SPE WORKSHOP

Mapping the orientation of downhole sensing cables and control lines using an engineered hybrid distributed acoustic sensing system

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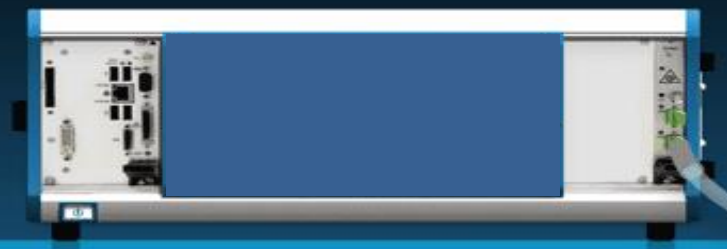
Society of Petroleum Engineers

Content

- Introduction to DAS
- Definition of the problem
  - Risk and additional cost of behind-casing fiber optic cable installations
    - *i. Extra downhole hardware*
    - *ii. Extra rig time for borehole conditioning*
    - *iii. Additional cable mapping intervention survey*
- Proposed engineering hybrid DAS solution
- Field trial results
- Summary

DAS operation

- Simultaneous measurement of acoustic amplitude, phase and frequency at every metre along fibre
- 40,000 independent measurement points
- *Acoustic phased array detector*



Acoustic field

Optical fibre

Laser pulse propagating through the fibre

Backscattered light returning to DAS

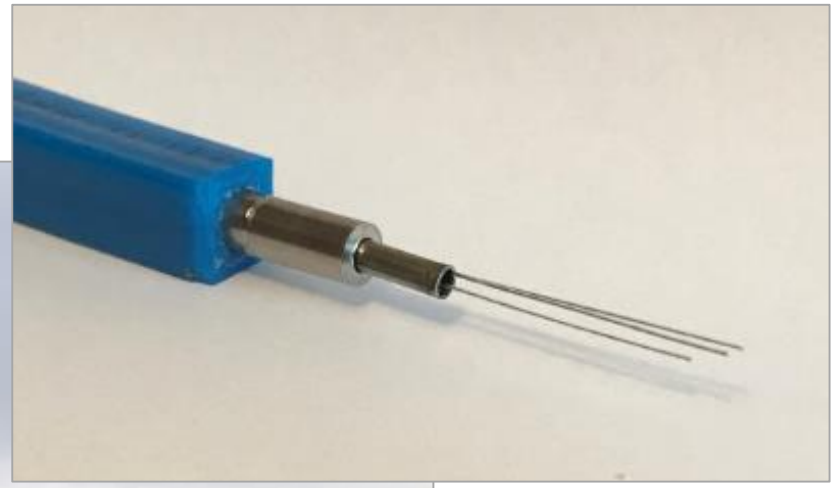
Tom Parker et al., EAGE First Break volume 32, pp. 61-69, February 2014

Downhole Fiber Optic Cables Installation

Encapsulated Fiber Optic Cable

Locked Casing Centralisers

Cable Clamps



Conventional Cable Mapping and Oriented Perforation

- Clamp assembly with long metal bars placed beside fibre optic cable
  - Metal bars provide a significant enough metal anomaly for wireline tools to detect using rotating sensor
  - Significant length of metal bars required to make it possible to target clamps with wireline point sensor
- Metal anomaly mapper data often validated with 360 degree ultrasonic imaging of casing and cement
- Subsequently zero-phased perforating guns can be oriented using a eccentric weight and indexing adapter

Engineering Solution

- Create a sealed (disposable) sensor package capable of measuring and communicating relative bearing
- *Relative bearing is typically the clockwise angle from the high side of a deviated wellbore to a downhole toolface*
  - *In this instance to the sensing fiber cable*
- **Leverage the ability to acoustically sample every position along the fibre with DAS**

- The Cable Orientation Beacon comprises:
  - Sealed pressure tight housing (10kspi Working Pressure)
  - Relative bearing sensor
  - Measurement and driver electronics
  - Downhole battery
  - Sound source

- Device must be deployable downhole without compromising completion.
- Such as enclosed within the envelope of typical cable clamp.

