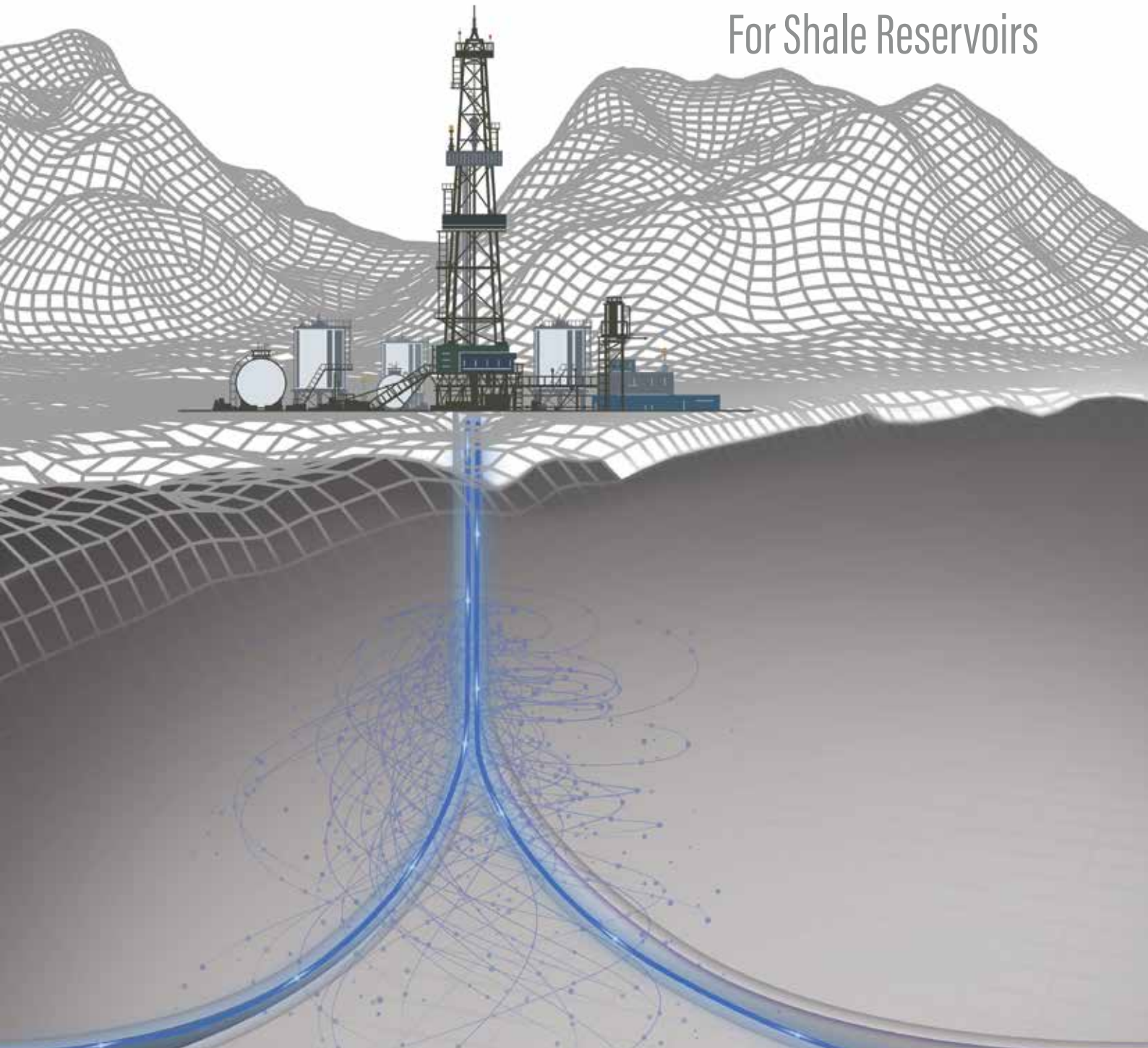
OptaSense®
a QinetiQ company

Distributed Fiber Optic Sensing

For Shale Reservoirs



Developing shale reservoirs can be challenging without the right insight

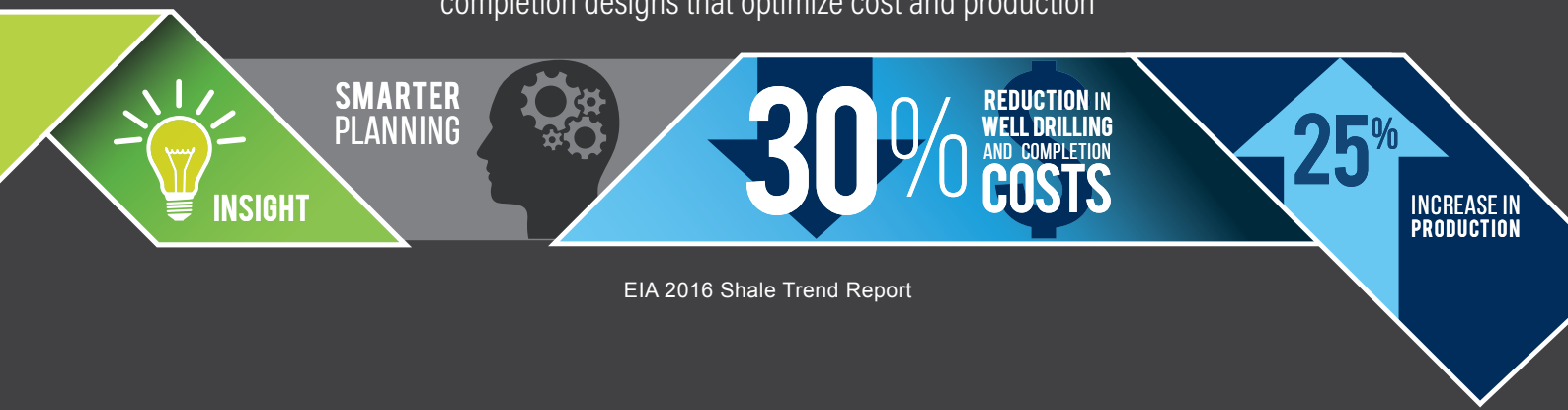
Shale gas development has become a vital component of the global energy mix— but many operators developing these plays are challenged by subsurface uncertainty, higher costs and declining production levels.

Shale reservoirs are complex. Formation characteristics and production rates vary significantly across plays, wells and stages. Due to cost, advanced downhole surveillance technology is often overlooked.

With limited subsurface knowledge, many shale formations are developed using factory drilling and geometric fracturing—resulting in unfavorable economics.

However, cost-saving tactics, such as optimizing site selection, well spacing and stacking, fracture placement and well refracturing, are allowing operators to extract reserves at a positive net present value.

Subsurface insight leads to smarter well and completion designs that optimize cost and production



EIA 2016 Shale Trend Report

The more you know about the reservoir,

the more successful you'll be at optimizing recovery

OptaSense Oilfield Services introduces a Distributed Fiber Optic Sensing (DFOS) solution for shale reservoirs, that provides vertical seismic profiling (VSP), hydraulic fracture profiling and production flow monitoring in real time, from a single system.

Using Distributed Acoustic Sensing (DAS) technology, this system enables operators to visualize borehole seismic data, completion operations, fracture propagation and productivity, along the entire wellbore, for the life of the asset.

This insight leads to smarter well planning that optimizes development costs and enhances recovery.

