbiological contamination in fracturing water can cause considerable damage, including souring and scale formation, leading to reduced production.

BWA's use of tributyl tetradecyl phosphonium chloride has been effective in dealing with the problem.

"This is the first new biocidal additive approved by the EPA in the last 10 years," said an executive, who has since left the company, according to reporting by *Oil & Gas Investor* from the conference. "It's not an ordinary biocide. We've used it for a long time in the cooling water industry. It has corrosion inhibition properties. It is synergistic with the oxidizing biocides we normally use in the cooling industry. It is safe for handling and is not a skin sensitizer. Those attributes have been very well received by the oil industry."

C&J Energy Services Inc.

Founded in 1997 as a hydraulic fracturing and coiled tubing services provider, C&J has diversified with several acquisitions since its initial public offering in 2011.

The company acquired Total Equipment and Service, an equipment supplier and manufacturer. That was followed in 2012 with the acquisition of Casedhole Solutions, which specializes in several oilfield services, including pressure pumping, pipe recovery, perforating, and wireline logging.

Founder and CEO Josh Comstock said in the Houston company's 4Q 2013 earnings report that they have expanded capacity in existing business and acquired new business such as data control manufacturing and directional drilling in 2013 while expanding service areas geographically. They are on pace to continue that expansion in 2014 and also have opened a new research center in Dubai.

C&J has sites in numerous liquids-rich basins and shale plays around the country, including two in the Eagle Ford, according to the company's website.

Dedicated To Providing Superior Oil & Gas Well Service Equipment

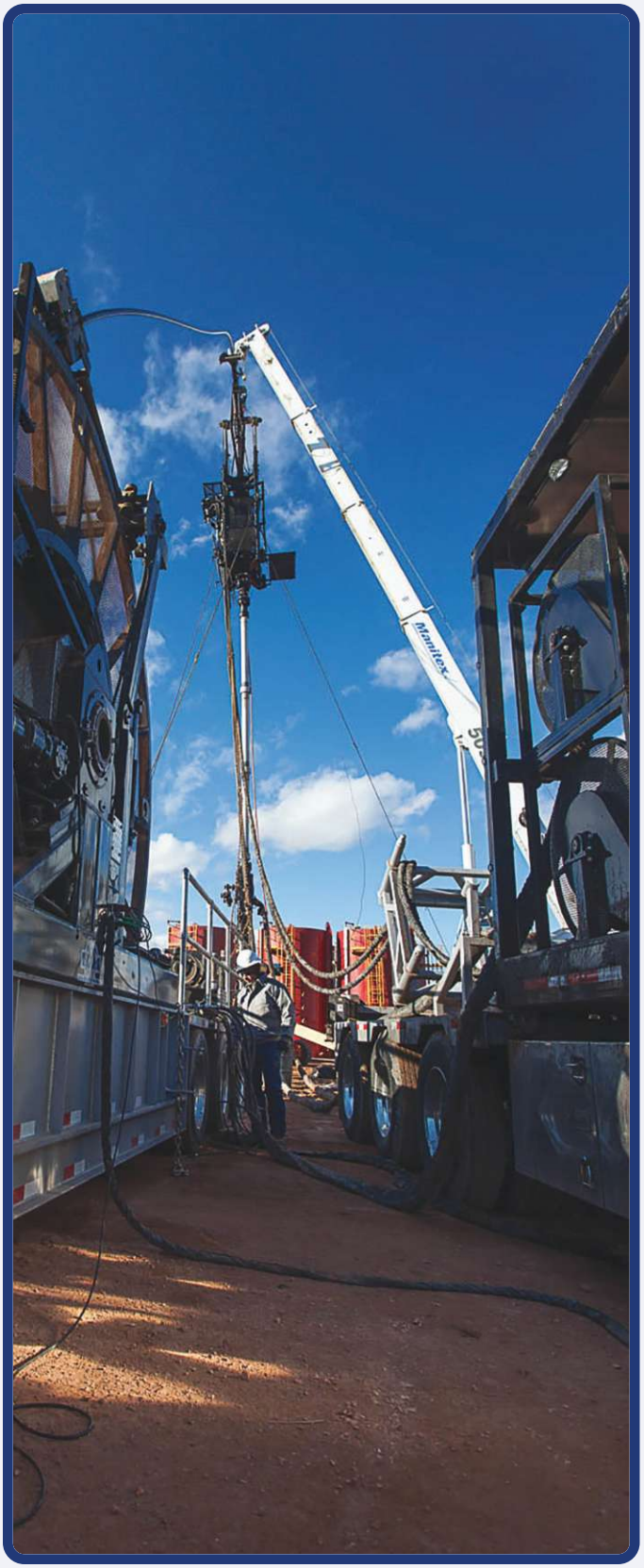
Custom designed originally manufactured Fracturing and Cementing equipment that outperforms that of all other manufacturers

Highly trained Mechanical and Electronic Field Service Crews always available to service and maintain your equipment

Equipment Refurbishing and Restoration with the mission of making it new again

Freemyer Industrial Pressure LP.

Phone: 817-548-5010
Toll Free: 800-826-8379
www.indpress.com



C&J's AR12 is a coiled tubing unit on location in North Dakota. *(Image courtesy of C&J Energy Services Inc.)*

Through Total Equipment, the company is working to bring even more manufacturing functions in-house and hired 30 new engineers in 2013 to help achieve that, according to a December 2013 presentation at the Cowen Oil Service and E&P Conference.

Calfrac Well Services Ltd.

Calfrac made its move into the Eagle Ford shale in 4Q 2013 with the US $147 million acquisition of hydraulic fracturing and coiled tubing (CT) firm Mission Well Services LLC.

The company tests fracturing chemical solutions in simulated conditions at its technology and training center in Calgary, Alberta, Canada, where the firm is headquartered. Calfrac laboratories are working on additions to their lines of fluids designed to work best in unconventional formations, according to the company's website.

That has made them a major player in some of the most active shale plays in the US, including the Bakken and Marcellus shale, according to the company's 2013 earnings report. The company is now introducing that expertise to the Eagle Ford, including customized well completion simulation programs for clients.

With the acquisition of Mission, which has its Eagle Ford base in San Antonio, Calfrac gains 157,500 hp of pumping capacity. It also comes with high-rate blenders, sand handling, three deep-capacity CT units along with the fluid and nitrogen pumping equipment, according to a company release.

Cameron

Cameron, a Houston company specializing in equipment to manage the flow of products in the oil and gas industry,

Delivering Technology-Driven Engineered Solutions to the Oil & Gas Industry

World-Class Pre/Post-Frac Services

Water Transfer, Storage, and Treatment
After-Frac Flow Back and Production Testing
Completion Fluids and Displacement Systems

Focused on Energy.
Dedicated to Service & Safety.

TETRA®

tetratec.com

sales@tetratec.com

formed the CAMSHALE Services unit to bring specialized versions of Cameron products to unconventional plays.

At the wellhead, the company equipment includes drilling systems, BOPs, artificial lift, and thru-bore systems. Services include installation, torque and test, spare parts and replacement, greasing, tree and wellhead repair, and wellhead refurbishment, according to the company's website.

Cameron also manufactures and services numerous fracturing support and flowback products, including manifolds, control panels, flaring units, fluid and gas separators, and frac trees.

On the fluid management side, the company works with producers to design and fabricate systems used in the separation of oil, gas, produced water, and solids from the well. That includes storage tanks, sand separators, filtration, membrane gas treatment, and electrostatic dehydrators and desalters.

The fourth leg of Cameron's shale services business is gas compression. Reciprocating gas compressors are designed for reliability and performance in every part of the process from gathering to transportation and storage. Centrifugal compressors are designed for oil-free gas handling. Services in the area include installation and startup, leasing, contract maintenance, overhauls, and engine and rotor exchange programs.

In January, the company announced it would sell its reciprocating compression business to GE for US $550 million and is "exploring strategic alternatives" for its centrifugal compression business, according to a company news release. The deal with GE is expected to close in 3Q 2014.

Cudd Energy Services

Cudd Energy Services has its beginnings in fighting well fires in Oklahoma but grew into a diversified oil services company through numerous acquisitions and an eventual merging of Cudd and Patterson Rental Tools into RPC Inc. The Woodlands, Texas-based company now operates Cudd Pressure Control and Cudd Pumping Services as one unit with more than 2,000 workers in 60 markets, including a heavy concentration in unconventional shale plays.

Services offered by Cudd include well control, water management, well stimulation, coiled tubing, e-coil, nitrogen, hydraulic workovers and slick, braided, and electric line, according to the company's website.

Cudd opened a regional office in San Antonio in 2011 and began hiring about 200 drivers and logistics and inventory control personnel to support its growing hydraulic fracturing business in the Eagle Ford shale, the *San Antonio Express-News* reported.

The company is working to make its processes as environmentally friendly as possible by seeking out low-toxicity additives, silica sand dust control, and the use of Petro-Flow Microbiocide in the fracturing process.

Cudd's e-coil technology gives operators images, logs, and data immediately from all downhole operations.

Express Energy Services

Express Energy Services brings 12 service lines to the oil field in 34 locations, primarily in the major US shale plays and the Gulf of Mexico. The Houston-based company has an office in Pleasanton, Texas, in the heart of the Eagle Ford shale.

Services include running casing and tubing, pipe laying, drilling ratholes, pressure testing, and drillsite rentals, according to the company website. Completion and production services include water transfer, well testing, and wireline.

The company boasts its position as one of the largest rathole service firms in the country thanks to a large and new fleet of rigs to prepare new drillsites.

In 2012, the company acquired Wildcat Gas Well Testing Inc. of Mission, Texas, expanding its footprint in the Eagle Ford and Marcellus shale, according to a company news release.

FMC Technologies

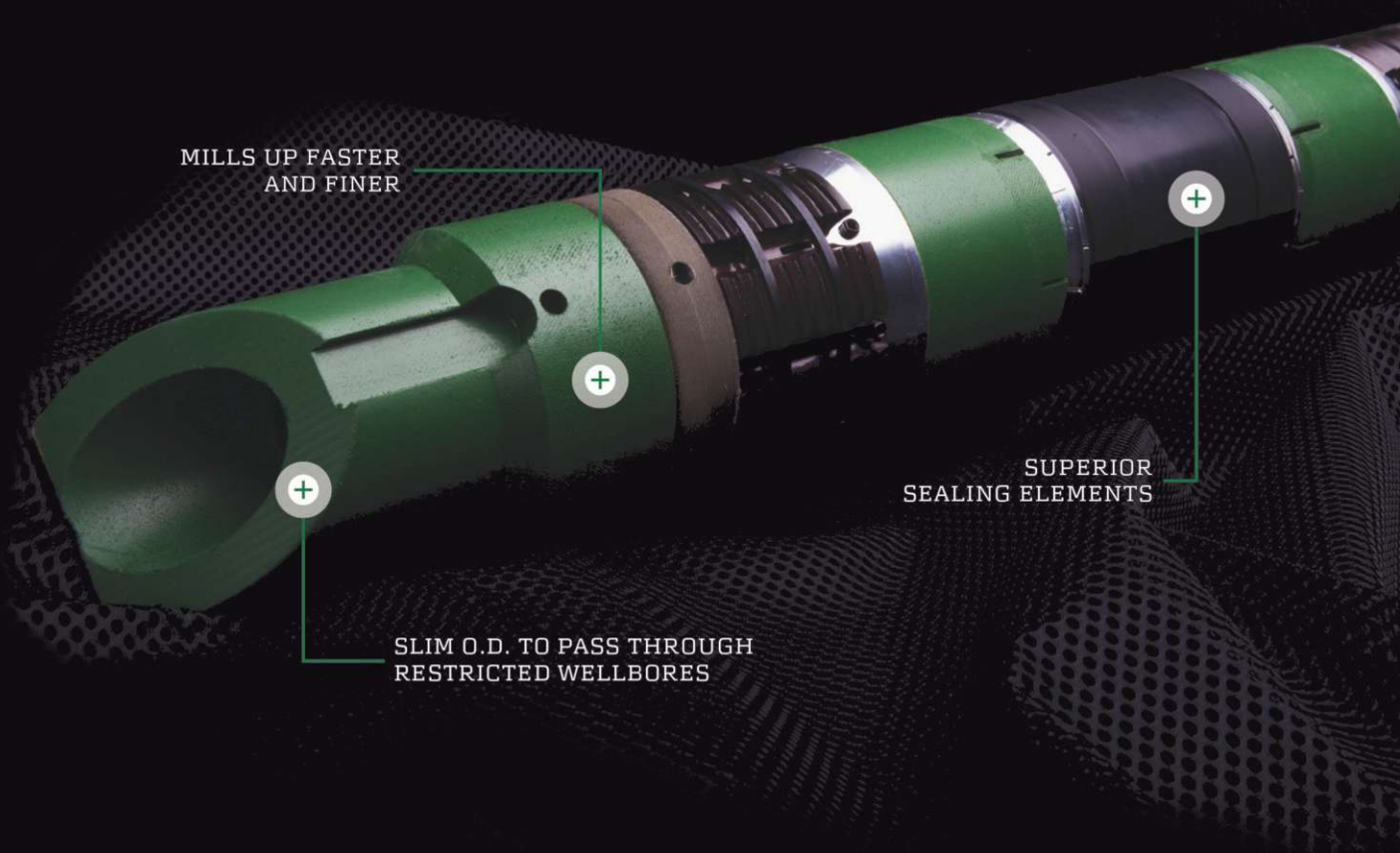
While FMC Technologies is probably best known for its subsea offshore services, the onshore business is growing with applications in unconventional shale plays.

Fracturing technology products and services offered by the Houston-based company include wellhead systems such as frac trees, manifolds, isolation

ALWAYS PACK A MAGNUM IN THE EAGLE FORD

MAGNUM OIL TOOLS INTERNATIONAL

Casing patches. High deviation. Partially collapsed casing. Whenever it's a tight squeeze downhole, you need the only completion product designed to pass through it with ease: The Magnum Long Range™.



No two plays come with the same challenges. That's why Magnum develops product solutions to address each and every one of them. By designing our tools with specific purpose in mind, we help ensure greater precision downhole—and smarter operations overall.

IT'S TIME TO PULL THE TRIGGER ON PRECISION PERFORMANCE.

Learn more at always-smarter.com/eagleford

sleeves, and flowback equipment. The isolation sleeves, on which FMC Technologies holds the patent, are intended to protect the wellhead from extreme pressure and erosion that can occur in the fracturing process, according to the company website.

For servicing the growth in the Eagle Ford shale, FMC Technologies maintains a sales office in San Antonio and a field operation in Pleasanton, Texas. The company also provides a variety of metering, monitoring, and valve products to the Eagle Ford through its Smith Meter line and distributes equipment made by Franklin and Invalco to provide complete packages to the wellhead.

Forum Energy Technologies

Formed in 2010 with the merger of five oilfield products and services companies, Forum manufactures and services drilling technology, subsea technology, surface production and process equipment, valve solutions, flow equipment, products for intervention, and downhole technology.

The Houston company brings dozens of brands to the table, including many acquired in recent years. Domestic growth for products and services has been driven largely by unconventional plays, including the Eagle Ford.

The company has operations in East Texas, West Texas, and South Texas and maintains a drilling manufacturing operation in San Antonio, the closest major city to the Eagle Ford play. One of Forum's downhole technologies companies, Davis-Lynch, also maintains a sales office in San Antonio.

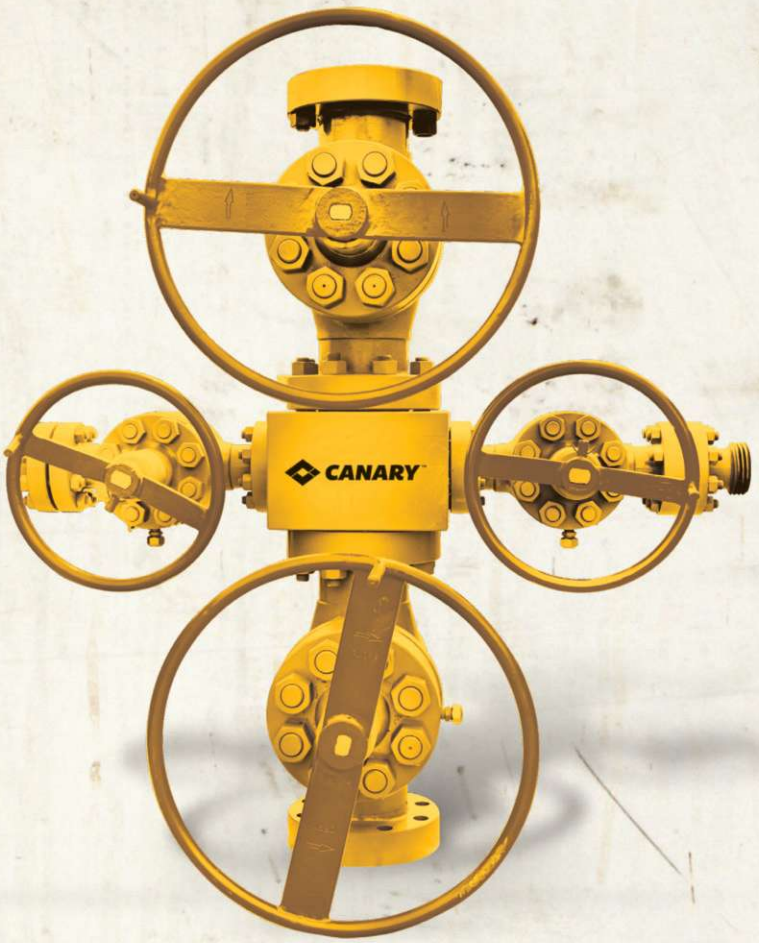
The most recent acquisitions include the 2013 purchase of Germany's Blohm + Voss Oil Tools and a joint venture buy with Quantum Energy Partners of Global Tubing. Blohm specializes in drilling technologies for pipehandling and Global Tubing of Dayton, Texas, in coiled tubing manufacturing, testing, and installation.

FTS International

The need for well stimulation with the development of the Barnett shale led to the formation of FTS International (FTSI) in 2002. The founders sold the company to an investor group in 2011, and it has developed into a significant supplier for well completion services.

FTS employees rig up on location at a well site. *(Image courtesy of FTS International)*

THE OILFIELD IS UNFORGIVING



IT'S NO PLACE FOR EQUIPMENT THAT CAN'T TAKE PUNISHMENT.

Canary is constantly innovating new products and equipment, while fine-tuning oilfield services to take advantage of new trends in technology, efficiency, and safety. With locations in every major shale play, Canary locally builds reliable, high-quality wellheads that ensure maximum production and profitability for America's largest energy firms.

CANARY™

UNLEASHING AMERICA'S ENERGY

WELLHEADS • FRAC EQUIPMENT • PRODUCTION SERVICES • MANUFACTURING

CANARYUSA.COM

With a focus on unconventional oil and gas, the Fort Worth-based company in Texas provides pressure pumping, wireline and pressure control, water management, and custom analysis and frac design services. FTSI has developed a pressure-pumping unit that can run on traditional fuel or cleaner-burning natural gas.

The company's R&D unit also is working on new fluids and technologies to create effective well stimulation designs that are more economical and environmentally friendly.

FTSI operates 29 fleets of pressure pumping equipment in the US in major shale formations, according to the company website. That represents about 1.5 MMhhp of pumping capability.

The company sold its proppant assets to Fairmount Minerals in 2013, but it signed a long-term contract with Fairmount to supply FTSI's proppant needs.

To serve the Eagle Ford shale, the company has district offices in Pleasanton, Asherton, and Bryan, Texas, and a sales office in nearby San Antonio.

GE Oil & Gas

As a subsidiary of the global conglomerate General Electric Co., it comes as no surprise that GE Oil & Gas cuts a wide swath in the world of oilfield products and services. The company has made about US $14 billion in capex in recent years and is building a large energy research center in Oklahoma City.

Services to E&P include compressors for natural gas, drilling and production services, inspection, environmental, capital drilling equipment, and valves.