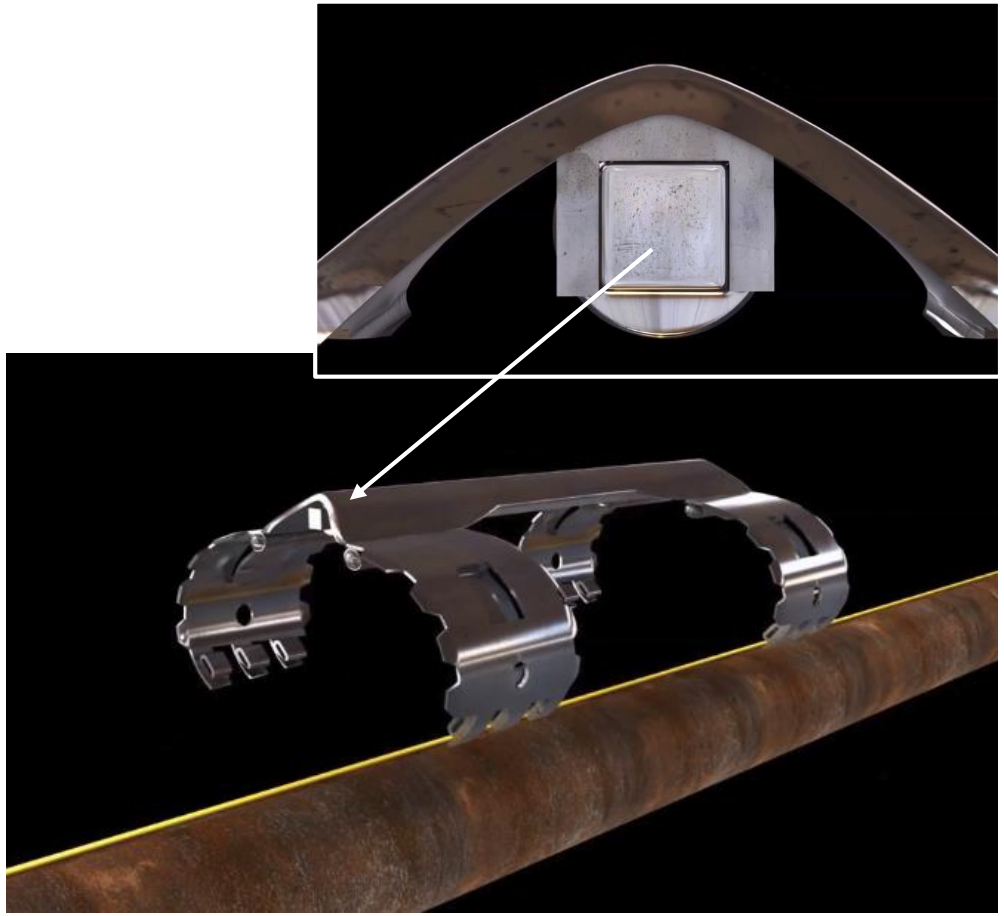
Beacon Operation

- Batteries are installed to beacon prior to dispatch from Silixa and end caps are welded on.
- Low power electronics monitoring an internal temperature sensor.
- A microprocessor is coded with an operational sequence including an activation temperature.
- *Multiple beacons are placed outside casing along the deviated or horizontal wellbore.*
- When a pre-defined downhole temperature is reached the beacon switches to full operation mode.
- The program can include a delay between temperature switch-on and full operation to allow for other planned operations such as cementing.
- Microprocessor converts measured RB to a coded driver signal to the sound source.
- Sound source is activated for 30 seconds every 30 minutes to prolong battery life.
- *DAS is used to interrogate fiber from surface*
- Interrogation continues until each beacon is identified
- Optical distance of signal can be tied to the casing tally depth of each beacon installed depth
- Beacon relative beacon at each depth indicates path of cable outside casing.