HOW IT WORKS

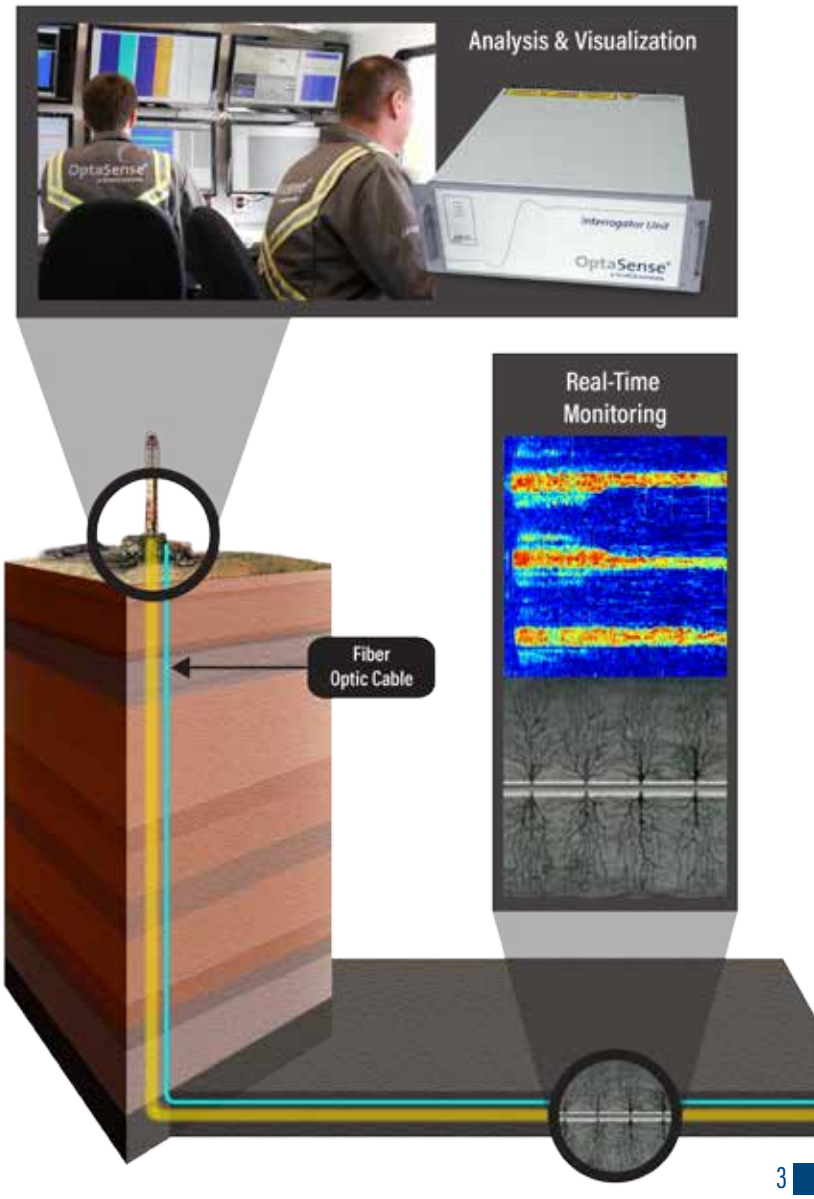
The DFOS System

The DFOS system works by transforming a standard fiber optic cable into an array of distributed acoustic sensors capable of detecting changes in pressure, temperature, stress and acoustics.

For measurement, the system utilizes a Coherent Optical Time Domain Reflectometer, or Interrogator Unit (IU), located on the surface. After injecting laser pulses down the length of the fiber, the IU processes and records changes in the backscattered light, that is a function of strain on the fiber.

The returned signal, carried by the backscattered light, is sampled at a high frequency (up to 20 kHz). Then position and amplitude of strain sites are determined and visualized using proprietary software.

The DFOS system leverages existing permanently installed fiber, which is ideal for low cost, nonintrusive evaluation and monitoring. Once installed, the system eliminates any future well interventions for repeat surveys and monitoring.



Delivering subsurface intelligence that powers enhanced recovery

Optimize development plans and reservoir exposure

The characteristics of shale reservoirs vary considerably across short distances, and this uncertainty has a direct impact on how effectively you find and recover reserves.

Once installed, the OptaSense DFOS system acts as a borehole seismic sensor array that acquires high resolution 2D, 3D and 4D VSP data.

This data enhances surface seismic by filling in the gaps near the wellbore—which is imperative to design development plans that maximize reservoir exposure.

Characterize the reservoir

- Enhance your understanding of near- and inter-well structural integrity, rock mechanical properties, in-situ stress and natural fractures—which is critical for successful site selection, well positioning and fracture placement.

Acquire quality data

- Rely on a cost-efficient, nonintrusive option rather than conventional downhole geophones, which can hinder the acquisition of VSP data, resulting in limited wellbore coverage

Eliminate uncertainty

- Resolve structural uncertainty from far-field surface seismic surveys by validating reservoir characteristics near and between wellbores

Optimize completion and fracture effectiveness

When faced with inconsistent production, many struggle to understand how successful their completions were at stimulating the formation and what they can do differently to increase performance.

The OptaSense DFOS system allows you to monitor the deployment of completion operations, as well as fracture performance, in real time to ensure operational success and effective reservoir stimulation.