GE also serves as a manufacturer of products used from drilling to delivery of natural gas and oil. Surface pumping systems and versatile surface pump skids are among its popular products.

The company recently bought out Salof Cos., a maker of small-scale and mobile cryogenic LNG plants that can be placed on site in the field. The firm already is expanding the 200-employee operation in Schertz, a city just to the north of the Eagle Ford shale, and announced in early February that it is hiring another 175 workers to meet demand.

Halliburton Co.

In 2011, Halliburton announced it would hire 1,500 people in the San Antonio area and started building a US $70 million regional headquarters on 150 acres there for its Eagle Ford shale operations.

The facility, which opened in September 2013, includes a 400,000-sq-ft building with personnel to support the business lines of production

Reducing the footprint for hydraulic fracturing has been one of Halliburton's goals. *(Image courtesy of Halliburton)*

SCALEGUARD proppant-delivered scale inhibition

SCALEGUARD is a chemically-enhanced ceramic proppant engineered to maintain optimum production and recovery rates from scale-prone wells, while reducing well costs and chemical usage.

SCALEGUARD technology is engineered for each application, and can be blended with any product from our proppant portfolio, without compromising the high conductivity of the proppant pack. Scale-inhibiting chemicals infused within the proppant are released into the fracture only on contact with water to deliver highly efficient production assurance.

Now long-term scale prevention is available throughout your entire production system from a single, simple treatment while you frac.

CARBO®

carboceramics.com/scaleguard

More space to flow

enhancement, cementing, Baroid, the well pressure-control and intervention Boots & Coots division, wireline, and perforation services. The company said in a written statement that it will move its completion tools business to the site later this year.

The Eagle Ford has been a testing ground for many Halliburton products and services it is developing for the unconventional plays around the world.

In September 2012, the company introduced the commercialization of PermStim hydraulic fracturing fluid in the Eagle Ford shale. Its use has since spread to other shale formations, with the fluid more efficient than guar-based fluids. The company's new CleanStim fracturing formulation is designed to save on the use of fresh water when stimulating wells.

Another case study on the company's website reported that it saved a customer $1 million using its RapidStage Completion systems in stimulating a tricky well that presented numerous challenges. SoluCement, which can be dissolved with acid, also has proven to be effective in dealing with challenges presented by the Eagle Ford formations while fracturing in multiple stages.

In February, a Halliburton service known as Pinnacle introduced the FracHeight, a fiber-optics based tool to better diagnose and map fracturing.

Key Energy Services

Through numerous acquisitions and organic growth during the last 20 years, Key Energy Services has expanded from a modest West Texas well servicing firm to 8,500 employees and an international reach, including unconventional plays throughout the US.

The Houston-based company specializes in rig services, rental services, fluid management, coiled tubing services, and tool fishing and operates Edge Oilfield Services for high-pressure equipment rental, according to the company website.

The rental services division includes pipe and rods along with proprietary services like SmartTong Rod Connection, the Hydra-Walk Pipe Handling system, and the Sand-X system.

Coiled tubing (CT) services address needs for unconventional plays such as fracture well stimulation, scale removal, logging, perforation, sand control, cementing, and well circulation.

In the Eagle Ford shale, the company operates field offices in Charlotte, just south of San Antonio, and Carrizo Springs.

Key's CEO Dick Alario told investors at a March 2014 Raymond James Institutional Investors Conference that 11% of the company's revenue came from Eagle Ford activity. By comparison, 28% came from Permian basin operations, where the company has operated the longest.

Eagle Ford work made up 36% of the company's US $193 million CT business. Tool fishing and rental services accounted for $239 million in revenue in 2013, and 18% of that came from Eagle Ford services, according to Alario's presentation.

Fluid management was a $272 million segment of the company's business in 2013, with 11% from the South Texas unconventional play.

Knight Oil Tools

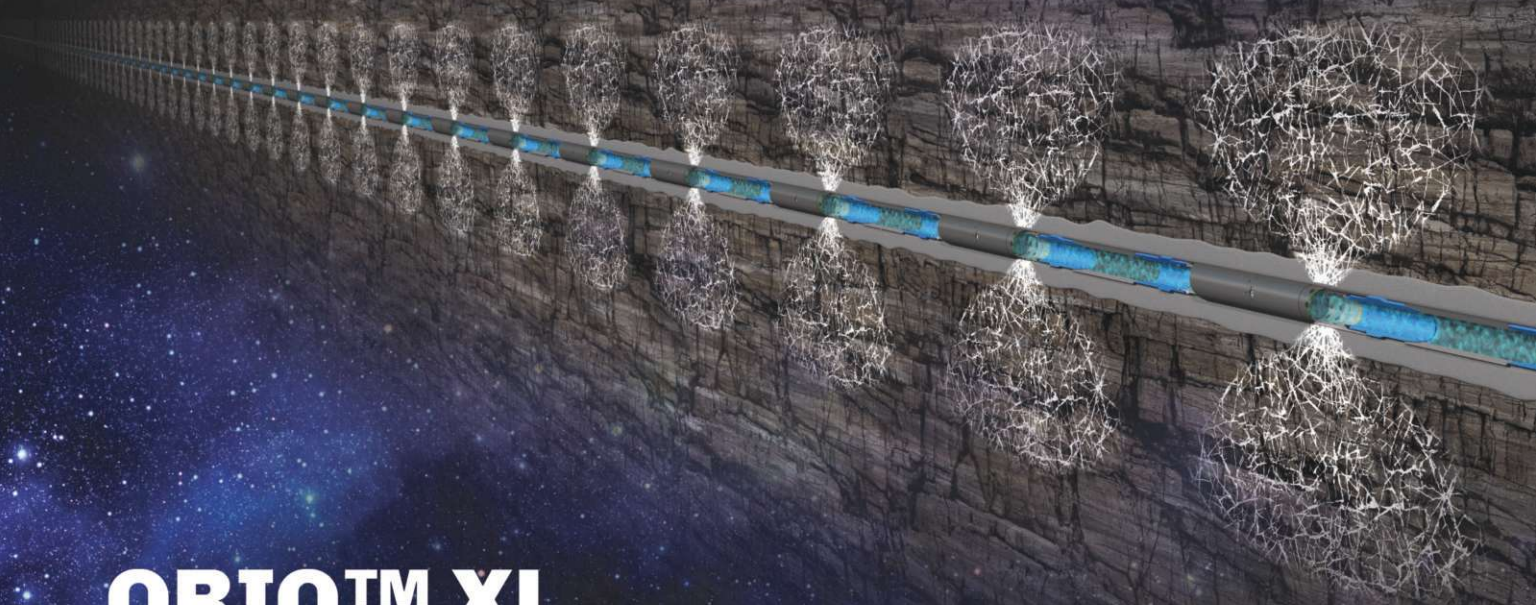
Knight Oil Tools, based in Louisiana since its inception 42 years ago, has had a strong presence in South Texas for years, operating out of Houston and Alice, Texas.

To further cement its service mix in the state and the Eagle Ford shale, Knight acquired Tri-State Tools & Inspection of Corpus Christi, Texas, in July 2012. The acquisiton greatly improved its reach into South and West Texas, particularly in the area of drillpipe stabilization and nondestructive testing all the way to the assembly components at the bottom of the hole, according to a company news release. The services have been incorporated into the TriDrill Services unit that has been part of Knight since 1996.

Services offered by the company include testing, hardbanding, tool rentals, saw services, cement blending, well abandonment and plugging, fluid pumping, management and consulting, and fishing services, according to the company website. The firm also manufactures and employs the Megaton Fishing Jar, which has been used to successfully recover tools for years in the North Atlantic and other locations and has now been deployed in the Eagle Ford and other unconventional plays.

TEAM Oil Tools

BOLDLY GOING WHERE NO ONE HAS GONE BEFORE



ORIO™ XL
Unlimited Frac Sleeve

This is one of those rare moments in history when "it can't be done" gives way to "been there, done that." Introducing the frac sleeve system that enables you to open more than 100 independent sleeves one at a time without ever dropping a ball smaller than 4 inches. It took a unique, patented design to pull it off. A design that sandwiches all the tasty technology between two layers of steel so the tool's moving parts are protected from the cement inevitably left behind by the wiper plug. The result is absolutely smooth operation that increases fracturing efficiency exponentially. The ORIO XL 5.500 System is so versatile, it can be used as a single selective valve where one ball opens one valve, or for clusters where one ball opens multiple sleeves. But it gives you the unprecedented control to concentrate all your horsepower in a single sleeve—use less and still get more bang for the buck.

Learn more at info.teamoiltools.com/orio-xl

Knight has more than 50 offices in 10 oil-producing states in the US and internationally.

Loadcraft Industries Ltd.

Loadcraft specializes in total design and manufacturing of 250 hp to 2,000 hp drilling and workover rigs, drawworks, heavy haul trailers, dollies, beams, and multi-axle components to support the heavy haul and oilfield transportation sectors. The company has a machine shop in Brady, Texas, where it boasts it can "build or repair any type of oilfield, wind energy, or other mechanical products," and a spare parts/field service that is on call 24 hours a day. Types of spares and parts available include frac tanks, mud tanks, both rigid and telescoping structures and substructures, masts, mud pump packages, and rotary drives.

The Loadcraft facility includes everything from a machine shop, three weld production lines, and onsite testing areas to a vast warehouse and indoor assembly area. Recently, Loadcraft introduced a new frac sand silo system it developed, with six silos on a skid operating on a hydraulic flip system. The silo system is capable of handling 2.5 MMlb of sand at one time, compared with old systems that handled about 500,000 lb.

Magnum Oil Tools International

Corpus Christi-based Magnum Oil Tools engineers, manufactures, and sells specialty downhole completion tools and has been active in the Eagle Ford since it became a major play in 2009. One product that the company has seen work especially well in the complicated Eagle Ford environment is its long-range composite frac plug, which can be deployed on wireline or coiled tubing and is designed to pass through damaged casing, restricted internal casing diameters, and existing casing patches in the wellbore. Suitable for use in both vertical and horizontal wells, the slim plug design incorporates a composite material and aluminum construction that is millable and easily removed, making it possible for wells previously marked for abandonment to be recompleted (unlike other available systems using steel plugs, which will not drill out).

This year Magnum will expand its patented dissolvable technology in the Eagle Ford play with plans to roll out a "fast flow" system and a complete line of dissolvable plugs. The company's dissolvable frac balls were introduced a few years ago, are "100% environmentally safe," and work anywhere sliding sleeve systems or composite frac plugs are effective, according to the company. These frac balls offer a predictable dissolution period under heat, after which, hydrocarbons can flow freely between the formation and the wellbore. By bypassing the need for drillouts, the dissolvable ball eliminates the risk of events that would require well interventions like stuck frac balls or loose frac ball fragments. The company markets a wide range of dissolvable ball sizes and will even custom-make sizes upon request.

National Oilwell Varco

National Oilwell Varco (NOV) offers a wide variety of services to Eagle Ford operators, including drilling, downhole, tubular, corrosion control, well service and completion, and production solutions. The company employs more than 1,000 workers dedicated solely to Eagle Ford operations out of several locations throughout the region.

The company also supplies enclosed vapor combustors made from all stainless steel components (304, 310, and 316 grades) to ensure long lifetimes of the burner stack, burner crowns, and nozzles. These NOV combustors have replaced many competitor units that use carbon steel stacks in the shale plays, which are susceptible to the more than 1,500°F temperatures needed inside the stack to completely combust the heavy hydrocarbon flash gas. NOV's stainless steel design can avoid many of the typical problems associated with carbon steel components and materials, including melting of the stack, hydrogen sulfide corrosion, very short lifetime, and scaling/degradation of the combustor.

NOV's rig solutions group has increased its product offering by developing a new walking system for its AC Ideal Rigs. This is a shale-specific product that is essential for the pad drilling that is commonplace in the Eagle Ford. Additionally, the Environmental Protection Agency's (EPA) 2012 New

THIS CHANGED EVERYTHING.

DITTO.

Outer circumference provides a lower coefficient of friction for easier movement

Efficient proppant transport to fractures

Maintains crush strength and conductivity of uncoated proppant substrate

The invention of the wheel allowed mankind to go farther than ever before. That's how Propel SSP™ proppant transport technology rolls, too. Our proprietary coating swells in water allowing the proppant to self-suspend and flow deeper into fractures. You get improved hydrocarbon recovery and better fracture economics. That's a game-changing idea that will go a long way.

To learn more, visit PropelSSP.com.

SANTROL
A Fairmount Minerals Company

Source Performance Standards for volatile organic compounds (VOC) will come into effect on April 15, 2014 for tanks that have potential VOC emissions of six or more tons per year. All recently installed tanks will have to have controls to reduce tank VOC emissions by 95% by April 15. NOV's stainless steel enclosed vapor combustor has passed the EPA third-party testing audit at "99% plus" for destruction of vent emissions from oil and condensate tank batteries, loading operations, and storage facilities. NOV provides quick in-stock delivery to meet most site requirements.

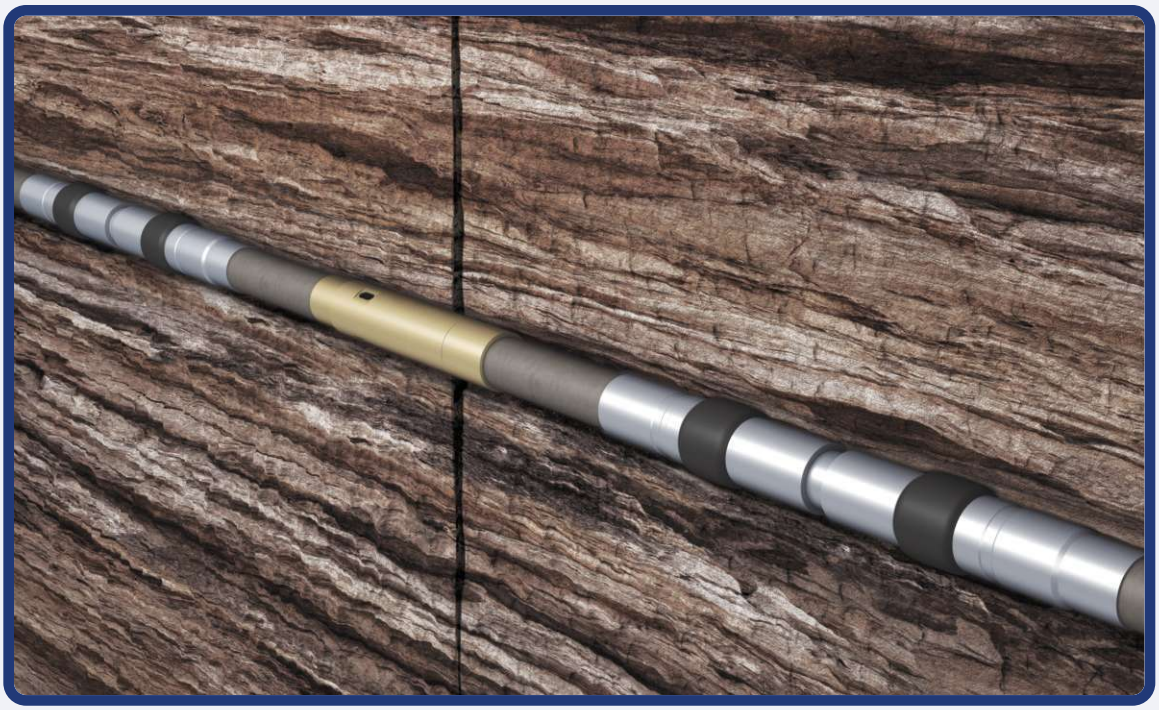
Packers Plus Energy Services Inc.

Packers Plus specializes in horizontal multistage fracturing and providing solutions for technically challenging completion applications in horizontal, multilateral, and HP/HT wells. Last month, the Canadian-headquartered company acquired Texas-based Eagle Downhole Solutions and CMC Machine Works, with the goal of fast-tracking expansion into emerging completion product lines. Eagle Downhole Solutions provides downhole tools and product development to solve completion and production issues in shale field development. CMC Machine Works offers high-end manufacturing and machining services that will add to Packers Plus' manufacturing capabilities and allow Packers Plus to expand its R&D efforts specific to the region.

Peak Completion Technologies Inc.

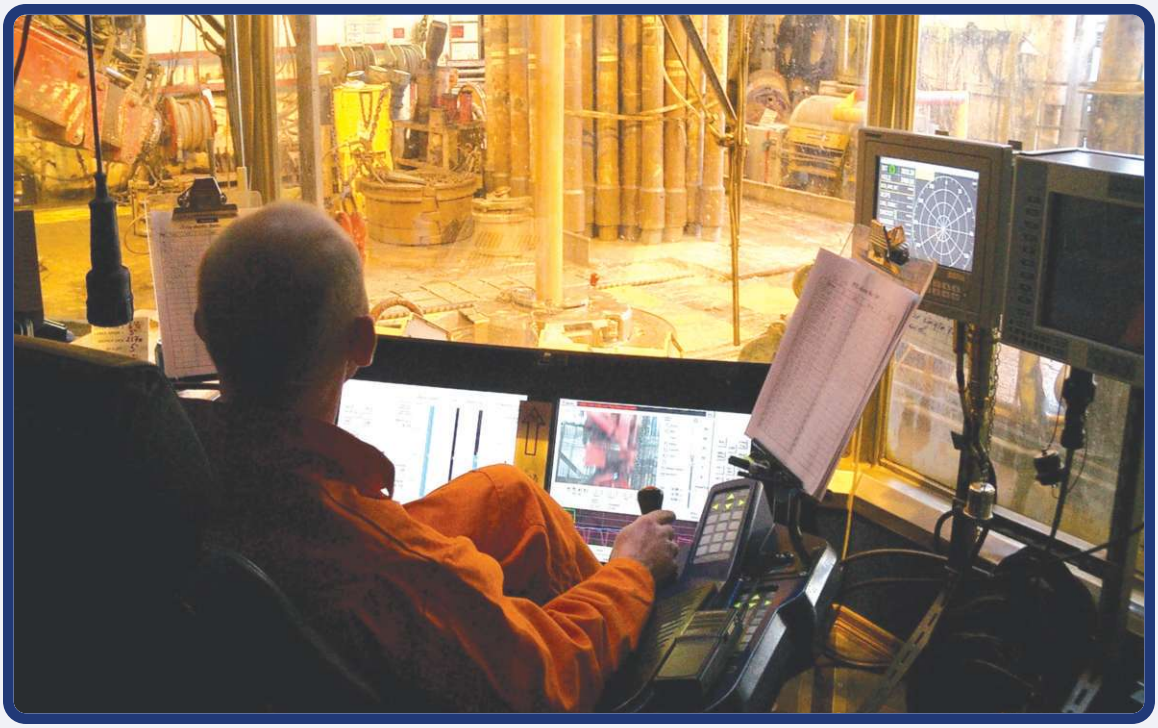
Peak Completions specializes in horizontal completion systems, including openhole and cemented sliding sleeves, zonal isolation packers, dissolvable frac balls, liner hangers, and composite plugs. Of particular interest to Eagle Ford operators is the company's toe initiation sleeve that can save operators up to US $150,000 per well by eliminating the initial tubing-conveyed perforating (TCP) run. The tool's small outer diameter allows for a smooth installation, and the drift inner diameter allows for standard wiper equipment to be used. The tool also can be configured to provide a full casing pressure test.

With more than 1,200 successful runs, the toe initiation sleeve tool is a reliable, effective means of improving return on investment in well completions. Secondarily for Eagle Ford operations, Peak Completions offers a new composite frac plug with ratings of up to 10,000 psi and 350°F. The plugs are designed 30% shorter and 20% lighter than the pre-



A single stage of Packers Plus StackFRAC HD openhole multi-stage completion system is shown. *(Image courtesy of Packers Plus)*


You're building the future.
We're here to help.™
From commercial construction to industrial operations and public projects, the United Rentals team is proud to provide our customers the best equipment, tools and solutions in the industry.
United Rentals®
UnitedRentals.com/ep | 800.UR.RENTS
#URBuildingFutures
Visit us at booth #431 at DUG Bakken in Denver, CO
© 2014 United Rentals, Inc.