Engineering Solution

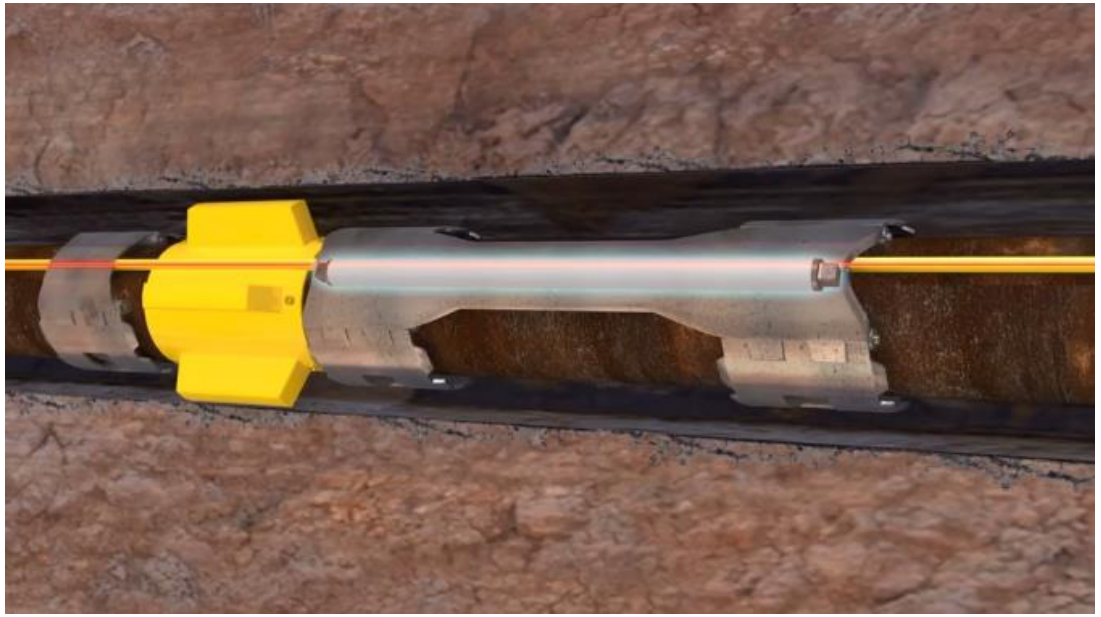
- Beacon must remain in keyed orientation within the clamp so that measured relative bearing is the same as the sensing cable
- Clamped beacon should present as low, and well friendly a profile as possible

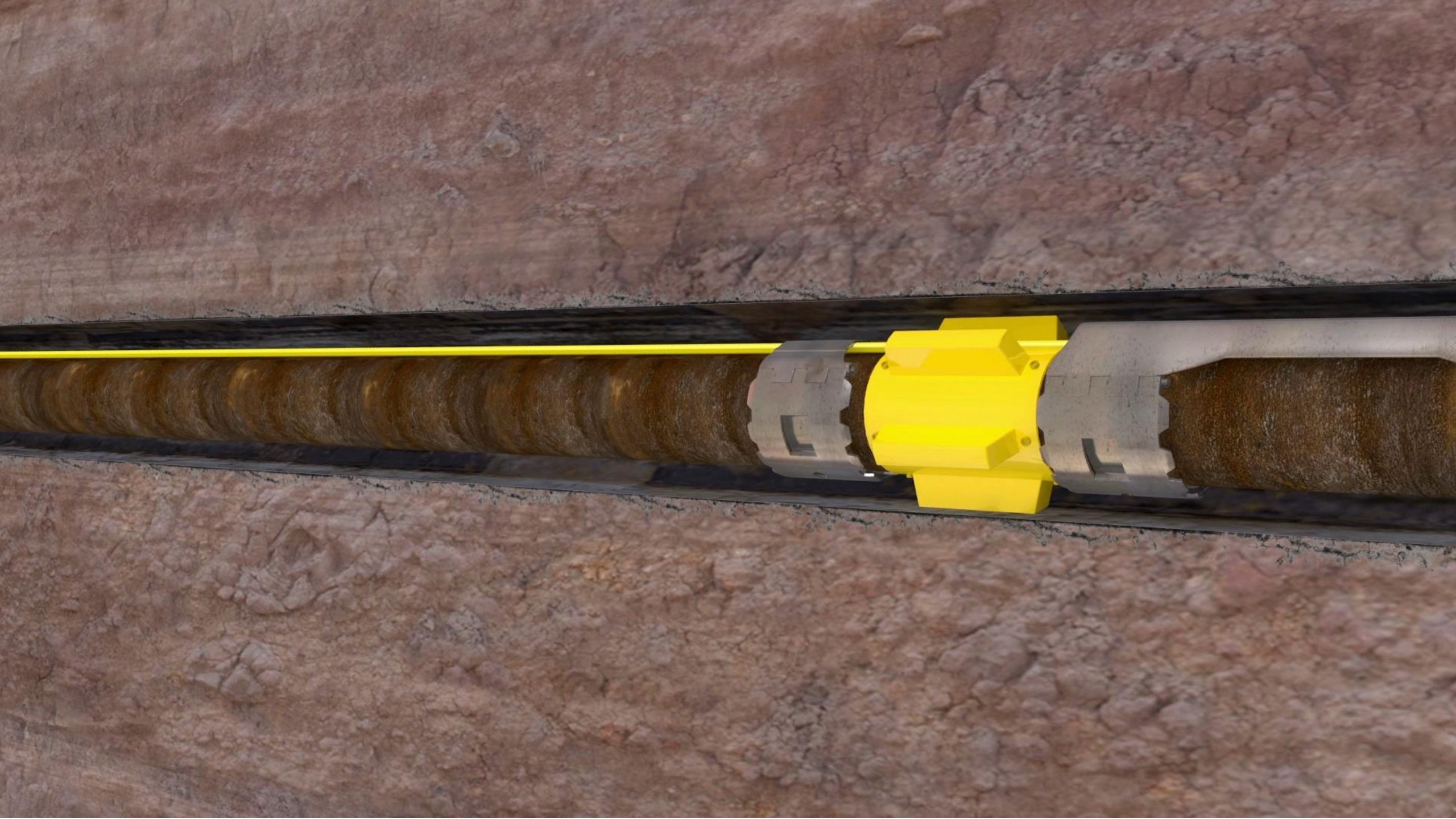
Clamp secures beacon next to 11mm encapsulated fiber optic sensing cable