Ensure successful completions

- Confirm that placement of downhole tools, such as bridge plugs and perforation guns, are in the targeted zone for optimal well performance
- Confirm the seating and integrity of ball-activated bridge plugs for successful stage isolation, which is key to achieving designed fracture growth
- Confirm ports are successfully opened to manage pumping execution and achieve desired placement of proppant for each stage

Monitor fracture performance

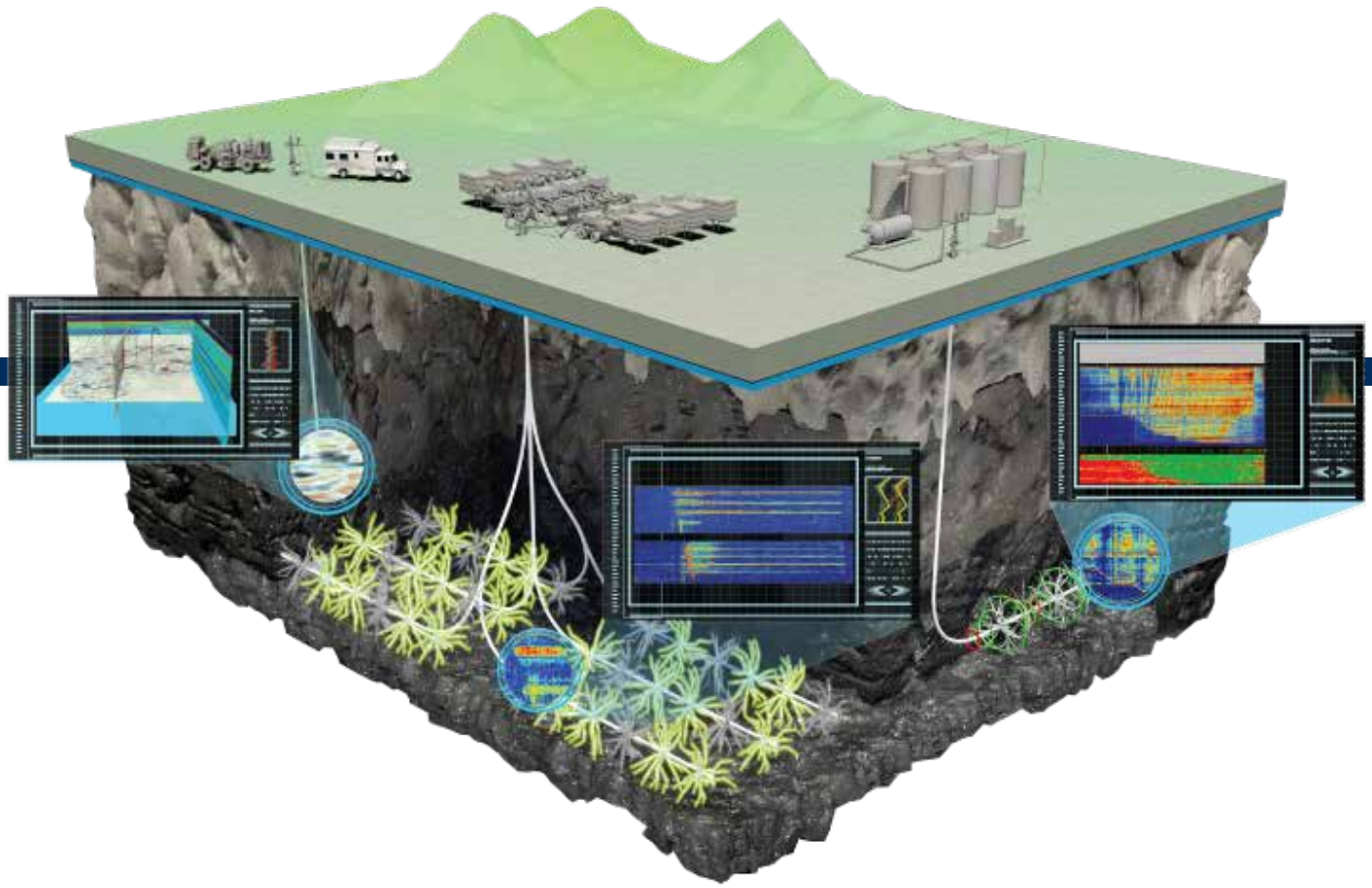
- Quantify fluid and proppant volumes at the perforation level to identify under stimulated zones for possible diverter or refrac applications.
- Monitor the distribution and placement of proppant and fluid to diagnose the effectiveness of limited-entry designs and prevent under or over stimulated zones—which have a negative impact on fracture height containment, offset wells and ultimate recovery.

Mitigate risk in real time

- Optimize fluid and proppant placement in real time with diversion technology, or adjust future stage perforation designs and spacing
- Monitor cross well strain and temperature on a vertical monitoring well or horizontal offset treatment well for valuable insight on fracture geometry.
- Detect channeling outside the casing to mitigate risk in real time

Borehole Seismic Services

Through OptaSense Borehole Seismic Services, you can leverage a team of experienced analysts for sophisticated processing, time-lapse analysis, velocity and anisotropy modeling, depth migration, log calibration and surface seismic model calibration.