Providing downhole data to the driller's console in real time improves ROP and reduces nonproductive time.

vious generation to provide quick drill-out times. The patent-pending mandrel and lock design ensure the plug cannot be preset or pump the mandrel during the fracturing operation.

Platinum Energy Solutions Inc.

Platinum Energy Solutions (PES) specializes in hydraulic fracturing, coiled tubing, and other pressure pumping services. The company's fleet of high-specification hydraulic fracturing units is rated at 15,000 psi or higher and is specially designed for complex and challenging hydraulic fracturing projects such as those found in the Eagle Ford, which typically involve long lateral segments and multiple fracturing stages in high-pressure formations. PES also touts that it is set apart from its competitors by the ability to supply, transport, process, and store wet and dry sand supplies used in the hydraulic fracturing process thanks to some prime contracts negotiated early on with suppliers of this much-in-demand commodity. The company began working in the Eagle Ford in 2011 and has several offices in the region.

Ryan Directional Services

Nabors subsidiary, Ryan Directional Services, has been involved in directional drilling and efficient wellbore placement in the Eagle Ford since the play's inception. The company boasts that it is a specialist in precise wellbore positioning and a leader in footage drilled per day in the region.

Ryan also conducts MWD services and recently commercialized a proprietary service in the Eagle Ford that provides reliable high-speed data transmission from downhole to surface in all drilling fluid types. This new technology is designed for low power consumption, enabling extended bit runs, and works by transmitting data continuously using low-frequency electromagnetic (EM) waves. The system employs the latest in signal processing, providing accurate decoding in high-noise environments.

To show the benefits of using EM MWD on unconventional wells, Ryan undertook a case study in the Eagle Ford comparing EM MWD with traditional mud pulse MWD gamma systems. A significant improvement in time savings was achieved through the use of the EM MWD system, which also included a continuous inclination measurement

that further reduced surveying time. This example well was about 15,000 ft in overall length with a true vertical depth of close to 10,000 ft. As compared to previous wells, this well was drilled with a 10% reduction in nonproductive time related to surveying each day, which the company said relates to about US $5,000 to $6,000 per day, depending on activity and spread rate.

Other services offered in the Eagle Ford include multilateral horizontals, extended-reach design wells, cased and openhole whipstock sidetracking, unmanned MWD, and high-temperature MWD. Last year, the company purchased the assets of Navigate Energy Services to further strengthen its position in the horizontal and directional drilling market.

Sanjel Corp.

Headquartered in Calgary, Canada, Sanjel has grown to be an international supplier of pressure pumping and multistage completion systems. The company has been active in the Eagle Ford since May 2011 and offers fracturing, coiled tubing, acidizing, cementing, and multistage completions services from its facility in Cibolo, Texas. The company employs a team of more than 400 personnel from the Cibolo region dedicated to serving the resource play.

Sanjel said that it focuses on providing customized solutions to ensure its clients are able to overcome the complex challenges presented in developing unconventional resource plays. Of particular interest to Eagle Ford operators is the company's full range of customizable fracturing fluids, including a low toxicity spearhead acid system developed specifically for the Eagle Ford. The company has implemented aggressive initiatives in developing products, which have an ultralow impact on human health and the environment. Other technologies include a patent-pending dry-guar delivery system to reduce fracturing fluid costs and environmental impact, a full range of multistage completion systems, and equipment designs to improve equipment reliability.

Sanjel leverages a vertical integration model, which incorporates internal equipment design and manufacturing, engineering, chemistry development, and product distribution to optimize the delivery of the right solution for the right challenge. The company is optimistic about its future in the Eagle Ford.

Schlumberger Ltd.

Schlumberger has been engaged in the development of the Eagle Ford shale since its discovery. The company has an extensive network of operational bases in South Texas that provide a full range of services, including directional drilling, drilling fluids, formation evaluation, cementing, stimulation, coiled tubing, completions hardware, testing, and production management.

The versatile HiWAY flow-channel fracturing technique can be applied to all or select stages of a multistage stimulated completion. Proppant pillars (inset) support the fracture leaving a network of linked infinite conductivity channels between the fracture tip and the wellbore. *(Image courtesy of Schlumberger)*

To address the complications of the Eagle Ford's lack of vertical and horizontal homogeneity, Schlumberger recently participated in a consortium with four Eagle Ford operators to study whether engineered completions technology could improve production performance. The group determined that, while there are significant hydrocarbons in place, production differences on a well-by-well basis cannot be understood without knowing landing point, stress along the lateral, or the effectiveness of stimulation in terms of effective proppant placement. Engineered completions, which rely on measurements along the lateral to determine the length of each interval to be treated and optimal position of clusters, were found to perform significantly better than completions in which such array was set empirically. On a sample of wells, 82% of clusters in engineered wells contributed to production, up from 64% for offset wells completed geometrically. When compared with a larger collection of wells in the area, average production from engineered completions was in the upper quartile whereas offsets completed geometrically performed sub-average.

This engineered workflow is now empowered by the latest generation of Schlumberger stimulation solutions, including a proprietary product flow-channel fracturing technique, which increases production in excess of 20% when compared to neighboring wells with significant gains in water and proppant utilization efficiency. This technique is being used in more than 90% of all Schlumberger operations in South Texas.

Additionally, the company also is using a new fracture sequencing technology in the Eagle Ford that results in improvements in production by preventing over flushing and further enables fracture initiation in additional clusters.

Scientific Drilling International

Scientific Drilling International (SDI) has been active in the Eagle Ford since 2010, offering design, engineering, and manufacturing of directional drilling, wellbore positioning, magnetic ranging, MWD/LWD, and surveying technologies.

The characteristics of the Eagle Ford shale play create difficulties in transmitting data to surface for some mud pulse technologies. SDI's electromagnetic (EM) MWD technology is suited for this challenging shale play as it is neither flow rate nor fluid dependent. The company said its EM MWD data transmission is usually four to five times faster than typical mud pulse MWD telemetry speeds, significantly reducing survey time after connections and ultimately increasing drilling efficiencies. The EM MWD has no moving parts, thereby eliminating the potential of lost telemetry data due to plugged pulsers or washouts, ultimately decreasing drilling risk.

The company also offers magnetic ranging services that provide needed solutions for production recovery, fish bypass, relief well drilling, plug and abandonment, close proximity drilling, collision avoidance, ghost well detection, and kickoff assurance. The magnetic systems work by isolating the earth's naturally occurring magnetic field from magnetic interference signatures and then calculating the distance and direction to an offset drillstring or casing using raw data obtained from MWD sensors. This method is used to ensure wellbore separation, close proximity drilling, or wellbore interception. With more than 11,000 wells permitted in the Eagle Ford since 2008 and estimates of up to 85,000 wells still to be drilled, SDI feels confident that accurate wellbore positioning and navigation will be crucial for the safe development of the entire shale play.

Also, the company recently began providing cased-hole services, including casing integrity, flow monitoring, and production logging in the Eagle Ford. The company is privately held — an attribute that gives SDI an "independent" culture and encourages practices such as designing and building fit-for-purpose solutions for individual customer needs. SDI manufactures and engineers all of its technology components down to the sensor level. The company is working on new products for its Eagle Ford customers, including robust drilling motors, high-temperature MWD technologies, new magnetic ranging techniques, next-generation gyros, high-temperature calipers, and compact wireline solutions.

The AquaView boat is shown generating a hydrographic map of a water source in preparation for hydraulic fracturing activity. *(Image courtesy of Select Energy Services)*

Select Energy Services

Select Energy Services decided to reorganize in February, announcing it will focus exclusively on oil and gas related water logistics and spin off its infrastructure and wellsite support sector to allow each entity to grow and operate independently. This change will better enable Select to concentrate on the end-to-end use of water in shale-based drilling, completion, and production operations, including water sourcing, transport, containment, well testing, water treatment, and disposal.

The company's new mission is to "change the oil and gas industry's approach to water management" by providing strategic water management solutions from sourcing to disposal, while maintaining a clear focus on safety and environmental issues according to Select. The company transports, tests, treats, and disposes of water and fluids from well sites in every major North American shale play.

With a large office in San Antonio and field offices in locations spanning from Kenedy, Texas, to Big Wells and Laredo, Texas, Select offers strategic sourcing; well testing and flowback; water transfer using innovations such as multiple no-leak piping systems and lay flat hose; large volume containment, including steel, above ground, frac tanks, and in-ground pits; and a wide portfolio of water treatment options to Eagle Ford operators. The company also offers hydrographic surveys and an advanced remote pit monitoring system using Sonar remote control and GPS data that allows crucial information to be delivered in real time to computers, smart phones, and tablets with email and text message alerts.

TAM International Inc.

TAM International provides inflatable packers, swellable packers, and associated downhole products and services to the oil and gas industry and has been active in the Eagle Ford since the play was first exploited in 2008. The company has an extensive inventory of inflatable service packers and accessories for lost circulation problems and zonal isolation in remedial and workover operations. TAM also provides casing annulus packers and port collars for cement integrity as well as swellable packers, frac sleeves, and accessories for stage isolation and reservoir access in multistage hydraulic fracturing completions.

As a smaller, privately owned company, TAM is able to react quickly to design and deliver specialty

TAM International's new Houston global manufacturing facility was completed in September 2013. *(Image courtesy of TAM International)*

solutions using its in-house integrated R&D, manufacturing, sales, and operational capabilities. The company is focused on inflatable and swellable packers and accessories and "makes it a practice not to diversify outside of its realm of expertise," according to TAM.

"We have the most complete portfolio of swellable elastomers in the industry, specifically designed for very diverse customer requirements such as fast swelling needs for multistage fracture applications in low-temperature/high-salinity conditions, effective openhole zonal isolation in steam injection applications, or in permafrost harsh conditions," a company spokesperson said.

Of particular interest to Eagle Ford operators are TAM's swellable packers rated to work in temperatures up to 375°F (GT packers rated up to 575°F), making them an ideal alternative to cement for isolation in multistage completions in the Eagle Ford, according to TAM.

TEAM Oil Tools LP

TEAM Oil Tools offers full completion services in the Eagle Ford region from two service centers – one in Seguin and the other in Alice, Texas. The company's newest tool is a ball launcher with several unique features, including the ability to launch six to18 balls from a high-pressure stackable system. Each ball is launched remotely using a proven quarter turn pneumatic actuator operated from a self-contained control panel. The ball launcher, rated to 15,000 psi, incorporates both a flag indicator to give visual indication of launching and a manual override, should it be required. The system also has an optional manual ball launcher tool, which allows for manual loading without having to take down the ball launcher if there is an issue.

The company also plans to introduce new frac sleeve technology for cemented horizontal completions, currently in use in the Marcellus and Utica shales, into the Eagle Ford play this year. The technology used a ball-activated frac sleeve where one ball size is used multiple times.

"It does so mechanically, not electronically – but exactly how is proprietary," said Steve Chauffe, TEAM's vice president of new technology and business development. "We can do 90 individual sleeves with 90 individual balls, never getting below a 4-in. ball."

Forum has assembled some of the most well-known brands in the industry to offer an integrated package of innovative products to customers worldwide. But, at the end of the day, we know that it's not about the products we provide. It's about the solutions you need. We're ready to hear about the challenges you face and how we can help you tackle them.

Talk to us at **f-e-t.com/yourforum**

It's your Forum.
Let's talk.

Subsea Technologies

Well Construction & Completion Tools

Valve Solutions

Drilling Technologies

Surface Production & Process Equipment

Stimulation & Intervention Products

FORUM™
ENERGY TECHNOLOGIES

Smart Solutions. Powerful Products.

To learn more about our exceptional products and services, visit us at f-e-t.com

The ball launcher "simplifies manual dropping of a ball, [and] it prevents the time-consuming breakdown and reassembly of the unit formerly required to manually override the system," said Michael Harris, vice president of engineering and manufacturing, at TEAM Oil Tools. *(Image courtesy of TEAM Oil Tools)*

TEAM recommends using dissolvable balls with the system. These dissolvable balls, in conjunction with the large ball seat inner diameters (ID), offer the operator the option of not drilling out after the frac job. Eliminating the drillout reduces the overall cost of the completion, allowing operators to complete cemented laterals with cemented frac sleeves. Not only can the operator run the system as a cluster valve, the system also can be set up to stimulate 90 single sleeves at a time.

The technology that enables this frac sleeve system to replace traditional plug-and-perf operations literally is embedded within the three-layer tool. This mechanical device is removed from the flow path of the cement and frac slurry. This design avoids the problems associated with cement, because the ID of the tool is relatively smooth. The smooth ID of the tool allows the use of a heavy duty cement wiper plug, which more effectively wipes the pipe.

Tetra Technologies Inc.

Long before the advent of the Eagle Ford shale, Tetra Technologies' Alice, Texas, office served the South Texas oil community with fluids, production enhancement services, and an onsite laboratory. Today the company's South Texas operations are busier than ever, offering a full range of clear brines for workover, well control and completions operations, completion fluids additives, portable mixing plants, custom onsite blending of potassium chloride or sodium chloride for fracturing services, water-based drilling fluids, and the additives to treat those products. The company also provides operators with comprehensive frac water management services. Tetra's brine plant is capable of blending up to 500 bbl at any time, 24 hours a day.

According to the company, its brine services are much in demand in the region, thanks to the company's ability to transport its high-density brines to customer locations on short notice. Operators call on Tetra when local expertise is needed for well control and other difficult operations.

"Our personnel, fluids, services, and technical support are at the full disposal of our customer until the issue is resolved," a company spokesperson said.

The company acquired WIT Water Transfer in early February and is planning to expand service locations in the Eagle Ford, the Permian basin, and the Bakken shale in the near future. Additionally, the company is working on a new chemical to improve performance while reducing environmental impact and is developing the next generation of portable mixing plants.

Universal Pressure Pumping Inc.

Universal Pressure Pumping Inc. (UPP) provides hydraulic fracturing, cementing, and acidizing services in the southwestern US and has been successfully fracture treating horizontal shale wells since

Universal Pressure Pumping's Powder-Stim Dry FR unit. *(Image courtesy of Universal Pressure Pumping)*

2003. UPP addresses the many challenges unconventional operators face each day, which include logistics, water quality, dual-fuel equipment, and green additives.

A subsidiary of Patterson-UTI Energy Inc., UPP focuses on developing new technology, protecting resources, and creating jobs. Recognizing that water is a precious commodity, the company developed a new technology that uses produced water as the primary fluid in a fracturing fluid system. According to the company, this technology is being successfully used by operators in South Texas, saving money on disposal costs of production water and allowing for reuse of treated water, resulting in reduced freshwater requirements on new wells.

Additionally, the company has developed a service that provides near real-time hydraulic fracturing job data to customers at remote locations. This service offers customers the convenience of viewing job-critical data without leaving the office, requiring only access to the internet and a web browser. The company also offers engineering support and technical solutions.

Varel International

Varel International is the world's largest independent supplier in the global oil and gas drillbit market. Headquartered in Carrollton, Texas, Varel services oil and gas, mining, and industrial markets with its comprehensive suite of roller cone and fixed cutter drillbits. The company employs more than 1,300 workers and has manufacturing facilities in Houston; Matamoros, Mexico; Tarbes, France; and Kurgan, Russia, as well as sales offices worldwide.

Specific to the Eagle Ford, Varel provides drillbit solutions and well analysis for drilling optimization for this area. The company has been an active player in the Eagle Ford since 2009. Varel has offices to serve this area in Houston and Corpus Christi as well as multiple stock points throughout the field to ensure close proximity to drilling locations. The staff includes field salesmen, engineers, and technical salesmen in the city. Varel said it prides itself on quick turnaround times when designing new products to stay on the leading edge and is always evolving to meet ever-changing demands and expectations.

The company recently started production on a new sealed bearing bit series — a line of completion roller cone drillbits. Designed for the fast and effective drillout of frac plugs, these new bits incorporate a hybrid cutting structure matched specifically to the distribution of high hardness, high abrasion, and elastic or plastic materials found in such plugs.

Weatherford International

Weatherford is proud to have been on the very first Eagle Ford well completed in South Texas. The company has since expanded to more than 20 district offices with 1,300 employees providing drilling, completion and production equipment, services, and products throughout the region.

Weatherford provides a full suite of services, including directional drilling (and rotary steerable), casing and tubular running, cementation accessories, rotating control heads, BOPs, drillpipe, jars, fishing, completion products, wireline, pressure pumping and stimulation, thru-tubing, liner hangers, capillary, pumping units and services, rods, hydraulic lift, plunger services, and gas lift.

The company said its greatest challenge in the Eagle Ford is safety. "In a market of high-employee demand and short supply, ... our record is one area that sets us apart from our competitors," the company said. Weatherford uses a performance management system that reduces nonproductive time through service quality enhancements and technology offerings, combining both safety and performance management to deliver faster, safer, and more productive wells for operators.

The company also recognizes that shale operators are looking for continued cost savings in their field operations and are increasingly turning their attention to fuel. Conventional pressure pumping has traditionally been powered by diesel fuel, a commodity that is prone to price swings. For large-spread frac operations, large volumes of diesel are required, which translates to a large number of fuel trucks traveling to and from the job site. To address these issues, Weatherford has developed a pressure pumping unit powered by a 2,500-hp Caterpillar (CAT) engine and transmission equipped with a dual-fuel conversion package. The package allows for the use of diesel, natural gas, liquid propane, or compressed natural gas in various combinations. The result is a dependable and economical fuel alternative that saves money and reduces the number of diesel tanks required to fuel the fleet of pumps during operations. Weatherford reports that some operators have been able to replace up to 70% of diesel with unprocessed gas sourced right from the same field and have achieved the same level of pumping efficiency at a lower cost.

Beyond pressure pumping, advancements also will be seen in completion sleeve technology. ■

Weatherford International's San Antonio office, serving the Eagle Ford region. *(Image courtesy of Weatherford)*

Fracturing
With Purpose

Hydraulic Fracturing is a large investment.
We strive to provide you the best return on this investment by being safe, timely, innovative, and cost-effective.

Our local knowledge & experience allow us to overcome the many challenges our customers face, such as logistics, water quality and green additives.

Let's work together to maximize your hydrocarbon production.

Experienced Innovative Horizontal Hydraulic Fracturing

Fracturing
Cementing
Acidizing

Director of Sales
Jeff Wilkinson
817.688.8738
Jeff.Wilkinson@univpp.com

West Texas – Midland
Mark Acklin, Sales Manager
432.238.6880
Mark.Acklin@univpp.com

North Texas & South Texas
Harry Littleton, Sales Manager
940.389.4999
Harry.Littleton@univpp.com

UNIVERSAL
PRESSURE PUMPING, INC.

www.universalpressurepumping.com

Milking the Measurements

The integration of multiple data sources helps operators make better decisions about induced fracture location.

By Rhonda Duey
Executive Editor

The shale gale in North America is the envy of the world, but when one digs down into the weeds, it's not the perfect manufacturing process that some operators would like to claim. Despite the obvious engineering challenges of drilling long lateral sections, perforating them, and fracturing them to crack the tight formation, in the past many operators have taken a rather brute-force approach.

"Operators divide the lateral into stages and decide how much fluid is needed per perf cluster to get the desired frac length and height," said Carl Neuhaus, lead engineer for MicroSeismic Inc. "That determines the number of perf clusters per stage and their overall completion design. It's a lot less sophisticated than you would think."

More data would help, but up until now operators have been desperate to drill wells to hold their acreage. They haven't always had the luxury of a 3-D seismic survey or a full suite of well logs prior to running their completions. And often the different disciplines haven't seen eye to eye on which measurements might truly be necessary.

"With unconventional reservoirs, we have to make an effort to integrate as much data as possible," Neuhaus said. "It can be difficult, because everybody has their specific discipline, and sometimes it's hard to get the geophysicists and the geologists and the engineers to talk to each other."