Engineering Solution

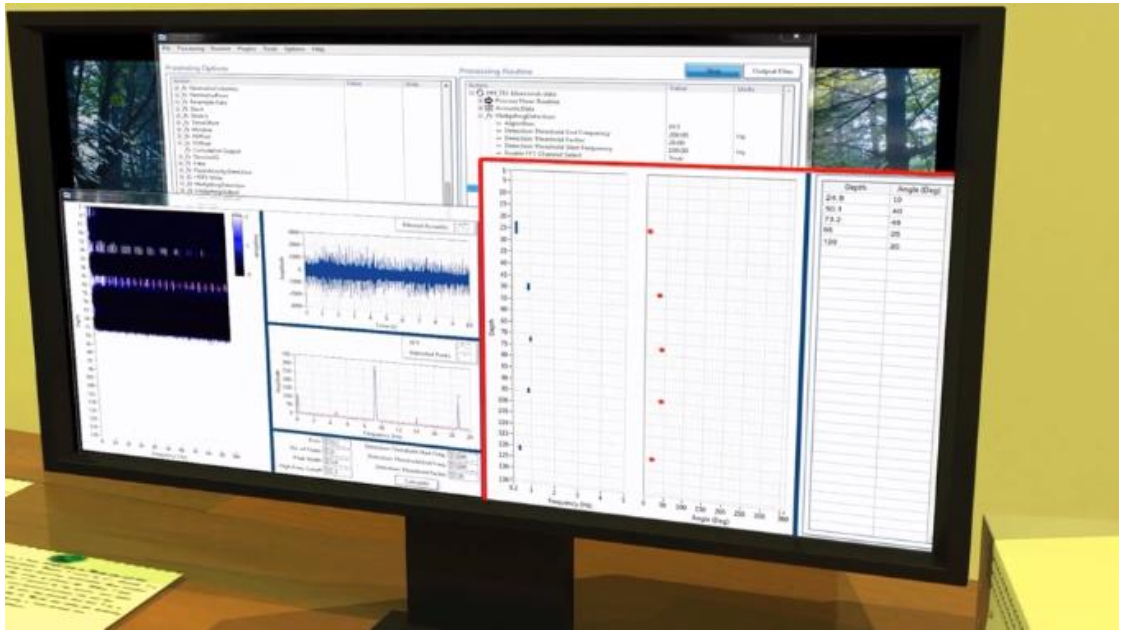
- Installation on the rig floor must be safe and easy
  - Beacons are secured into the clamps offline so that there is no risk of dropping into well
- Beacons and clamps should integrate well with other installation hardware: clamps and centralisers
- Proximity to DAS sensing fibre should enable beacon signal capture