Optimize future well designs

The DFOS system, combined with our in-house processing and imaging services, help you identify areas of the reservoir influenced by fracture stimulation to optimize future well designs.

Leveraging high definition 4D VSP surveys, time-lapse imaging and microseismic mapping, you'll gain a clear understanding of fracture propagation, quality and integration to improve well placement and efficiently recover reserves in large, stacked reservoirs.

Determine the location and volume of the reservoir accessed

- Characterize induced and natural fractures by acquiring 4D time-lapse surveys pre and post frac, to visualize subsurface regions that have been permanently affected by stimulation. This insight optimizes infill drilling operations
- Understand the location, magnitude and timing of seismic events using our microseismic mapping services, to identify fracture and proppant degradation that can accelerate well declines and reduce reserves

Evaluate hydraulic fracture quality

- Identify the location and quality of fractures, and differentiate between open and closed fracture networks, through application of 4D time-lapse borehole imaging and microseismic mapping
- Gain the insight to arrest rapid decline rates by detecting closures over time, while optimizing well treatments and future refracting designs

Reduce spatial uncertainty

- Incorporate seismic-derived data into reservoir drainage and fracture simulation models to reduce spatial uncertainty associated with low resolution 3D seismic images. High resolution seismic images from DAS VSP can illuminate the petrophysics surrounding microseismic events

Optimize recovery

Conventional production logging methods have drawbacks that make it difficult or impossible to use on deviated and complex wells. Tracers provide a limited snapshot of production at certain point in time.

Unlike other conventional production monitoring methods, the DFOS system lets you visualize inflow and axial flow along the entire wellbore, in real time, at the perforation level, for the life of the asset.

By using an optical fiber clamped to the casing or production tubing, the DFOS system offers nonintrusive data acquisition for continuous logging and on-demand surveys, without interrupting production, at a significantly lower cost compared to conventional production logging.

Enhance production levels

- Pinpoint underperforming stages and clusters by monitoring production at the perforation level, across the length of the well
- Correlate production flow data with geologic properties and fluid and proppant placement, to evaluate profitable field development designs.
- Integrate DAS and Distributed Temperature Sensing (DTS) with subsurface parameters to evaluate choke management practices and their ability to effectively drawdown across the lateral.

Monitor production over time

- Combine production data with 4D VSP monitoring and time-lapse imaging to monitor and evaluate the impact of production on the reservoir over time. This provides the insight to evaluate enhanced oil recovery placement and efficiency for optimal refracturing operations
- Combine passive microseismic monitoring to detect induced and natural fractures for effective drawdown management. This will enhance recovery by ensuring fracture pathways remain open

Enable predictive maintenance

- Listen to production flow across artificial lift valves and pumps, providing the condition monitoring necessary to support predictive maintenance and lower lifting costs

The DFOS Solution
A cost-effective, flexible offering

One system with multiple applications to enrich planning, production and profitability.

Solution	Services	Capabilities
Reservoir Characterization	VSP Acquisition Services	‣ 2D, 3D and 4D VSP
	Borehole Seismic Processing Services	‣ 2D, 3D and 4D VSP processing ‣ Time-lapse analysis ‣ Velocity and anisotropy modeling ‣ Depth migration ‣ Log calibration ‣ Surface seismic model calibration
Well Placement	VSP Acquisition Services	‣ 2D, 3D and 4D VSP
	Borehole Seismic Processing Services	‣ 2D, 3D and 4D VSP
Completion and Fracture Effectiveness	Completion Monitoring Services	‣ Hydraulic fracture profiling ‣ Cross well communications ‣ Pre/post frac VSP
	Borehole Seismic Processing Services	‣ Microseismic event detection and mapping ‣ Anisotropy modelling ‣ Microseismic interferometry imaging ‣ 4D time-lapse VSP imaging ‣ 4D amplitude and time analysis ‣ Velocity analysis
Production Optimization	Production Monitoring Services	‣ Production flow monitoring
	Borehole Seismic Processing Services	‣ 4D time-lapse VSP imaging ‣ 4D amplitude and time analysis
	Artificial Lift Monitoring	‣ Artificial lift monitoring

Powering Enhanced Recovery with Subsurface Intelligence

OptaSense delivers the technology that transforms sound into insight to evaluate, measure and monitor properties, performance and productivity.

Contact your local Oilfield Services representative or visit us online for a cost-effective system that combines multiple capabilities into a single technology to deliver the subsurface intelligence that powers enhanced recovery.

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