The good news is that the fields get developed quickly. The bad news is that they might get developed incorrectly. "Operators go in with a completion design and a treatment design that they think is the optimum combination of different parameters, or at least a very good starting point; then they start developing a field," he said. "It will take about a year to 18 months to have enough production data from the first wells to determine the success and efficacy of that particular configuration. During that time period, the operator will likely continue with a completions program that might not be optimal for that reservoir. The wells underperform, and the operator can pretty much write off that part of the field as remedial operations can be hard to perform."

This is starting to change. Now that their acreage is mostly held by production, shale operators have the luxury of paying more attention to their fields. "The shift in the business going from held by production to more of a development phase has allowed some of these teams to slow down and take a look at their data," said John Cadenhead, strategy manager for Schlumberger's unconventional group. "We've seen a lot of plays where just sheer brute force doesn't bring added production. Bottom line, it's about production."

Part of the shift in attitude is no doubt driven by studies by Schlumberger and others indicating that a geometric pattern to fracturing is not necessarily delivering the desired results. Schlumberger put together a consortium of companies active in the Eagle Ford and shared data that indicated that only 64% of perforation clusters were producing in the average lateral. Additionally, industry studies show that about 40% of the wells being drilled in shale plays were subeconomic, primarily because not all of the perforation clusters were producing. A study published by the Society of Petroleum

Facing page:
A technician installs a downhole microseismic geophone array. *(Image courtesy of ESG Solutions)*

Engineers indicated that 30% to 40% of the perforation clusters along a lateral were not being effectively stimulated.

The Eagle Ford group took measurements along the lateral prior to completion to engineer the completion better.

"We saw good results," Cadenhead said. "We actually could reduce the number of unstimulated perf clusters by more than half, and we're seeing even better results today."

In fact, customers in that consortium were seeing an average of US $1.5 million in net present value improvement per well. Good results indeed.

There is an increasing trend in shale plays to gather more data prior to completion and integrate it with other data types – microseismic data, production logging, core measurements, and downhole sensors – to go from "drill, baby, drill" to a more field-centric approach to developing unconventional plays.

"We call this 'completing smarter,'" said Rob Fulks, director of the unconventional resource team for Weatherford. "This involves using LWD logs or cuttings analysis and gas ratio analysis to adjust the stage and/or packer positioning. Everybody's been talking about it for a long time, but there has been some recent success in the Eagle Ford."

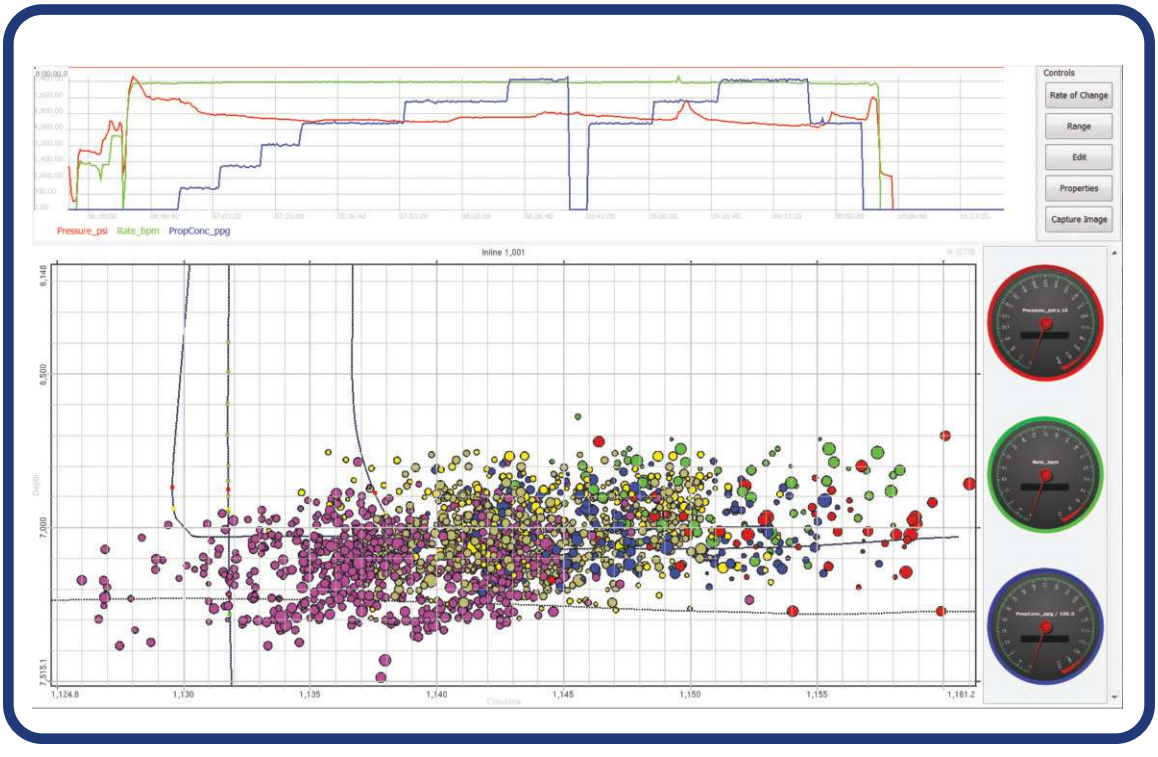
Logging

Taking measurements in the lateral section of the wellbore is a critical factor in placing perfs correctly. This can be done via LWD tools, through-bit measurement, or wireline tools.

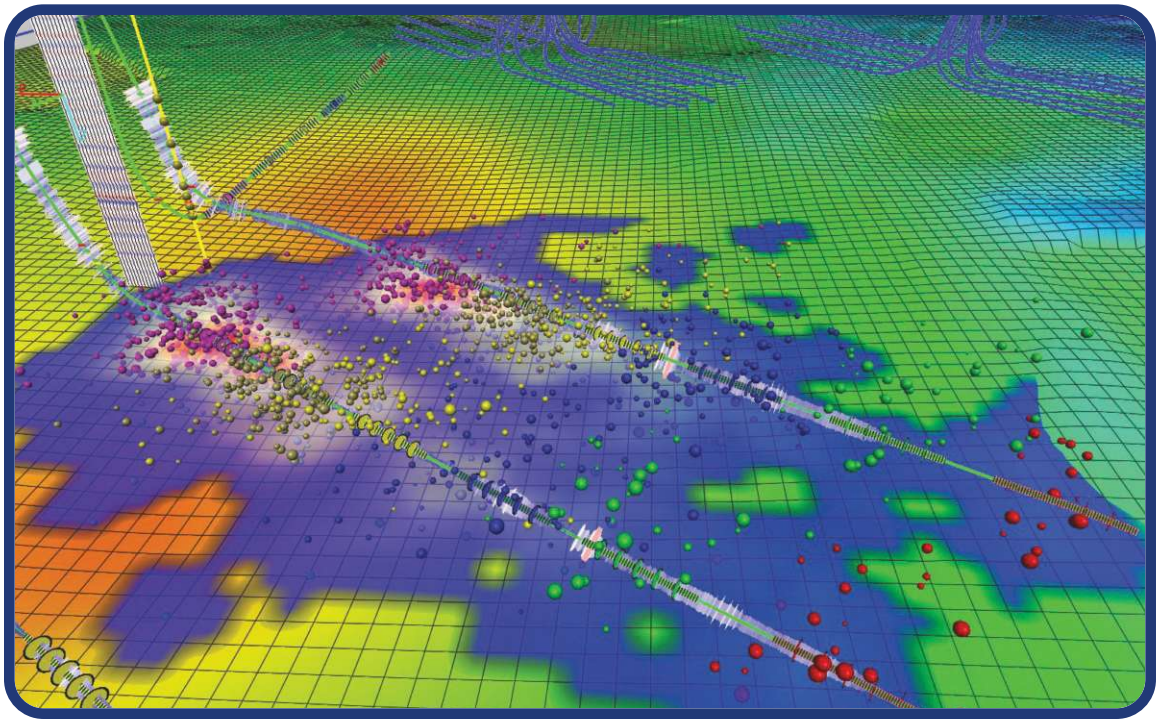
Logging brings a host of information to the operator. Sonic logs are used to generate velocity models, which describe the speed at which seismic waves travel through various rock layers, according to Ted Urbancic, executive vice president of Global Energy Services for ESG Solutions.

"To account for velocity variations caused by subsurface heterogeneities as well as changes to the reservoir rock as a result of fracture stimulation, velocity models are typically refined using proprietary inversion methods throughout the monitoring program," he said. "The sonic log gives us a starting point.

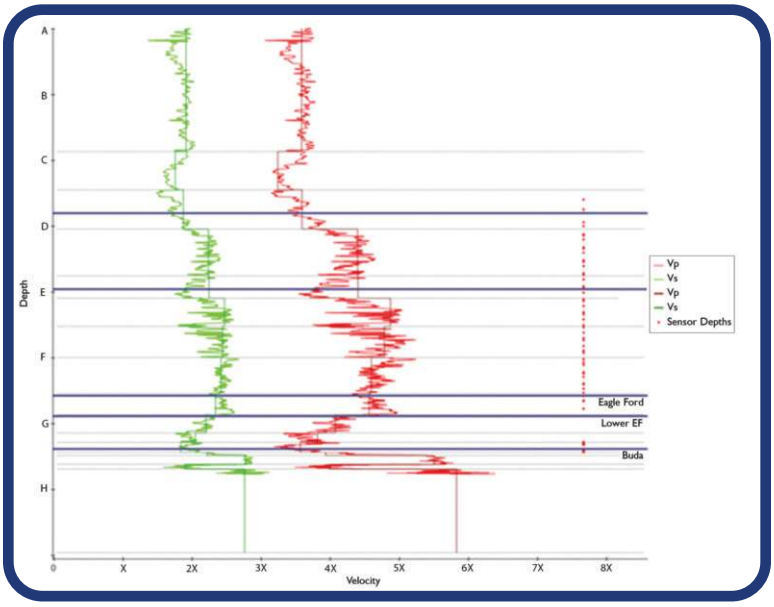
"With an acoustic tool, we're computing the stress along the wellbore, and we want to place the



Real-time stimulation data in time-series and gauge views with a cross-section view of microseismic with well paths of both treatment wells and observation well. *(Image courtesy of Weatherford)*

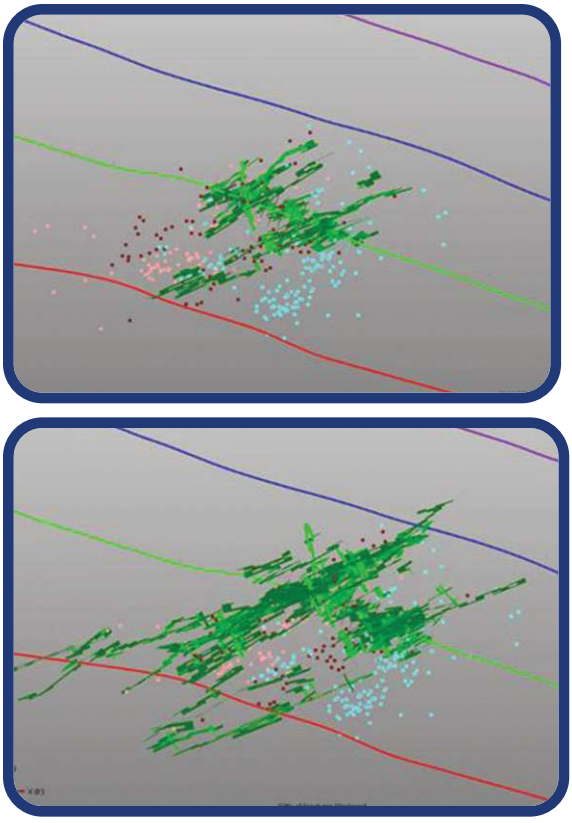


Full integration and time-dependent 3-D view shows dynamically computed stimulated volume, vertical seismic profile, bottom reservoir surface, logs along multiple wellbores with perforation locations and microseismic during zipper frac. *(Image courtesy of Weatherford)*



This image shows an initial microseismic velocity model developed from sonic log data. *(Image courtesy of ESG Solutions)*

perforation clusters in areas of similar stress. It's not necessarily about low stress but similar stress. When we initiate fractures, they propagate at a similar size in all perforation clusters. We also want to make sure that we have good porosity, low clay in most instances, permeability, and hydrocarbon presence," Urbancic said.



In this map view of a discreet fracture network model with lower (top) and increased (bottom) treatment flow rate, the contiguous lines represent the wellbores. The microseismic data are shown as colored dots, and the discs on the wellbore are individual perforation intervals. Fracture planes are shown in green. *(Images courtesy of MicroSeismic Inc.)*

Other useful information comes from gamma-ray and resistivity logs, which indicate lateral heterogeneity along the wellbore, said Jim Rangel, manager of petroleum consulting at Weatherford.

"The gamma ray is very useful in determining the contents and small changes in the rock to help you steer," Rangel said. "The density and velocity logs can give you a brittleness reading of the rock. Knowing the differences between the brittleness in the rock can help avoid perforating in nonproductive zones."

For instance, he said, when the logs indicate a shift from brittle to nonbrittle within a stage, there will be a preferential breakage out of the perfs in the more brittle rock. "You want to place the stages so that you're fracturing like rock with like rock in all of the perforations in the stage," Rangel said.

Compared to a 3-D seismic survey, logging methods do not add much time to the overall process. Still, the percentage of wells receiving this treatment is small.

"You have to be efficient, so that's why Schlumberger acquired the Thrubit logging services conveyance platform," said Chuck Catchings, the North America Land measurement domain manager for Schlumberger. "It's a very low-impact and low-risk way to acquire the measurements in the lateral. We also can do this while drilling, which is no extra time, and we can do it in cased hole after drilling.

"The customer spends additional money, but we've demonstrated in the Eagle Ford consortium that extra production more than offsets the additional spend on lateral measurements."

Other logging measurements can be taken after the well is on production. Production logs offer information as to just how well each perf cluster is producing, further adding to the database of understanding. Additional measurements such as distributed temperature, pressure, and acoustic data can help operators understand the difference between the water and the gas as well as the volume that's coming out of each stage, Rangel said.

Overall, gaining information from the lateral, while still a controversial concept to many, helps make field development more economic. "A lot of people think that if they're going to run logs, that means they're spending more money," Rangel said. "We've got to get across the fact that spending extra money but putting that information to good use provides better production."

Microseismic

Microseismic measurements are a relative newcomer to shale development, but the technology has revolutionized the understanding of how the rock actually fractures when stimulated. Microseismic surveys are acquired during the fracturing process and record the sounds taking place subsurface, helping create a 3-D "map" of the fracture orientation, length, and height.

Until recently the tool was strictly diagnostic, validating (or not) the effectiveness of the completion design. Lately, however, operators are using the microseismic information from one well to implement completion changes on subsequent wells.

"Microseismic tells you where you actually did break out, and it lets you see the areas of the reservoir you were able to cover," Rangel said. "There may be some rock that didn't get touched, and you'll see that in the microseismic."

Microseismic can be gathered in a number of ways: a retrievable surface array, a permanent buried array, or a downhole array. Mike Donovan, marketing and sales manager at Microseismic Services for Schlumberger, said that the decision regarding which method to use relies on the client's objectives.

"Primarily, clients would prefer to utilize downhole surveys, because there is better sensitivity to imaging that natural fracture," Donovan said. "But there are some benefits to doing it from the surface. Our approach is to work with the client on the key objectives and offer the geometry that makes sense for that project."

A LITTLE TECH TRANSFER

Devon Energy Corp. is a newcomer to the Eagle Ford, having recently reached a definitive agreement to acquire GeoSouthern Energy's assets in DeWitt and Lavaca counties. But it hopes to take some of its Barnett shale expertise with it.

Jeff Dahl, production engineer, and John Spaid, geologist, recently have been reassigned to the Eagle Ford to work some of their magic on the new assets. Their team has brought to bear some of the data integration exercises detailed above in its Wise County acreage in the Barnett. Key to its success there has been the running of image logs in all of its lateral sections.

"The image logs show us where we have open fractures, closed fractures, or sealed zones and faulting, and we use that information in our completion," Spaid said. "We pick the perforations on the stages that we're going to fracture-stimulate on the wells, trying to avoid the open fractures so we're not pumping an entire frac job into a fracture that's already open."

The team has been collaborating with Halliburton to create a full reservoir characterization of that portion of the shale. Dahl said that this included the creation of an earth model that enables his team to alter landing points. "That progressed into making changes in our stimulation design along with picking the image log data and adjusting our perf clusters locations," he said. "Overall, the results have been very promising because of that, and we're making those technology leaps in a field that has thousands of wells drilled in it already.

"It's proof that even in some of these older shale plays, we can bring new ways of looking at the field and applying the appropriate technology to add even greater value."

But what about the Eagle Ford? Industry mantra dictates that "not all shale plays are the same." This is certainly true of tech transfer from North Texas to southwest Texas.

The immediate issue is that formation image logs, which have proved so helpful to Devon's Barnett work, are not currently feasible in oil-based muds (OBMs), which are required in the deeper, hotter, overpressured Eagle Ford formations. Image logs will need to be drillpipe-conveyed in these conditions.

"There aren't a lot of tools that are like that," Spaid said. "There are some sonic scanners that you can use for the image data, but for a resistivity-type tool, it's not there yet because the OBM interferes with that. That's going to be one of the challenges."

Another issue in the Eagle Ford is that its development is not as fracture-based as the Barnett. However, Spaid said, these issues almost offset each other, because the lack of natural fractures in the Eagle Ford means that image logs aren't as useful or necessary as they might be in the Barnett. "We're thinking, 'Gosh, we'd like to have them, but we're lucky that we really don't need them,'" Spaid said, adding that microseismic information in the Eagle Ford will play a larger role in tweaking completions than it has in the Barnett.

"Our plan going forward is that we want to understand the reservoir first, characterize it, and alter our design based on that scientific information," Dahl added.

The team's hope is to see service companies streamline the 3-D fracture model into something that is used routinely in the development of shale plays. "To look at something in three dimensions and actually develop a model for the fracture network that either exists or is being induced is something that's being developed," Spaid said. "We need to model that and understand that."

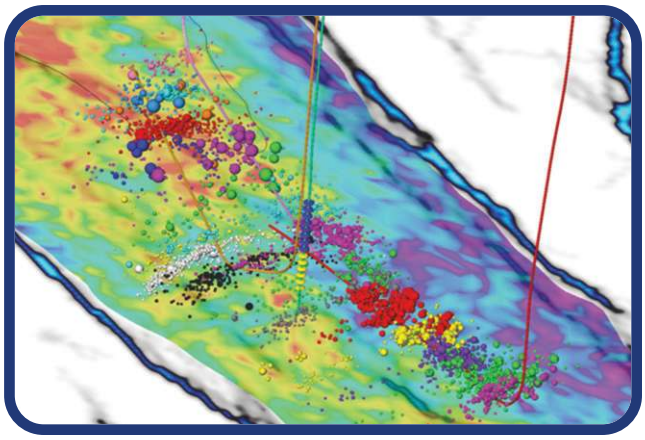
Schlumberger recently released MS Recon, a high-fidelity microseismic surface acquisition system. According to the company, the MS Recon system improves sensitivity to smaller events by boosting the signal-to-noise ratio more than twofold compared to its standard system.

Microseismic data are not just used to validate the effectiveness of a fracture stimulation. Ron Dusterhoft, a technology fellow for Halliburton, said in some cases microseismic data also can be correlated to well productivity and can be used to evaluate well and fracture spacing.