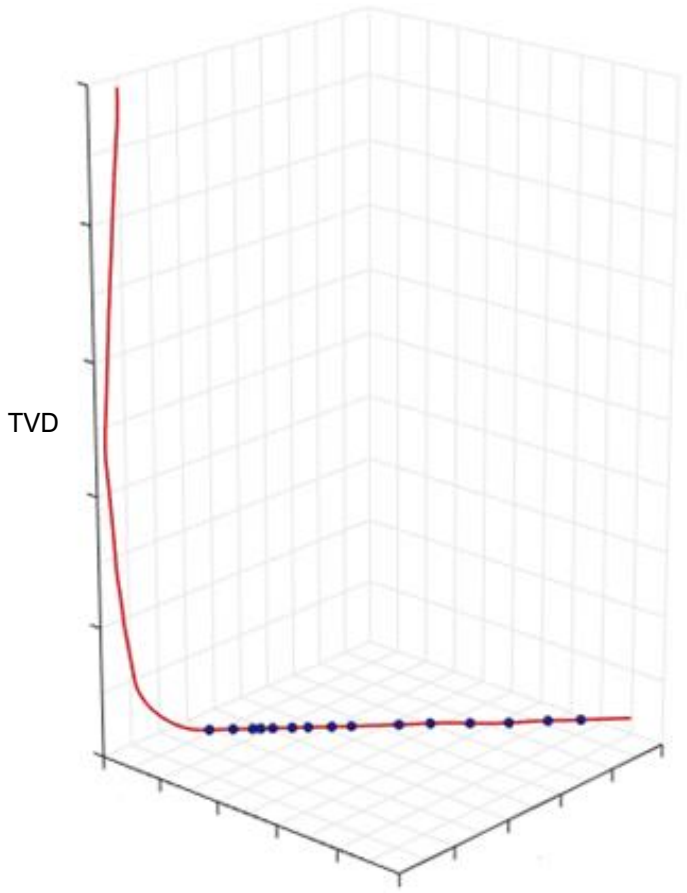


2017 Initial Field Trials

- Two horizontal well trials in North America
  - Trial 1: 15 beacons spread along the horizontal
  - Trial 2: 5 beacons placed in the horizontal
- One deviated well trial in North Sea
  - Trial 3: 5 beacons placed with hydraulic control line package. DAS sensing fibre introduced by intervention to survey beacons