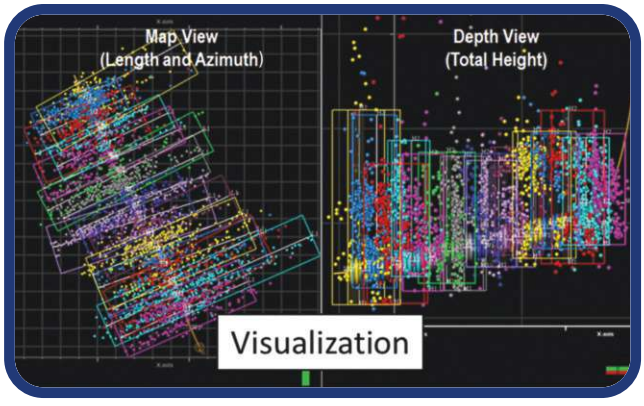
Urbancic said that microseismic results also can indicate fault activation. "In formations experiencing a faulted geology, it is not uncommon to see larger events between 0 to +2 in magnitude during a hydraulic fracturing program," he said. "Larger magnitude events release more energy, have broader implications for deformation within the reservoir, and represent a much larger fracture surface, which may extend beyond the target treatment zone.

"Operators don't want to waste resources by fracturing into nonproducing zones. Assessing the role of faults in a reservoir also is important for operators concerned with intersecting water-bearing formations or generating induced seismicity."

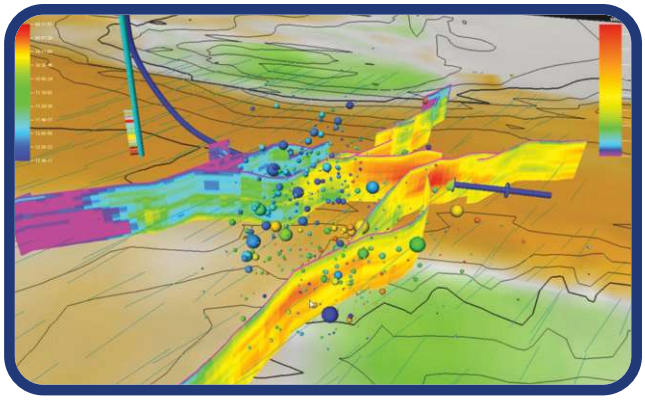
Having accurate information about the size of the events also is important in the design of future stimulation programs, he added.



Data integration is critical in understanding the microseismic results in the context of the earth model. *(Images courtesy of Schlumberger)*



Traditional interpretations were limited to estimating the hydraulic fracture dimensions. Now clients are looking for ways to incorporate microseismic into field development decisions.



Microseismic provides valuable insight into modeling the hydraulic fracture and is the basis for having a predictive tool.

On the other side of the spectrum, microseismic data can reveal faults that are too small to image on standard surface seismic. "There are a lot of these faults in the Eagle Ford that, even with very high-resolution seismic surveys, don't show up," Neuhaus said. "Suddenly they show up in a microseismic survey, and because they extend over multiple pads, you can use that information to avoid pumping into these fault features."

Microseismic adds a unique dimension to unconventional development in that it brings together disparate disciplines in a way that few other technologies in these plays do. "It's a multidomain offering in that you need both the geoscience and engineering expertise to extract full value from microseismic measurements," said Donovan. "Clients are emphasizing the geophysics, how the measurements are made, and the accuracy of the measurement, and that then allows them to understand the caveats that come along with interpreting the data."

Shawn Maxwell, microseismic adviser for Schlumberger said, "In terms of how microseismic

is used, the operators don't just collect it to see a pretty picture of the fracture. They're using it proactively, and the engineers are realizing the benefit of how best to complete the wells. They gather the data to answer some of the fundamental questions they've been scratching their heads about."

Bringing it all together

Data integration is where the rubber really hits the road. The industry is just now beginning to tackle the challenge of looking at all of the data together to get the best possible information about these difficult reservoirs.

"We have to find a way to integrate these data so that different technologies, different software packages, and different platforms can talk to each other," Neuhaus said. "Otherwise you're always going to be looking at only one more or less isolated piece of the puzzle."

Several companies already are hard at work finding ways to integrate disparate datasets to get closer to the big picture. Schlumberger has developed the Unconventional ROC workflow for reservoir-optimized completions (UROC), based in part on its Eagle Ford consortium work, to implement a work-flow that takes into account many different types of information – discrete fracture network and 3-D finite earth modeling, completion optimization, stimulation design, microseismic monitoring, and production simulation, to name a few – to help its clients maximize value through data integration.

The UROC workflow is broken into two pieces: basin resource assessment and well optimization. The basin assessment looks at the basin's production mechanism, the play fairway, the sweet spots, and developing a drilling inventory. The well optimization piece evaluates each individual well in the process. The workflow is optimized through the Schlumberger Mangrove engineered stimulation design in the Petrel platform.

"We've demonstrated that by using log measurements in the lateral and placing the perforation

"Clients are emphasizing the geophysics, how the measurements are made, and the accuracy of the measurement, and that then allows them to understand the caveats that come along with interpreting the data."

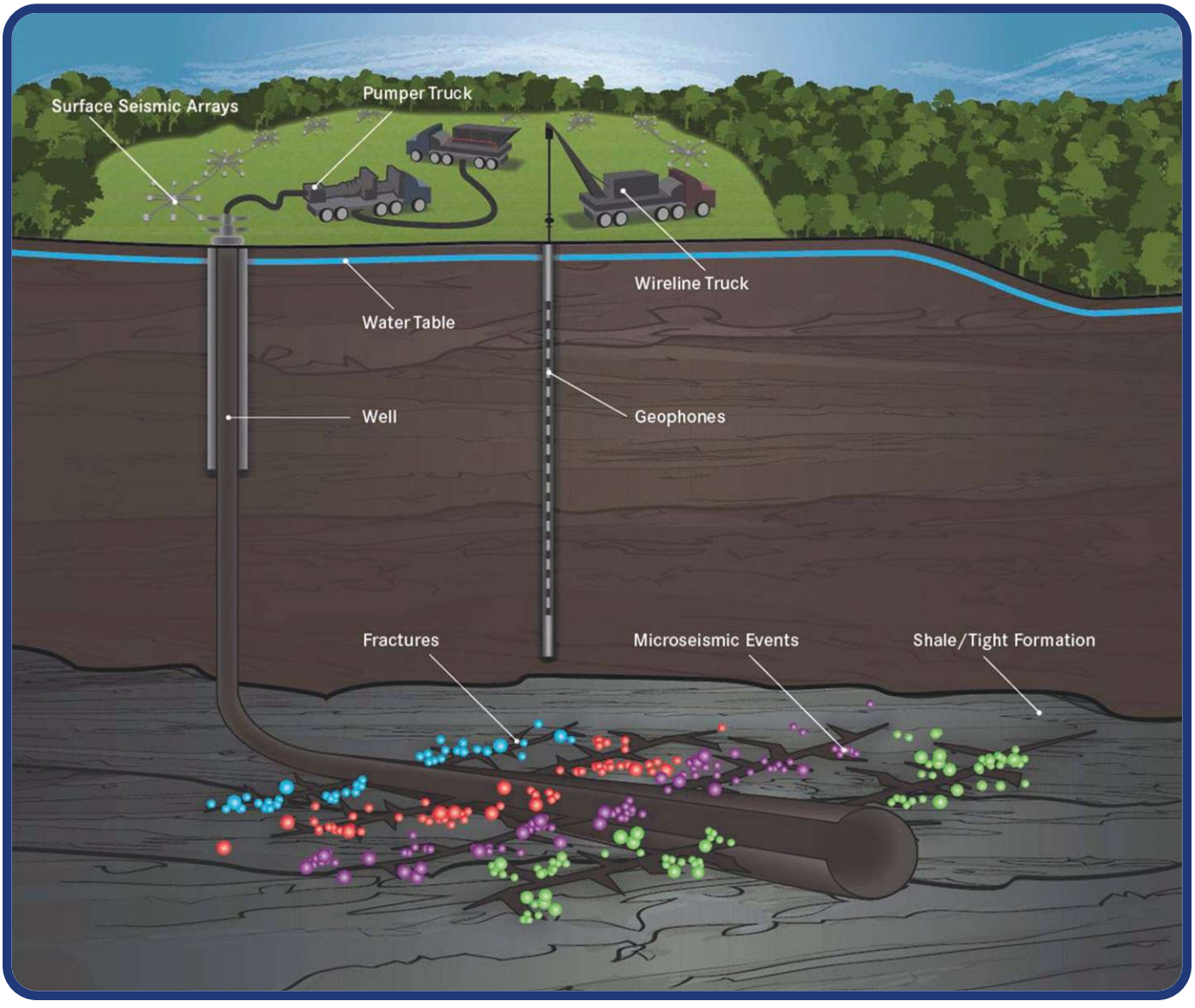
—Mike Donovan, marketing and sales manager, Microseismic Services, Schlumberger

clusters in similar stress and good-quality reservoir rock, we can improve the percentage of perf clusters contributing to production," Catchings said. "It increases the success of initiating similarly sized fractures at each perforation cluster and placing those fractures in the best reservoir-quality rock."

Cadenhead added, "If you look back at when this all started, we really didn't have the knowledge, the workflows, the things that have been developed over the last few years. Even a year before we started this consortium, we didn't have a proof statement that measurements help increase production. Today we have that. It's indisputable."

Even though there is tremendous focus on the well optimization piece, Donovan said that the basin assessment brings field development into the mix. "That's sort of a new trend that we're seeing with clients," he said. "They're more interested in using microseismic to understand things like well spacing." This helps when dealing with stacked laterals and interference between wells, he added.

Cadenhead said that the impetus for the UROC came from within Schlumberger as well as



ESG's Hybrid deployment configuration combines data from surface and downhole microseismic arrays to capture large and small events during hydraulic fracturing. *(Image courtesy of ESG Solutions)*

from customers. Different groups of petrotechnical experts were learning about the different shale basins in North America, trying to understand the same problems. "We realized that the workflow itself was similar," he said. "We try to put an engineered approach behind everything we do, and in each basin parts of this workflow have been going on for years. But putting it together and ensuring that we are following it has been fairly recent."

ESG also has had success with the data integration approach through its patented Hybrid system. "In this configuration, all data are microseismic in nature, whether they are acquired from surface stations or by using wireline tool strings," Urbancic said. "The data are integrated to form a single large time-synchronized microseismic dataset where many of the seismic events will have been detected using both the surface and downhole arrays."

He added that larger magnitude events are systematically underestimated through conventional microseismic monitoring equipment. "To obtain a more accurate representation of event characteristics, larger magnitude seismic data must be acquired using the correct equipment for the given magnitude range," Urbancic said.

This requires a combination of surface arrays tuned to large events along with downhole sensors

tuned for smaller events. When combined, these arrays provide reliable assessment of seismicity across a wide range, he said. This in turns helps operators better understand the impact of their completion strategy on the reservoir.

John Ughetta, executive vice president of sales and business development, microseismic workflows and solutions for SIGMA^3, said that microseismic activity can be related to the geomodel that has been derived from the relationship of wireline logs to prestack or post-stack seismic trace data through inversion.

"We take the inversion process a step farther by forming relationships between our inversion-propagated rock physics properties to various structural and spectral seismic attributes," Ughetta said. "Ultimately, we want to determine the reservoir properties, including brittlenesss, total organic carbon, porosity, fracture density, and closure stress and then validate these properties with microseismic and production to provide a more accurate predictive model as to where to drill and complete.

"Additionally, if operators run production logging tools on tracer logs, these can be used to correlate the production stage by stage with the microseismic data."

Overall, the complexity of unconventional plays is causing operators to consider a wider range of measurement tools than they perhaps would have had time or patience for in the past. "Clients today would like to have more of a data-driven workflow, where they move from reservoir characterization to incorporating the microseismic back into the model they've built in a way that allows them to use the new tools to simuate the hydraulic stimulation and then the production afterward," Donovan said. "That bridges multiple domains." ■


BLACK
3733
BLACK
3717

Perfecting Completions

Operators in the Eagle Ford are relying on the tried and true, all the while improving strategies and technologies.

By Bruce Nichols
Contributing Editor

Completing an oil, condensate, or gas well in the Eagle Ford shale play usually means plug and perf (PNP) frac initiation of a 5.5-in. cemented wellbore, a mixture of slick water and gel for fluid, and a blend of raw sand and resin-coated sand as proppant — and, of course, lots of pumping horsepower.

However, new methods and new technology are getting more attention as operators consider whether wielding a high-tech scalpel along with blunt instruments and brute force could improve results at a reasonable cost.

"There's a lot of buzz now that's creeping in — not only for the Eagle Ford specifically, but for unconventional plays — that traditional methods are not optimal to improve wellbore economics or initial production [IP] or ultimate recovery," said Ben Wellhoefer, Halliburton's global product champion for horizontal completion.

"There are many operators now trying to find a better way of doing what they're doing. Still, the main driver happens to be cost. So whatever method they're choosing, they're trying to make sure it doesn't bring significant cost without improving production," Wellhoefer said.

PNP — using wireline to isolate a section of wellbore with plugs, perforating the casing with an explosive charge, and forcing fluid under high pressure into the target formation to fracture it — remains the dominant completion method in the Eagle Ford.

Results are good at reasonable cost, companies understand it, and it fits into the cemented-wellbore regime required by the Texas Railroad Commission.

Equipment makers argue that sliding sleeves, popular in plays where uncemented or open holes are common, could be more efficient. Eagle Ford operators, though, are largely focused on maximizing PNP by reducing downtime between operations and improving frac designs by adding stages and clusters.

"Plug and perf works, and as they've improved cycle time, it's working better," said Chris Robart, a partner at PacWest Consulting.

PNP efficiency up

Efficiency is surging as batch completions follow pad drilling, according to data collected by PacWest. Batch completions — fracturing multiple wells with the same equipment and crew — are slashing the time required to complete an Eagle Ford well to four or five days from seven or eight days a few years ago, Robart said.

Those data compare to PacWest's finding that average drilling time from spud to rig release has dropped to 15 days from 26 days. Jeff Chestnut, business development manager for Tryton Oil Tools US, said, "They're drilling them faster than they can complete them."

Still, the increased savings in completion crew time and equipment rental are significant, and more efficiencies are coming, according to Robart.

"The big focus is on reducing frac time," he said.

The emphasis shows in operator presentations to investors. Chesapeake expects 20% faster cycle time in 2014. Swift's completion costs have fallen to less

Facing page:
A completions crew from Nabors Industries checks equipment between fracture-stimulation stages on Hedge Hog 1H, an 8,000-ft horizontal lateral well for Halcón Resources in Brazos County, Texas, in the East Texas Eagle Ford shale. *(Photo by Mieko Mahi)*

than US $4 million from more than $5 million in 2011. EP Energy touts nearly doubling stages completed per day to 6.5 in 2013 from 3.4 in 2011.

"The impact of optimal completion techniques is a key factor," EOG said in its 2012 annual report.

At Anadarko's investor conference in November, Vice President of Exploration Ernie Leyendecker said, "It's gotten to where our drilling and completion folks are looking at efficiencies down to the very minute of every sequence of every operation. Over the last couple of years, we've been able to drive down the time it takes for us to drill and complete a well from somewhere a little bit less than 20 days to, on average, about eight."

Batch completions speed process

Batch completions are a big driver of efficiency, and most are "zipper" fracs, according to Ryan Henderson, technical sales director for Peak Completions. Henderson listed the steps in a three-well job as an example.

"I'm pumping a plug on Well 1 while I'm stimulating Well 2, and I'm prepping Well 3. The same equipment is out there fracing all three wells. They just keep going, increase efficiencies, and get that surface crew off location as quickly as possible," Henderson said.

Sammy Clary, technical sales director for Magnum Oil Tools, added, "By the time they finish fracing all three of those wells parallel to each other, all that rock is pretty much pulverized to the point that there's a bunch of flow channels in there to produce your fluid."

Batch completions continue to evolve. Operator Matador Resources, which plans to keep two rigs busy drilling more than 40 wells in 2014, has done zipper fracs but lately does back-to-back fracs, finishing the process of completing one well, then moving to complete the next one.

Either way, "we're saving a lot of money," said Matador President Matthew Hairford.

Savings are occurring all across the Eagle Ford even as the number of stages per frac has grown to 20 to 22 from 16 to 18, according to a PacWest analysis. Meanwhile, stages have shrunk 200 ft to 250 ft from 300 ft to 350 ft, and the number of perf clusters per stage has increased.

As operators streamline PNP operations, sliding sleeves are making inroads as an element in toe valve systems that don't require coiled tubing or wireline to install or operate.

Rather than having to be installed after the well casing is in place, the new toe systems ride to the end of the lateral attached to the end of the drillstring.

They open hydraulically as pumping of frac fluid raises wellbore pressure. Once open, they allow the circulation necessary to start pumping down the plugs and guns used to perforate the clusters arranged along a cemented horizontal wellbore.

Are your wells performing like they should? Check these numbers.

1

Bakken Shale / North Dakota
Multiple wells: avg. 9400-ft laterals, 28 stages
30-day cum. avg. rate: 1204 boe/d
180-day cum. avg. rate: 694 boe/d

2

Eagle Ford Shale / Texas
Multiple wells: avg. 3050-ft laterals, 14 stages
Avg. IP: 1447 boe/d
30-day cum. avg. rate: 605 boe/d

3

Green River Basin / Wyoming
Multiple wells: avg. 4800-ft laterals, 18 stages
Avg. IP: 9789 mcf/d
180-day cum. avg. rate: 3865 mcf/d

We've partnered with pumping services providers on wells in different shale plays, delivering high-conductivity results on every job. Operators continue to choose Rainbow because they know we work side-by-side with their completions team to maximize every well's performance.

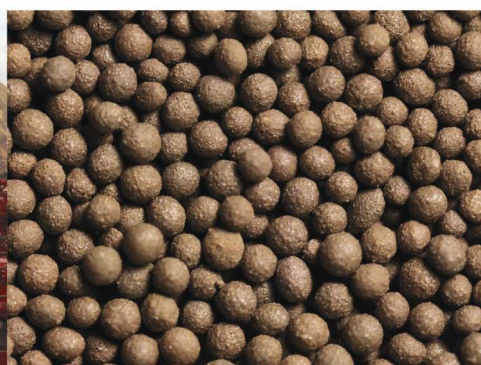
We engineer, manufacture and supply ceramic proppants that meet or exceed API and ISO quality standards. With distribution and transloading facilities across major shale plays including the Bakken, Eagle Ford, Permian Basin, Haynesville and Green River Basin; we supply best-in-class, cost-competitive proppants used in hydraulic fracturing.

Your success depends on how well the proppant you pump performs.

Let us help pump performance into your next well.™

RAINBOW® CERAMICS

rainbowceramics.com
1.888.618.PROP (7767)
info@rainbowproppants.com



Toe sleeves 'skyrocket,' wellbore sleeves lag

"The one technology that has really skyrocketed recently is toe sleeves," said Halliburton's Wellhoefer. Halliburton's brand is RapidStart. "You just apply pressure to the casing to open the RapidStart Initiator Sleeve and then pump down plugs and guns. That's a very good way of cutting cost out of your completion."

Almost every equipment maker and service provider offers a version. Schlumberger has KickStart, Weatherford has ZoneSelect SMART Toe Sleeve, Magnum has Smart Sleeve, and Team has ORIO.

Some operators remain more comfortable with the old approach, but Magnum's Clary said success rates are high. "To date, we have 100% success with these devices functioning as designed," Clary said.

Systems come with time delays to allow a casing test before the toe valve opens.

Halliburton's RapidStart CT, for example, "allows a 30-minute casing test before it'll open, [which] allows you to get a true casing test to comply with government regulations. Industry best practices are just company best practices," Wellhoefer said.

Service providers are pushing sliding sleeves for the rest of the wellbore, most of them activated by ball-drop systems, but adoption is slow in the Eagle Ford amid concerns about cost and the complexity of the systems compared with PNP.

"The business case has weakened for sliding sleeve," said PacWest's Robart. "There's additional cost for sliding sleeve. It's a much more complicated system."

Efforts continue, however, to provide a cemented sleeve with ball-drop initiation that will sell in the Eagle Ford. Baker Hughes, for example, is in field trials with a cemented multipoint entry sliding sleeve, said Clint Mickey, Southern US area engineering manager.