North America Fiber Optic Cable Mapping

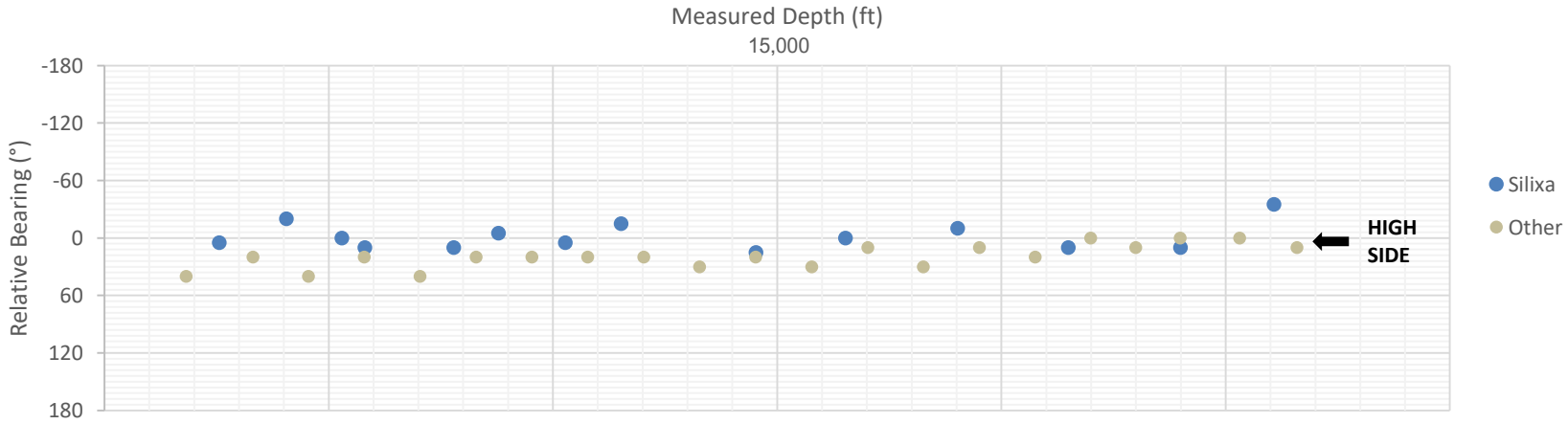


Courtesy of Chevron

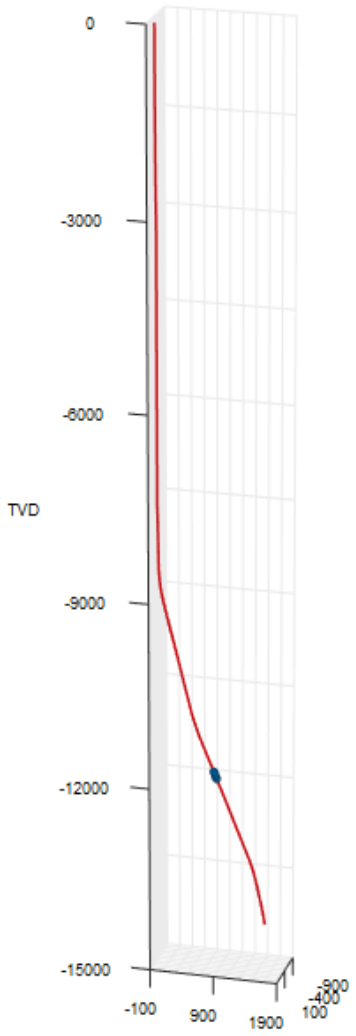
- 15 cable orientation beacons spread along lateral with encapsulated fiber optic cable
- DAS recorded on fiber during casing running and after casing landed
- Cable orientation decoded from DAS data at 14 of 15 beacon locations

Lessons Learned

- *Increased battery life required*
  - ✓ *2018 re-design provides 7 days of battery life*



North Sea Control Line Mapping

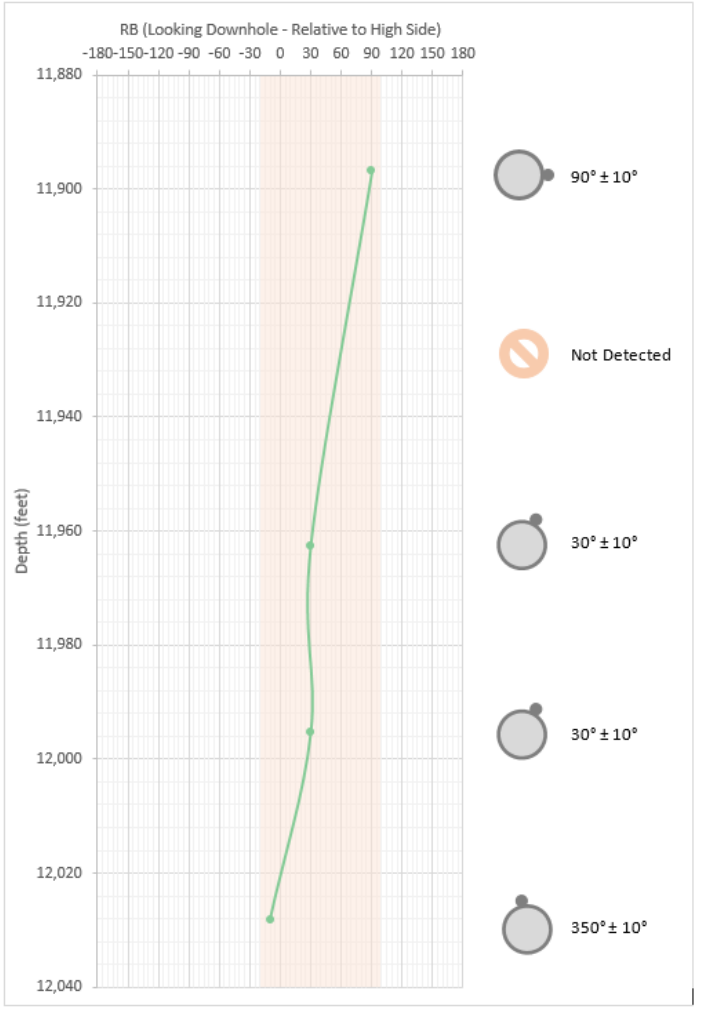


Customer wanted a low cost method to map the position of a control line bundle outside tubing on a new smart well completion.