"What you do with this system is drop one size ball, and it will open all the sleeves of a single stage. The fracture will be performed through all of the opened sleeves at the same time. Then you go to the next stage and drop the next size ball," Mickey said. "The sleeves mimic a multiple cluster perforation stage."

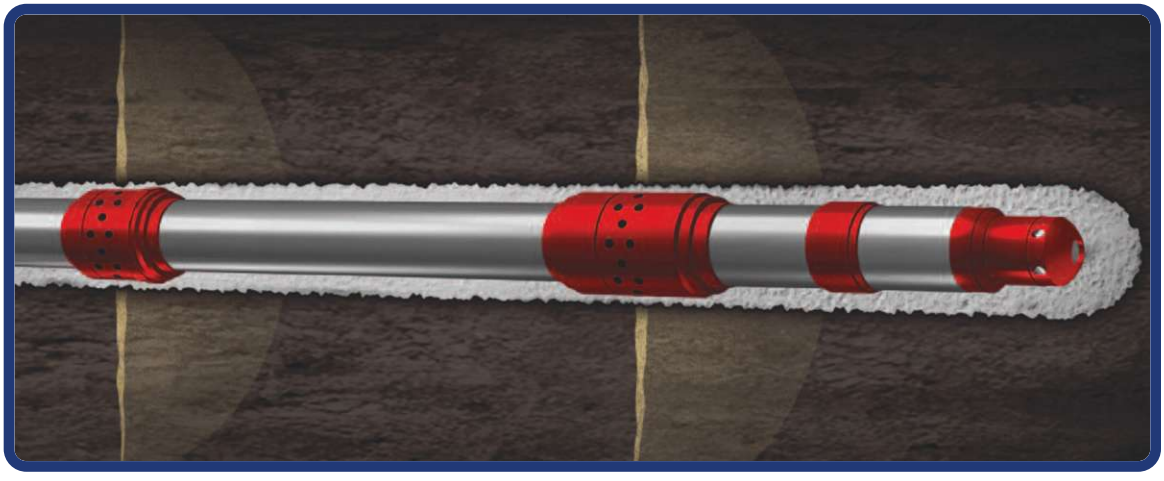
Sliding sleeve selling points

The approach eliminates having wireline on location to place plugs and guns. It cuts pressure pumping wait time. The sleeves already are in place when pressure pumpers arrive, so work can start immediately and go continuously.

Halliburton offers a similar tool called RapidFrac, a sliding sleeve system that can be cemented into the wellbore. "It allows multiple entry points per fracture stage," Wellhoefer said. "Since it is more similar to plug and perf, there's a lot of interest in that."

The system uses a metering process that enables a single ball to open multiple sleeves isolated within an interval by swellable packers. Each sleeve can be tailored to specific fracture requirements along a horizontal wellbore to enhance post-frac production, according to Halliburton.

Team Oil Tools' entry is the ORIO XL. It is a ball-activated frac sleeve relying on fewer variations in ball diameter — none are less than 4 in. — to open as



This multientry sleeve system allows access to multiple fracture points within an isolated interval, and its ball activation feature enables a totally interventionless completion. There are versions for both cemented and openhole applications. *(Photo courtesy of Halliburton)*

"If you think it's expensive to hire a professional... wait until you hire an amateur" - *Red Adair*

Our track record includes running over 11,650 open hole StackFRAC® ball drop systems accounting for over 146,200 fracture stages. Contact us today and let us help you maximize your assets.

DO IT ONCE. DO IT RIGHT.

Packers Plus®
www.packersplus.com

The Baker Hughes SHADOW frac plug is a permanent, large-bore, flow-through frac plug that eliminates coiled tubing operations from the critical well path. *(Photo courtesy of Baker Hughes)*

many as 90 sleeves, individually or in clusters. The design encases the mechanical parts in the walls of the device, removing them from the flow of cement and frac fluid and facilitating use of a heavy-duty cement wiper plug to clear the wellbore.

Stimulating individual sleeves enables concentration of hydraulic force at chosen points along the lateral, said Steve Chauffe, Team Oil's vice president of new technology and business development. It allows a greater net injection rate with less surface horsepower, and "you know exactly where your frac is going," Chauffe said.

As an alternative to the ball-drop activation approach, Baker Hughes offers the coiled-tubing-driven OptiPort, which doesn't use balls or seats that require post-frac mill-out. Still, it eliminates the rigup and rigdown of pressure pumping and wireline between stages that are associated with PNP.

The system has multiple pressure-balanced sleeves that are installed as part of the casing string. The sleeves are opened hydraulically using a specially designed coiled-tubing bottomhole assembly (BHA) equipped with a casing collar locator and a packer. The BHA is moved up the wellbore from sleeve to sleeve, isolating stages, and opening the ports for fracturing.

"When a stage is completed, you can just unset the packer and move up quickly to the next stage," said Luis Castro, Baker Hughes product manager for unconventional multistage completion systems.

Dissolvable balls, flow-through plugs

Most of the ball-drop systems operate with dissolvable balls made of proprietary material that do their job and then disappear in the heat and friction of production flow.

For example, Magnum offers a 2.25-in. ball that in 48 hours dissolves down to a quarter inch, Clary said, small enough to just flow out of the wellbore as waste. Not stopping at dissolving balls, Magnum offers the Vanishing Plug. It's made of materials that shrink in fluid flowing at 150°F and don't require a tubing run to mill them out.

"It's a risk every time you enter that wellbore with any type of tool. If they can alleviate that risk by leaving the plugs in the well, they're really looking hard at doing that," Clary said.

Some operators want to dissolve the ball but leave the plug in the bore, increasing its inside diameter to maximize production flow-through.

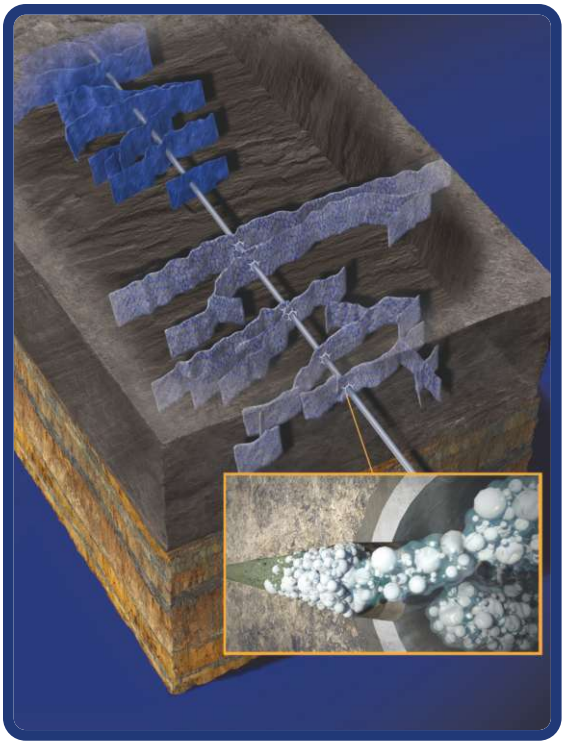
In this category, Baker Hughes offers the SHADOW frac plug. It doesn't dissolve, but it has a large bore to allow unimpeded production flow-through. It uses IN-Tallic disintegrating drop balls developed with nanotechnology.

"They can produce through these plugs, and if at a later date they decide they want to remove the plug, they're designed to be millable as well," said Aaron Burton, Baker Hughes' product line manager, unconventional multistage completion systems.

Rather than sleeves, balls, and plugs, Schlumberger's new completion method, the BroadBand Sequence technique, relies on dissolvable "pills" made of fiber and particles to focus pressure where it's needed. The system involves inserting 50-lb to 75-lb slugs of fiber and particles into the frac fluid flow to temporarily block some fractured zones and divert pressure to others.

It is a response to a Schlumberger study that indicated 36% of clusters in the typical frac job do not produce. BroadBand attempts to cut that failure rate by temporarily locking up a treated zone at the wellbore to allow stimulation of clusters requiring higher pressure to initiate. Afterward, the diverter material degrades completely and disappears to unlock hydrocarbon flow.

Schlumberger also uses engineered fiber to enhance the frac farthest from the wellbore. Its HiWAY fracture system couples engineered fiber with a high-frequency pulse-pumping technique.



The BroadBand Sequence fracturing technique enables sequential stimulation of perforation clusters. *(Photo courtesy of Schlumberger)*

Proppant loads, fluid volumes climb

There has been an increase in fluid volumes and proppant loads as the depth and horizontal reach of wells has grown.

The average depth is 9,550 ft, and the average lateral is 5,361 ft. Anecdotally, industry players said the longest Eagle Ford laterals now exceed 7,000 ft or 8,000 ft as operators reach for more production.

According to PacWest data, a typical crosslinked, slick water frac in the Eagle Ford lateral last year used 3.9 MMgal of water plus 559,000 lb of stimulation chemicals, including biocides, acids, gels, and friction-reducing agents to make the water "slick."

The average well used more than 5.5 MMlb of proppant in 2013, up from 4 MMlb at the start of 2011, PacWest data show, and it is not just due to longer wellbores but because "proppant intensity" is growing.

(continued on page 78)

ONE OPERATOR'S EXPERIENCE

An Eagle Ford operator relies on familiar methods but is watching for new technology.

Pioneer Natural Resources, which produces 40,000 boe/d in the Eagle Ford and plans to drill 110 more wells there this year, relies on the tried and true while keeping an eye out for cutting-edge improvements.

"At Pioneer, we strictly do just plug and perf [PNP] for the moment," said Jaime Lopez, completions engineering supervisor. "The technology has evolved allowing for better use of the sliding sleeve systems. We want to do some testing on the sliding sleeves, but currently it's just plug and perf."

Pioneer has tried sleeve systems at the toe for starting wellbore circulation at the beginning of a frac job, but the company prefers a coiled tubing run and a gun perforation.

"We've run various types. We've had mixed success," said Larry Fizer, Pioneer's drilling and completions director. "This is another area where technology keeps improving, but reliability vs. the cost is just not there yet. We continue to monitor."

J.D. Hall, Pioneer's senior vice president for South Texas operations, added, "We've had success running toe sleeves, eliminating the TCP [tubing-conveyed perforating] run, but remember, the sleeves are expensive …When we ran the cost differentials, there really wasn't that much of a savings. When you add in the potential operating risks associated with it, it just didn't work. But we continually evaluate the potential of sliding sleeves."

The company is not ready to trust dissolvable balls or plugs, the point of which is to eliminate a final coiled tubing run to mill out obstructions created during fracturing and to clean out the wellbore for production.

"The problem with using some of the other technology is until you actually run in there with coiled tubing, you can't confirm that that lateral is ready for production and completely clean," Fizer said.

Fracs with zip preferred

Batch completion has improved the efficiency of PNP operations for Pioneer.

"We typically do the zipper frac technique," Lopez said. "There are a couple of reasons. One is reduction in downtime. Waiting on the PNP method is pretty much minimized due to a mutiwell pad, and secondly, you induce a pressure wave to improve your stimulation in the zone of interest."

Pioneer's frac designs reflect optimized well spacing, lateral length, width of frac stages, and number of perf clusters per stage.

Pioneer uses three- and four-well pads and has downspaced wells from 1,000 ft to 500 ft and is evaluating 300-ft and even 175-ft spacing. Its typical lateral length is 5,000 ft to 5,500 ft, though some are longer. Frac stages range from 350 ft down to 250 ft, depending on location, and the number of perf clusters per stage is typically five.

"Doing completion optimization and zipper fracs, we've seen that we've been able to get a 20% to 30% EUR [estimated ultimate recovery] increase over when we originally started," Hall said.

Pioneer prefers "geometric" cluster spacing rather than "nongeometric." Geometric spacing describes evenly spaced perf clusters along the wellbore. Nongeometric means varying the spacing in response to the particular geology along the horizontal wellbore.

Service providers are pushing more detailed engineering of fracs, varying stage and cluster spacing to target promising zones and avoiding less prospective ones, but that engineering requires data collection and analysis.

More clusters, nongeometric spacing

"That drives cost," Lopez said. "We've seen good results just doing geometric perf clusters."

Pioneer is reducing the distance between clusters to get more clusters per stage, and it is relying on technology as it makes those choices.

"We use microseismic. We use chemical tracers. We use RA [radioactive] tracers. We've done a few production logs," Hall said.

Fizer added, "We've met all the major service companies and looked at their technology, and they'll be the first to admit there's some flaws." He continued, "When you take that into consideration, the cost and time it takes to do the operations that they're talking about, we're just not there yet."

But Hall added, "We're in favor of them progressing on it. It's a progression. It's just going to take time to perfect it."

As for fluids and proppants, Pioneer is increasing the volume of both and has gone through several iterations.

"It has been a progression from the start, basically going from slick water to hybrid-type treatments. Now we're pretty much doing crosslinked-type gel fluid treatments, and what we've seen lately is just an optimization on the fluid itself," Lopez said.

Pioneer typically relies entirely on white sand as proppant. "If you go back four years ago, we were doing almost all our completions with ceramic, and over the last few years, we've slowly transitioned until this year we're 100% white sand," Hall said.

"We have tested some wells lately with higher mesh ceramic proppants, and we're evaluating those at the moment," Lopez said. "As of right now, we're just doing white sand."

—Bruce Nichols

A Pioneer Natural Resources frac job was performed in June 2013 in the Eagle Ford play near Campbellton, about 30 miles southeast of San Antonio.
(Photo courtesy of Sands Weems, Pioneer Natural Resources)

(continued from page 75)

"There are higher proppant volumes on a per-barrel-of-carrier-fluid basis as well as a per-foot-of-stimulated-length basis," Robart said.

Studies show higher fluid and proppant volumes raise production, and companies have taken notice.

Choices of fracing fluid greatly vary, from slick water to linear gel to crosslinked gel, as operators seek to maximize fracture networks.

Pure slick water fades, sand gains

Use of slick water alone as a fluid has been decreasing, though water remains a major component of frac fluid volumes. Only 10% of Eagle Ford fracs use slick water exclusively, while 61% use a hybrid of crosslinked gel and slick water, PacWest data show.

Matador, for example, pumps a hybrid design using slick water and both linear and crosslinked gel to boost proppant penetration.

"We pump slick water first, create an intense fracture network, then fill that up with proppant. We do believe it's important to pump more viscous gel with proppant, so it will carry it farther into the formation and into the fracture system," Robinson said.

Research continues to perfect fluids, particularly to create gels that break down and don't leave residue in fractures.

Operators "need a viscous fluid that will break to a fluid with near zero gel strength ... If the broken gel has even a small amount of gel strength, the fracture may not clean up," said consultant Stephen Holditch, the former head of petroleum engineering at Texas A&M who now chairs the Oxane board and is a member of the Matador board.

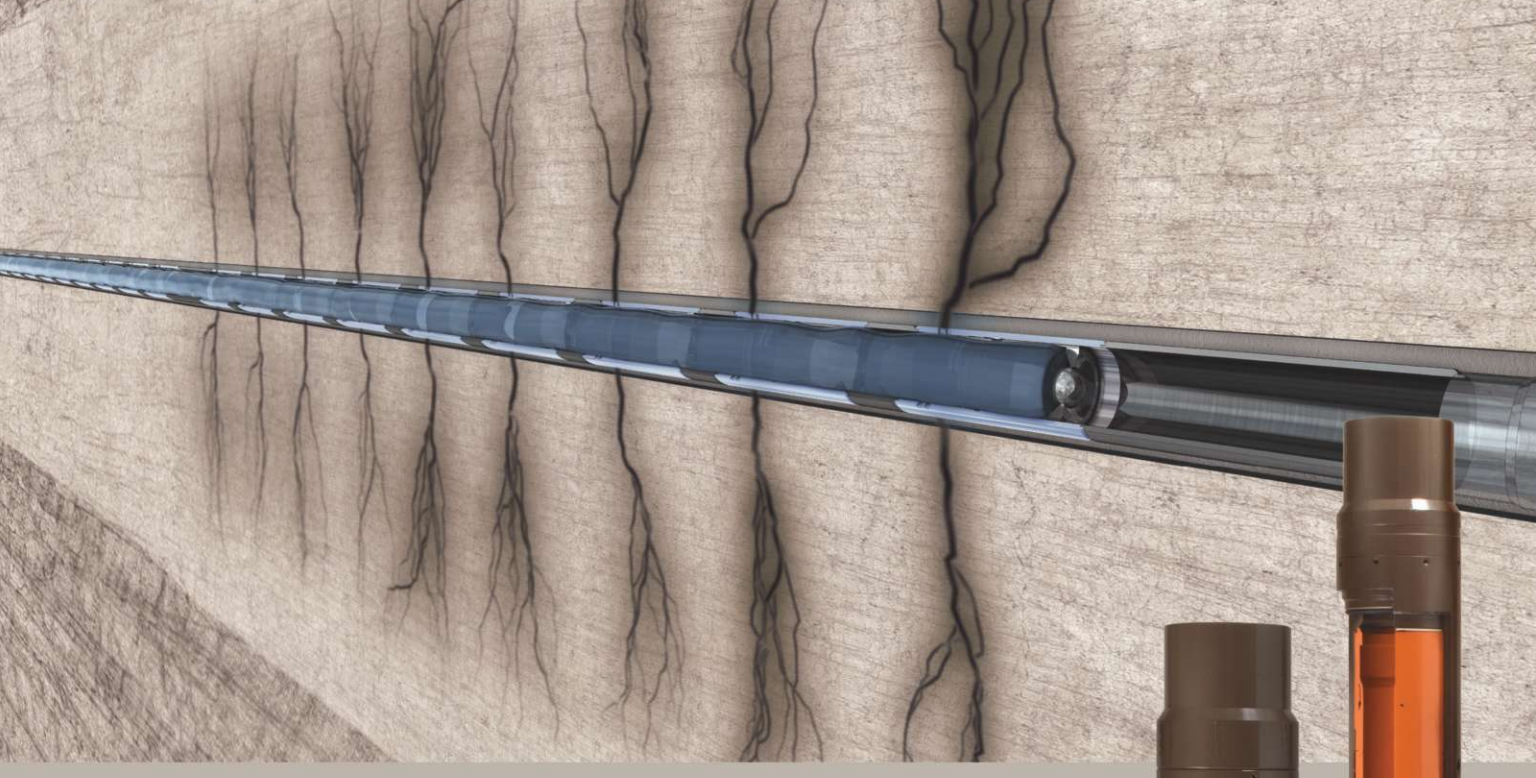
In the area of proppants, sand has been gaining vs. higher tech resin-coated sand and ceramics. As a percentage of proppant used, sand rose to 94% in 2013, although use of resin-coated sand and ceramics will grow 8% and 9%, respectively, through 2015, PacWest data show.

Cost is a factor. Sand costs about 10 cents per pound compared with resin-coated sand at 30 cents or 40 cents and ceramics at 70 cents or 80 cents.

New proppants coming

Higher tech proppants are in the works. One proposed alternative comes from Santrol, a unit of Fairmount Minerals, which is field-testing a self-suspending proppant dubbed Propel SSP.

Details are proprietary pending commercial launch, but the key is a hydrogel coating that can be used with sand or ceramic. In contact with water, the coating expands, creating



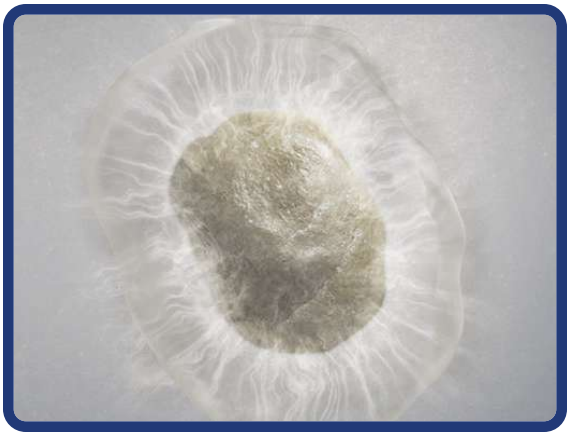
TARGETED STIMULATION. EFFICIENT OPERATIONS.

i-Frac CEM™ – a **cemented** multistage horizontal completion system from Trican Completion Solutions.

Contact us today at **completions@trican.us**, or visit us at **www.trican.us/completions** for more information.

TRICAN

Trican Completion Solutions



Applied to a particle of proppant, Santrol's proprietary Propel SSP polymer coating hydrates and swells upon contact with water, increasing the surface area and significantly lowering the effective specific gravity. It offers the possibility, without using gel, of efficient transport into every fracture for improved hydrocarbon recovery and increased net present value. *(Photo courtesy of Santrol)*

a particle 300% larger and lower in effective specific gravity than the uncoated substrate particle would be.

An operator can create what amounts to viscosity without gel, keeping the proppant suspended so it will travel deeper into a formation.

"This is not a gel. It's a dry coating that, when it gets wet, will hydrate and create a gel-type structure around a particle," said Brian Goldstein, Santrol's product line director for self-suspending proppants.

"Propel SSP is a new category of proppant," said Nick Johnson, Santrol's vice president of marketing.

Another approach to facilitating deeper proppant penetration comes from Oxane, a company that grew out of nanotechnology research at Rice University. Since 2010, Oxane has offered proppants dubbed OxBall and OxSteel that are hollow but crush-resistant.

"They're strong because they're ceramic. They're light because they're hollow," said Mark Mack, Oxane's vice president of engineering.

Opportunities in data, but cost weighs

In the data-gathering and computer-analysis arena, a growing number of tools help characterize fields, plan drilling, maximize completions, and analyze fracing results, and operators are using them where the benefits justify the cost.

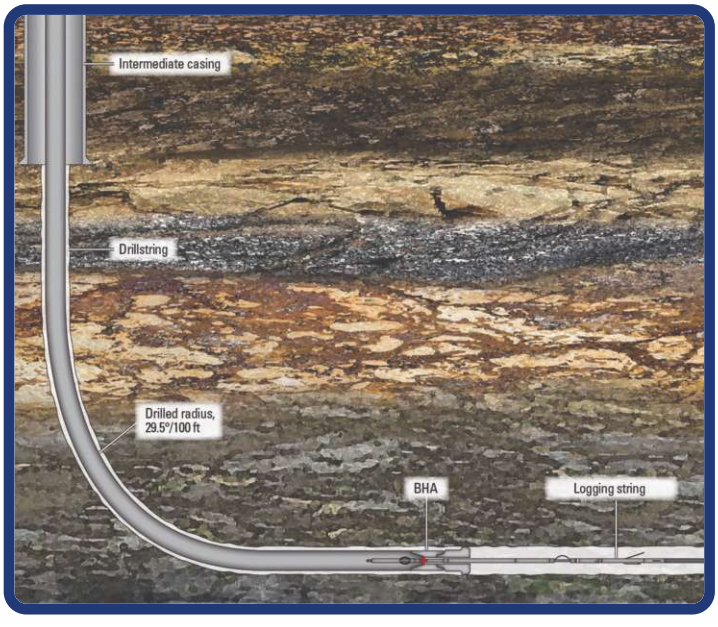
The idea is to increase both IP and estimated ultimate recovery (EUR). IPs have been strong, but EURs hover around 5% of oil in place and 30% of gas.

"We want to try to increase that recovery factor as much as possible and get it out on the first try," said Matador's Robinson.

Core sample analysis and seismic data are widely used. Less common are LWD, microseismic, and such gee-whiz tools as tilt-metering. Companies monitor flows in the wellbore using in-bore meters and information tracers, both chemical and radioactive.

"There's tremendous upside to getting more out of the rock," Schlumberger's Sobernheim said. "There's also a focus on more outlying areas to take some of the rock that has not been economic in the past and bring that solidly into the realm of being economic."

Halliburton offers Cypher, a software package that allows companies to plug in data and evaluate full field development. Halliburton's ControlFrac uses data to determine the best completion design.



When logging in memory mode with ThruBit while tripping pipe out of the hole, actionable information along the lateral can be acquired to drive improved completion performance, according to Schlumberger. *(Photo courtesy of Schlumberger)*

Schlumberger's ThruBit "allows you on your last trip out of the hole to, at relatively low cost, get some meaningful data along the lateral," Sobernheim said. "This lets us get information on the rock properties along the lateral."

Baker Hughes has its own set of advanced field development tools, but as always it's a cost-vs.-benefit decision for operators, said Burton.

"There are additional upfront costs associated with that," Burton said. "Because operators are getting somewhat economic wells without the characterizing and additional upfront cost, it has been slow to catch on." ■

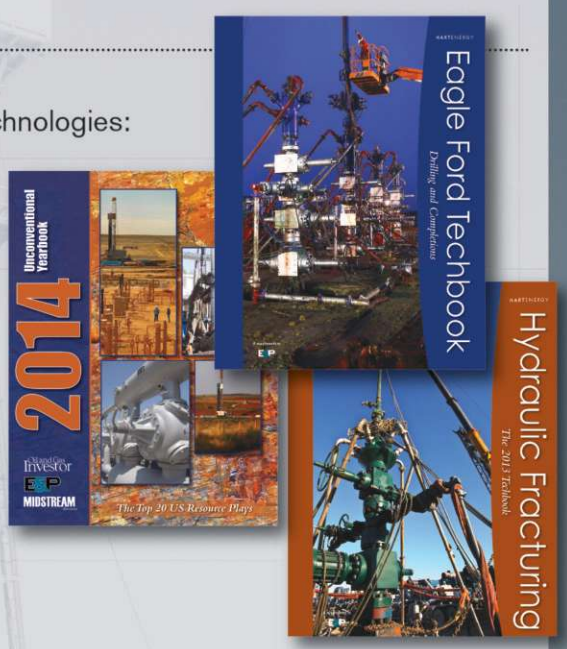
GET IN-DEPTH DETAILS ON ALL THE UNCONVENTIONAL PLAYS

SUBSCRIBE TO THE ENTIRE 2014 SERIES

Hart Energy proudly produces annual supplements specifically written to help industry professionals stay ahead of the unconventional curve.

Now all these products can be yours for a one-time fee of **$197**

- Unconventional Yearbook
- Eagle Ford Drilling and Completions Techbook with Wall Map
- Rockies Playbook with Wall Map
- Artificial Lift Techbook
- Hydraulic Fracturing Techbook
- Permian Basin Wolfcamp Drilling and Completions Techbook with Wall Map
- Tuscaloosa Marine Shale Playbook with Wall Map



TECHBOOKS

Each Techbook covers effective and emerging unconventional technologies:

- Market overview and key technology providers
- Field application case studies
- Technology-specific trends
- Wall Maps with production forecast, operator's net acreage, active rig counts, well activity and much more

UNCONVENTIONAL YEARBOOK

Updated for 2014, the fifth Unconventional Yearbook and map showcases the most active unconventional plays in over 200 pages of exclusive content.

- Production levels
- Rig counts, permits
- Significant wells
- Significant deals and players

PLAYBOOKS

Hart Energy's exclusive delves into North America's most compelling unconventional resource plays.

- Reservoirs
- Active operators
- Economics, key technologies and infrastructure changes
- Wall Maps with production forecast, operator's net acreage, active rig counts, well activity and much more

HOW?

ORDER YOUR COPY NOW!

CONTACT: Chris Cimpson, Business Development Manager at **713.260.5206** Use Promo Code **C44TEC**

HARTENERGY


Austin
San Antonio
Eagle Ford Shale

Understanding the Eagle Ford

Operators share their thoughts on best practices, new technologies, and the most pressing challenges they face in the region.

By Kelly Gilleland
Contributing Editor

The Eagle Ford shale is, without question, one of the most challenging unconventional plays in the country. Dubbed a "technical play" due to its engineering-intensive requirements, operators and service companies alike are required to push the envelope to obtain maximum success. Hart Energy polled some of the most active players in the Eagle Ford for a perspective on the most frequently encountered quandaries and came up with some insightful and interesting results.

THE EXPERTS

Andy Agosto, vice president of business development, *Carrizo Oil & Gas*

John Branca, vice president exploration and geosciences, *Swift Energy Co.*

Aaron Burton, product line manager – unconventional multistage completion systems, *Baker Hughes*

Robert Drummond, president – North America, *Schlumberger**

Lance Robertson, vice president North America production, *Marathon Oil Corp.**

Paul Sheppard, southeast area vice president, *Halliburton**

**Comments presented at Hart Energy's DUG (Drilling Unconventionals) Eagle Ford Conference, October 2013.*

Thousands of wells have been drilled and completed in the Eagle Ford. What has the industry learned about best practices?

LANCE ROBERTSON (Marathon): One of the ways we can illustrate what we've learned is through efficiency. Two years ago, we were moderately efficient in terms of drilling efficiency, but we've gotten materially more efficient where we're averaging 12 days spud to TD [total depth]. Will the rate of change slow down? Absolutely. Realistically, we can't get faster forever, but everyone is figuring out how to do this much more effectively. They are integrating better learnings. They are being systematic in communicating across their teams, taking successes, and propagating that across their activity to get better and to drive capital efficiency. Now we are asking ourselves, what do we have to retire, what habit or dogma do we have to let go of to get from where we are today to the next level? And what does that level look like?

JOHN BRANCA (Swift): Swift Energy was one of the first operators to drill the Eagle Ford in South Texas. We treated this unconventional reservoir as an exploration play, and in our first wells, we drilled pilot holes to

Facing page:
A view from space shows the activity in the Eagle Ford shale, evidenced by the band of lights below San Antonio. *(Image courtesy of David Wogan and NASA Earth Observatory)*

conventionally core the entire formation, and then we ran a comprehensive suite of logs across the same intervals so that we could completely evaluate the entire Eagle Ford target. Prior to drilling the lateral section in the Eagle Ford, we assessed the logs and visually inspected the core for the best place to land the lateral. The information from these early wells was thoroughly evaluated, and the rock properties were assessed and integrated with 3-D seismic. This seismic with the core and log data was inverted to define lithologic units. We have learned that the location of the wells and the placement of the laterals are key to well productivity and ultimate recovery. This understanding of well placement was extended to completions. We log our lateral sections, and with this information, we plan our fracture stimulation. Refinement of the frac program and placement of the wells has improved performance significantly.

ANDY AGOSTO (Carrizo): Our industry has certainly come a long way in terms of learnings on best practices. For companies like Carrizo, which was already an experienced resource play operator, we were able to come into the Eagle Ford fairly high on the learning curve. In fact, we brought our pad drilling rigs and technology directly from the Barnett shale into the Eagle Ford when we began drilling in 2010. Similarly, we utilized the zipper frac technique we perfected in the Barnett from day one in the Eagle Ford. Other less experienced operators started a little lower on the curve but are catching up quickly.

Whether purposefully through participation in industry groups or on a more ad hoc basis, it is typical for information to be shared among operators and service providers once the more competitive phase of leasing activity subsides. Some of the specific best practices on the drilling side involve identifying where in the lower Eagle Ford section the lateral is landed, directional control techniques, bit technology, mud system design, and rig design that provides for pad drilling. On the completion side, perforation strategies, fluid volumes and selection (slick water/linear gel/crosslink gel), and sand/proppant concentration and placement have all been areas of focus.

AARON BURTON (Baker Hughes): It is very important to communicate between the drilling, completions, and fracturing aspects of the well. If the wrong hole or casing size is used, the intended completion option might not be available. Also, if the well is poorly drilled, it can be difficult to get the completion to the intended depth and achieve annular isolation. The completion system will directly affect the flow area, pressure ratings, and control of the volume of fluid into each stage. If these services are not correlated properly, it can affect the overall well plan and performance. This best practice applies across all of these types of plays and is not specific to just the Eagle Ford.

PAUL SHEPPARD (Halliburton): As far as efficiency goes, we are now getting well down the road as you look at multiwell pad completions. I think the industry has gotten a lot better over the last couple of years working together with the multiple product lines on a location, and the advent of the zipper manifold and zipper fracturing has enabled us to do that. In the Eagle Ford, if you ask five different operators what type of frac is working in their play, they'll give you five different answers. The Eagle Ford has such a wide range of geology that the same job might work in one area but not in another area of the field. As companies continue to drill more pads, additional completion efficiencies are going to be realized.

ROBERT DRUMMOND (Schlumberger): Success in unconventionals has been built on two major technology changes – directional drilling and hydraulic fracturing. In the Eagle Ford in 2008, the average

HARTENERGY

Hart Energy produces informative, impactful and innovative oil and gas conferences that attract the industry's best and brightest. In 2013, Hart Energy organized 12 events covering nearly 600,000 square feet of exhibit space and attracting more than 19,000 attendees, 340+ industry-leading speakers, 450+ sponsors and 1,500+ exhibitors.

Online registration is now open for all Hart Energy Conferences. Secure your seat early and save!

DEVELOPING UNCONVENTIONALS DUG PERMIAN BASIN	**NEW LATER DATE!** May 20-22, 2014 DUGPermian.com	**Fort Worth, TX** Fort Worth Convention Center	• Exploration, Drilling, Completions, & Production • Permian Basin & Emerging Shale Plays
DEVELOPING UNCONVENTIONALS DUG EAST	**NEW EARLIER DATE!** June 3-5, 2014 DUGEast.com	**Pittsburgh, PA** David L. Lawrence Convention Center	• Exploration, Drilling, Completions, & Production • Marcellus & Utica Shale Plays
energycapital CONFERENCE	June 9-10, 2014 EnergyCapitalConference.com	**Houston, TX** Omni Hotel	• Raising & Deploying Capital • Capital Providers, Investors & Small E&Ps
DEVELOPING UNCONVENTIONAL GAS DUG AUSTRALIA	August 26-28, 2014 DUGAustralia.com	**Brisbane, QLD, Australia** Royal International Convention Centre	• Coal Seam Gas, Shale Gas & Oil, & Tight Sands • Asia-Pacific Liquified Natural Gas
A&D STRATEGIES AND OPPORTUNITIES Conference & Workshop	September 3-4, 2014 ADStrategiesConference.com	**Dallas, TX** Ritz-Carlton Hotel	• Acquisitions, Divestitures & Mergers • Buyers & Sellers, Deal-Making
DEVELOPING UNCONVENTIONALS DUG EAGLE FORD	September 15-17, 2014 DUGEagleFord.com	**San Antonio, TX** Henry B. Gonzalez Convention Center	• Upstream & Midstream Operations • Eagle Ford & South Texas Plays
CRUDE IN MOTION	October 10, 2014 CrudeInMotion.com	**Houston, TX** JW Marriott	• Truck, Rail, Barge & Pipeline Activity • North American Unconventional Crude Oil
EXECUTIVE OIL CONFERENCE	November 10-11, 2014 ExecutiveOilConference.com	**Midland, TX** Midland County Horseshoe	• Raising & Deploying Capital • Permian Basin & Emerging Shale Plays
MARCELLUS-UTICA MIDSTREAM CONFERENCE & EXHIBITION	January 27-29, 2015 MarcellusMidstream.com	**Pittsburgh, PA** David L. Lawrence Convention Center	• Pipelines, Gathering, Processing & Storage • Marcellus & Utica Shale Plays

For a complete list of events, visit HartEnergyConferences.com

REV: 3/17/14

lateral length was about 2,000 ft; by 2012, it was more than 5,600 ft – more than double. Similar gains have been made in fracturing operations. Operators are exposing more reservoir rock to the completion process.

We've been very successful, but the question is can we do better? We need to understand two things about a reservoir to optimize completion. First, we need to understand reservoir quality – the total organic carbon, the porosity distribution along the lateral, the clay volume, and rock types. The Eagle Ford is not homogeneous, and fracing in the geometric spacing method is not going to give the same results from one stage to another. The second part of the lateral we need to understand is completion quality – how easy the rock will actually frac. In our Eagle Ford Consortium study, 12 wells were studied to determine where the production came from all the perf clusters. In this original well base that was used to compare, only 64% of the perforation clusters – i.e., the fracture – was giving up production. However, by using an engineered method, that number went up to 82% on average. This is a significant production change.

and size of [the] frac are all being tested and optimized. Production optimization and lift are key to extending the life of these wells and maximizing the recovery. On the cost side, we are focused on drilling and completing these wells faster and cheaper. We have eliminated strings of casing and reduced total drilling days. Additionally, fracs are delivered faster and more efficiently.

AGOSTO (Carrizo): As a result of our company's choke management practices, we have been able to defer the installation of artificial lift on our wells. As many of our wells enter this phase, the design, installation, and surveillance of jet-pumped and rod-pumped wells has become quite important for Carrizo. There still are significant opportunities for optimization in this area as every single Eagle Ford well ultimately will need some form of artificial lift to produce out its reserves. Choke management means we bring the wells online on a restricted (aka small) choke, which keeps more backpressure in the well. While this doesn't result in eye-popping IP [intial production] rates, we think it results in a flatter production decline profile and better long-term well performance.

"The Eagle Ford has such a wide range of geology that the same job might work in one area but not in another area of the field."

—Paul Sheppard, southeast area vice president, Halliburton

What problems still need solutions?

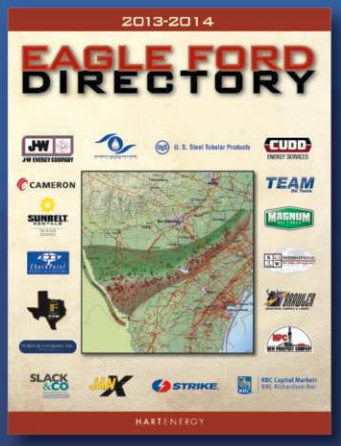
BRANCA (Swift): The Eagle Ford and other unconventional plays are relatively new to the industry, and we are learning at a very fast pace. We focus on improving productivity and at the same time work to drive down costs – the problems that need solutions fall into those two categories. On the improved productivity side, we continue to focus on well placement. Steering and logging technologies are being developed and employed to drill the wells straighter and to stay in tighter and tighter zones. Optimization of well spacing is a critical factor and changes depending on where you are in the play. Completion technology continues to evolve. Frac spacing, fluids, proppant,

BURTON (Baker Hughes): Improving efficiency is always one of the primary drivers to changes within these types of plays and the industry. The focus in the Eagle Ford would be to increase efficiency during the frac job while using cemented multistage completion systems.

ROBERTSON (Marathon): We see today that the majority of our acreage is going to work well below 80-acre spacing. In fact, through the middle of 2013, 80% of the wells we've drilled in South Texas have been on 60-acre or 40-acre spacing, so we're heavily into delineating infills across South Texas, and we're getting more confidence. We are continuously integrating subsurface data, integrating petrophysical

HARTENERGY

USE THESE TARGETED SALES RESOURCES.



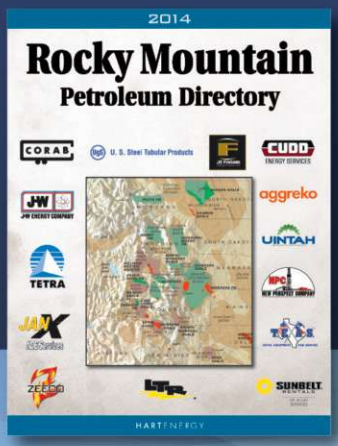
Eagle Ford Directory
- 1,200+ companies profiled
- 6,000+ key personnel listed

For 60 years, Hart Energy has been the top publisher of oil and gas directories covering North America. What began with the **Rocky Mountain Petroleum Directory** now includes four more directories: the **Eagle Ford Directory**, **Marcellus-Utica Directory**, the **Midstream Directory** and the **Permian Basin Directory**

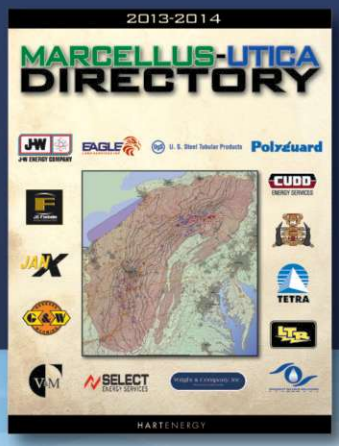
These go-to resources are valuable for anyone working in the area, looking to break in, or serious about investing in its potential. Each directory tells you who's who, what they do, where they are, and whom to contact. You'll find customers, prospects and suppliers — and know how to reach them.

Your subscription includes a copy of the print edition plus one year access to the online edition.

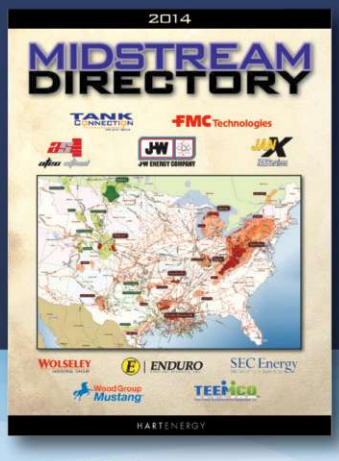
GET YOUR COPY TODAY!



Rocky Mountain Directory
- 7,500+ companies profiled
- 22,000+ key personnel listed



Marcellus-Utica Directory
- 2,000+ companies profiled
- 12,000+ key personnel listed



Midstream Directory
- 2,000+ companies profiled
- 11,000+ key personnel listed

Permian Basin Directory
- 2,000+ companies profiled
- 6,000+ key personnel listed

FREE SHIPPING: Use promo code DIRECTORY

3 ways to order: Visit HartEnergyStore.com, email rcruz@hartenergy.com or call 713.260.4635

data, and integrating well performance data, [while] asking: How does this work? How much value does this create? We recognize that we could downspace aggressively, but at some point it becomes more capital-intensive relative to the NPV [net present values] created with each incremental wellbore. As we become more capital-efficient, that margin of NPV growth grows, because we have less initial investment, and it creates a broader horizon at which you can drill wells at lower and lower spacing.

The second part of those completion studies is how much more recovery can we get from a well? If we think it's one number, and it's probably a single digit initially on wide spacing – 6% to 8% – then how much more would it take to get to maybe 10%, 12%, even 15% recovery? We can fundamentally change the way we stimulate wells in close spacing. We are still learning – Marathon Oil and our peers as well – how we do things at 40 acres, because as an industry we've simply not drilled horizontal parallel laterals on a really grand scale that are only 350 ft apart routinely.

SHEPPARD (Halliburton): Landing the lateral in the right part of the reservoir, engineering your perforations, having a mechanism to ensure that all of the clusters are taking fluid and you don't have one dominant fracture in each stage – these are the elements that are getting the most focus. Also, it takes far field diversion to generate complex fractures to try to keep you from knocking off that offset well with a dominant fracture. There is also surfactant optimization that is leading to increased production and low residue, high-retained conductivity fluids. Once the operators are able to get past the initial frenzy of drilling those initial wells to hold their leases, they get the time to put in a lot more science and thought into optimizing well performance through all those different variables. The effects of that extra focus bring increased production, higher EURs [estimated ultimate recoveries], and recovery factors.

How are technologies changing?

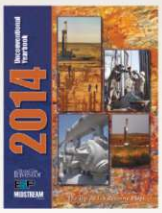
AGOSTO (Carrizo): As in every resource play, the cycle of implementing early drilling and production techniques, analyzing results, and then refining these techniques is ongoing. What we have seen in the Eagle Ford is a compression of this cycle time compared to earlier resource plays like the Barnett shale. While the basic drilling and completion technologies continue to be fine-tuned, the larger step-change improvements have diminished. Technological innovations are now both equipment- and process-related, the latter in large part due to [the] industry's view of the Eagle Ford as more of a manufacturing process. There has been a trickle-down effect into the service sector as a result of the huge service opportunities generated by the volume of activity in the Eagle Ford. For Carrizo, many of our technological/process improvements have been as a result of working as a team with our long-term service providers.

BRANCA (Swift): The tight rock plays were all made possible through horizontal drilling and multistage frac technology. Those technologies continue to evolve as we try to accelerate and improve our wells. Geosteering and visualization technology has been adapted for steering wells in real time and logging technology has further enabled rapid evaluation and modification of well trajectories. The whole completion technology continues to evolve to enhance completions. Drilling technology has been adapted to drill longer laterals and higher rates. Multiwell pad drilling created the need for rapid rig moves, so walking rigs were built that enabled rigs to move within hours to a new location, a move that previously would have taken days.

BURTON (Baker Hughes): The plug and perf method is still the preferred method in the Eagle Ford. Some of the primary changes with this type of completion are pad drilling and a new type of interventionless frac plug. The pad drilling places the wells close enough together that simultaneous operations can be used. While one well is running a plug and the perforations on wireline, the other well is being fractured. Once completed, the services are swapped out on the two wells drastically reducing nonproductive time. The new style frac plug has a large enough bore to produce through and uses disintegrating frac balls, so it eliminates the coiled tubing run post fracture to mill out the plugs. Another way the technology is shifting toward efficiency is the use of cemented ball-activated and coiled tubing-activated frac sleeves. Several operators are currently testing and evaluating these technologies.

HARTENERGY

YOU NEED TO KNOW WHAT WE KNOW.



PLAYBOOKS

Hart Energy exclusives – Playbooks address topics in the plays everyone is talking about and deliver answers to essential questions about reservoirs, active operators, economics, key technologies, and infrastructure issues.

MAPS

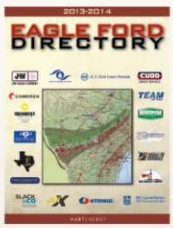
Maps for all the major plays – An up–to-date look at producing wells, rig counts, acreage, production forecast, stratigraphy, play boundaries, wet- and dry-gas windows, pipeline infrastructure, gathering units, refineries and more.

REPORTS & OUTLOOKS

Reports and Outlooks – Exclusive research and analyses that bridge the gap from information to action. Multi-client research studies for the upstream, midstream and downstream audiences, as well as "one-stop-shop" reports with a 360-degree views of the North American shale plays, updated quarterly.

GIS DATA

GIS Data Sets – Hart Energy is the proven leader in North American pipeline GIS data and the only company in the industry which provides a public accuracy statement for all its GIS data.



DIRECTORIES

Targeted Directories – The go-to-resources for anyone working a play or looking to break in, or serious about investing in the upside potential. Available in both print and online, these directories detail who is working a region, what they do, where they operate, and whom to contact.

PLACE YOUR ORDER AT **HartEnergyStore.com**

FREE SHIPPING ON ANY PURCHASE WHEN YOU USE PROMO CODE EFTB14

OFFER EXPIRES 5/31/14

A Baker Hughes crew member monitors proppant-mixing equipment on the Gloria Wheeler lease. *(Photo by Tom Fox)*

ROBERTSON (Marathon Oil): Rig count is one of those things that has a little bit less direct meaning than it used to, because the change in efficiency has been profound in South Texas during the last few years. As you drill wells, you need a substantial amount of stimulation horsepower to convert those wells to production in the field. We focus on completion design and subsurface integration to test pilots for completion studies, for spacing, for wider spacing down to very narrow spacing, and [we ask] how do we optimize that? The truth is, in the Eagle Ford, every well could be a 40-acre well at some recovery and some capital cost – how do you make those two things intersect for accretive value creation? That's our mission, and our wells continue to get better. We continue to have great results by managing stress-dependent permeability early in the life of the well, protecting an asset we've heavily invested in.

SHEPPARD (Halliburton): Sliding sleeves, plug and perf, and cemented sleeves are all driving completions. Although, you tend to lose efficiency of sleeve completions as you get into pad drilling and zipper fracs. You can be just as efficient with plug and perf once you go to zipper frac operations. Also, the industry is definitely heading in the direction of engineered perforations, and if you have sleeves cemented in the well, that kind of makes it tough to do that process. From a sleeve standpoint, one of the recent innovations now is a toe sleeve that allows you to pressure test your casing at the pressure required by the state then break the toe down at a lower pressure, but we haven't seen a lot of momentum with cemented sleeves in the Eagle Ford.

DRUMMOND (Schlumberger): One technology that is making a difference is material engineering of the fracturing fluids. A conventional frac will fracture the formation with fluid, fill the entire fracture with proppant, then the fluid flows through the prop pack to the wellbore. Our HiWAY flow-channel fracturing is pumped in a manner to create full channels that allow the fluid to flow around a prop pack and enable greater conductivity, and it can be done pumping a lot less material than a conventional frac. The most important thing is that, on average, we are getting more

production, and we're using significantly less proppant and water.

What is your most pressing challenge in the Eagle Ford? How would your operations change if you possessed a magic tool to address this challenge?

BURTON (Baker Hughes): I think the primary challenge in the Eagle Ford is very similar to the challenge most of these unconventional plays are seeing in the US. As an industry, we're not characterizing the laterals very often. There are some additional upfront costs to obtain all the data needed to characterize the lateral, so this obviously causes some hesitation in gathering the additional data. Most of the numbers I see and hear indicate that we only recover about 5% of the reserves in these types of plays. If we could use techniques to gather additional data that would improve that low recovery rate and keep the wells producing at higher rates for longer periods of time, it would be worth the additional upfront cost. As far as timing, there are already operators out there starting to gather this additional information, so if the value is proven, it could become a standard practice in the next several years.

BRANCA (Swift): There is no one pressing challenge or magic solution. The Eagle Ford is a very complicated rock and production challenge. The key to unlocking the best from the Eagle Ford is through multidisciplinary collaboration on all aspects of drilling and producing this formation from start to finish. Swift Energy is organized into asset teams comprised of landmen and regulatory staff, geoscientists, and drilling, reservoir, completion, and production engineers collectively focused on all aspects of drilling and producing the Eagle Ford. These assets are collocated, and the team members collaborate on these wells in well planning, drilling, completions, and production. The key to success is taking lessons learned in wells and transferring the best practices as quickly as possible to the next wells.

ROBERTSON (Marathon): We are materially improving our efficiency, over and over again. We've gone from just going faster to now systematically eliminating failures — a mud motor failure, an MWD failure. Can we drill a curve and a lateral in one run? We've got to eliminate those systematic failures to get better and more attractive. We have to keep asking ourselves, are we as good as we could be?

Completion design is at the core of every unconventional play in North America, not just the design but where you are in the lateral [and] how you integrate subsurface with it. We keep making changes. We keep having conversations such as let's throw out everything we've ever done, and let's keep turning over a new leaf. We're aggressively zipper fracing the overwhelming majority of our wells. We've changed our cluster spacing and stage spacing. We've actually leaned out the amount of guar we pump in our wells. We experiment and continue to experiment in a controlled way with everything.

"Rig count is one of those things that has a little bit less direct meaning than it used to, because the change in efficiency has been profound in South Texas during the last few years."

—Lance Robertson, vice president, North America production, Marathon Oil Corp.

DRUMMOND (Schlumberger): One innovation that is making a change is improved drilling efficiencies, as much as 30% improvement in wells drilled per rig in the Eagle Ford in the last several quarters. There are lots of reasons for this — pad drilling is part of it — but that success was achieved by engineering discrete technologies. There's one company selling the bit, another selling mud, yet another selling rotary steering or directional drilling, and we've had a lot of success doing things this way. But when you think about how this all goes about, there could be a design change to a bit to change the cutters to improve penetration rate, which might cause shock and vibration, which causes the motor on the steerable systems to fail. The future is going to have to be more about designing it as a system, as a whole unit from the surface to the mud system all the way to the bit. We are now starting to experience some success with this concept, bringing the entire planning process together.

One company planning the bit design, another company doing fluid design, and yet another company doing directional drilling is just not as optimal as looking at it from a consistent perspective.

AGOSTO (Carrizo): We see no single great challenge in the Eagle Ford play but rather a more global challenge of how to continue to improve our processes and equipment to drive costs down and EURs higher. In the western area of the play where we operate (primarily northern La Salle County), we can see the "light at the end of the tunnel" as far as infrastructure is concerned, so we think that issue is now largely behind us.

How does the Eagle Ford compare to other unconventional plays in terms of infrastructure and social-related challenges such as public services, environmental concerns, laws/regulations, crime, manpower, etc.?

AGOSTO (Carrizo): For us, the Eagle Ford is clearly the most "operator friendly" play we have participated in. This is due to a combination of several factors: extremely low population density where we operate, a favorable regulatory environment, relatively positive public perception of the industry, mature service sector and supply chain, good water supply and water disposal infrastructure, numerous midstream options, and mild weather. We have experienced some tightness in the local labor market, but that appears to be easing as the play matures.

BRANCA (Swift): Texas is a great place to work, and the Eagle Ford is a world-class play. For those reasons, Swift is presently dedicating most of its effort to this play. The regulatory environment is favorable, and the state works to make sure its citizens' best interests are served and at the same time has a skilled and dedicated staff to handle permitting and regulatory issues. Early in the Eagle Ford play, the products, services, and infrastructure were challenges all operators faced as the demand for these grew exponentially. We addressed these challenges through advanced planning, and our supply chain management team contracted for goods and services for the longer term. The service industry has risen to the challenge, and issues, such as rig and frac crew availability, are no longer a concern. The public in South Texas is accustomed to oil and gas activities and many have land and royalty interests in the wells we are drilling. Swift Energy is committed to being a good steward and neighbor, and we work with the land owners and the public to minimize and mitigate any inconvenience our operations might cause.

BURTON (Baker Hughes): One of the unique challenges in the Eagle Ford is the regulation put in place that requires certain geological layers above the Eagle Ford to be cemented across. This regulation has led to the wellbore completions primarily using cement to achieve annular isolation. We have developed new technology and improved on our existing technologies for cemented completion systems.

ROBERTSON (Marathon Oil): As we work in South Texas, we need to be responsible as operators, as service providers, [and] as people in the community. One of the things we have taken on to be responsible about from the very beginning is how we manage water across the basin. We are overwhelmingly in favor of using saline water in our wells – water that is going to be out of competition for local municipalities, for farmers, and ranchers. We've had great partners on the pumping services side to help us work on fluid chemistry so we could get that right, with fluids that might have 25,000 ppm [parts per million] natural salinity. We are going to move all of our water collection into aggregated sites, so we can treat it further and dispose of it responsibly. Piping it helps us take a lot of trucks off the road. Local communities want jobs and they want GDP [gross domestic product] growth, but they also want us to be responsible operators. This is one way we can do it.

We have 10 years' worth of inventory to drill, and those wells are going to produce for 20 years after that. And that's only based on technology we understand today. We've come a long way in the last five years. Where will we be in the next five years or the next 10 years? We look forward to being involved in South Texas for a very long time. ■

FASTER

They wanted a completion system that would allow a full wellbore ID after a multistage fracturing treatment. We said sure. Well, actually, we developed SUREstack™, a field-proven single-trip fully retrievable ball & seat system requiring no post-stimulation milling or drilling.

THE OPERATOR ASKED IF WE COULD SPEED UP BALL SEAT REMOVAL. WE SAID, HOW ABOUT 90% FASTER?

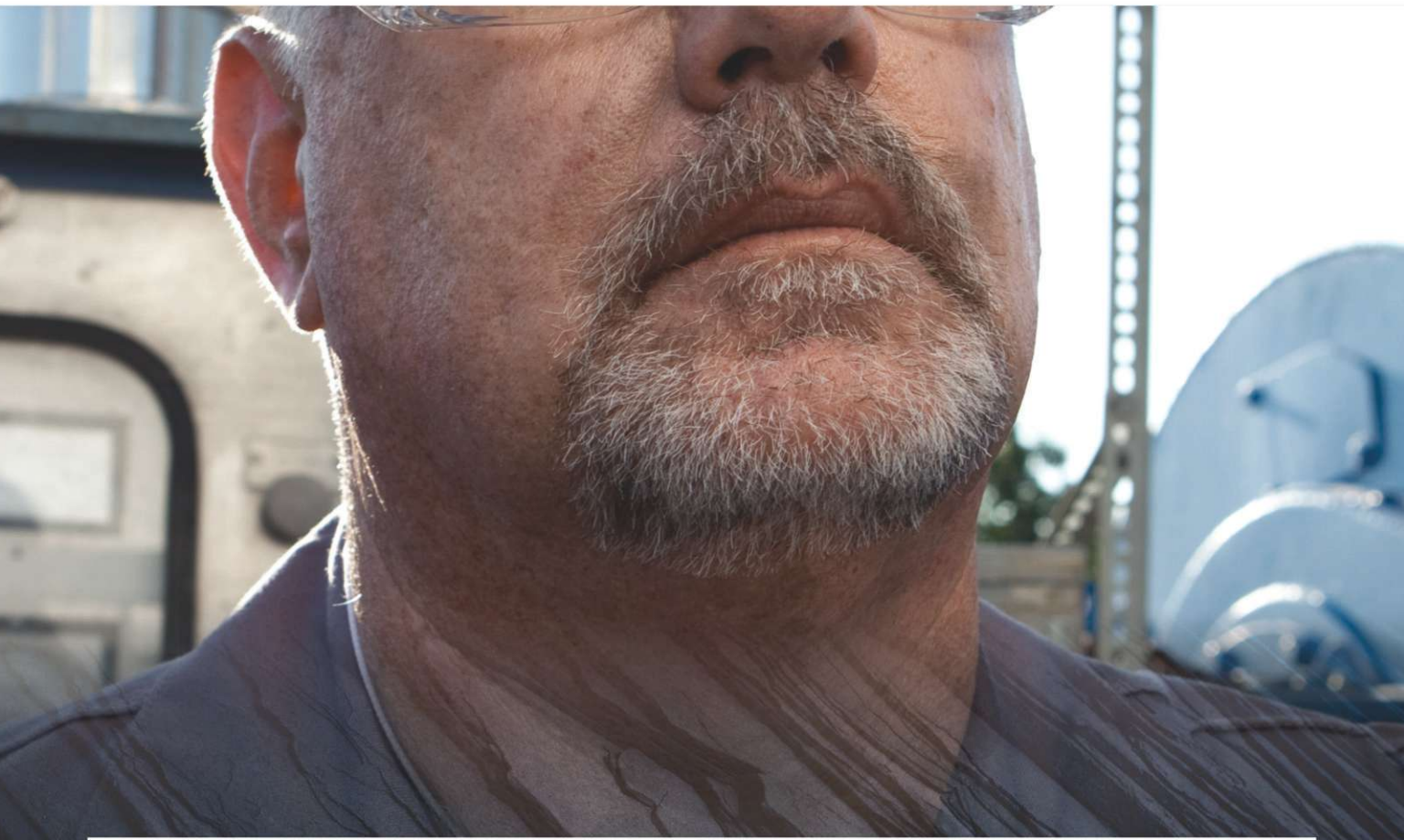
It took an average of two minutes per seat, reducing the total time required by 90%. That's just one more example of how we deliver solutions to tough problems, saving you time and money. So if you're as tenacious as we are about innovation, we need to talk. Expect the Unconventional.

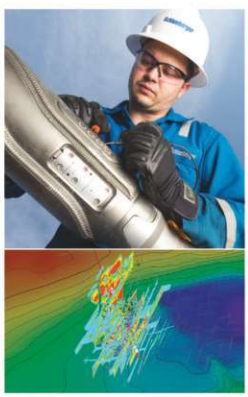
Pressure Pumping • Completions
Canada • USA • International

sanjel.com

Sanjel

How can we get our factory drilling to deliver factory production?





Start by attacking that 30% rejection rate.

Factory drilling in unconventionals has delivered exceptional results. However, no factory in the world would accept such a high rejection rate. For instance, 36% of zones stimulated on a typical multiwell program in the Eagle Ford did not contribute to production. Getting the production part of the factory on track requires technologies to understand geological variability, optimize well placement, and deliver effective stimulations.

Our technology has led to a 99.9% placement success rate in more than 21,000 unconventional treatments in 20 different countries with a 20% average productivity gain.

Now that's a well-performing factory.

slb.com/shale

Schlumberger