The control lines ran through a secondary reservoir to sleeves in the main target.

Required option to add perforations to secondary reservoir without losing hydraulic function of deeper components.

- 5 Orientation Beacons installed outside tubing string alongside hydraulic control lines for smart completion
- Well deviation approximately 20° at beacon depth
- Fiber optic slickline cable run into tubing to log DAS
- Acoustic signature of beacons recorded and analysed
- Relative bearing of each beacon decoded from data
- Depth log of control line azimuth delivered to customer



2017 Initial Field Trials Learnings

- Battery life affected by passivation due to un-even battery draw during sound source activation.
  - ✓ Electronics re-engineered to reduce and flatten battery draw using newly available components
  - ✓ Relative bearing sensor replaced with 3-axis accelerometer
  - ✓ Additional battery cell
  - ✓ 2018 performance gives 2 weeks of downhole operation

- Difficulty in testing function at wellsite

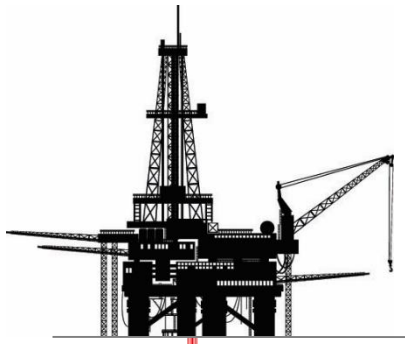
  Although ends welded there was a roll sequence to activate a test function.
  - ✓ Replacing welded end cap on one end with threaded o-ring sealed cap to allow final wellsite testing

Final beacon dimensions OD: 1” Length: 11.2”

Summary

- Reduced hardware makes running the casing easier and improves the chances of a successful cementing with no additional risks
- Direct DAS cable mapping (no additional cable mapping intervention survey is required)
- Provides accurate downhole depth calibration points
- The DAS can also be used for acquiring additional completion and wellbore data via a range of low-power hybrid sensors
- The permeant installation of the sensing fiber optic cable offers a cost-effective surveillance solution for the life of the well and the field

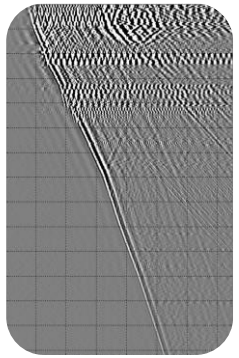
Summary



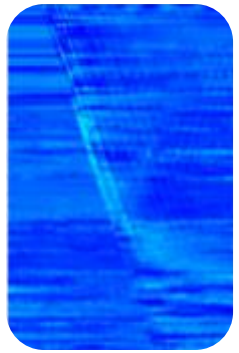
one fibre - life of field - multiple services

Single FO Cable Installation

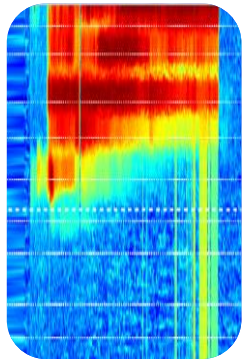
Borehole seismic



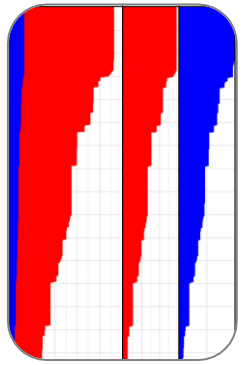
Cement evaluation



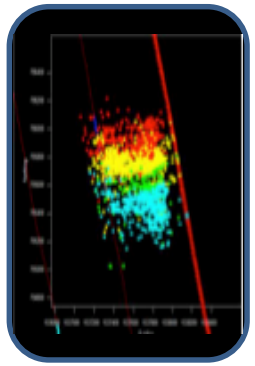
Fracture analysis



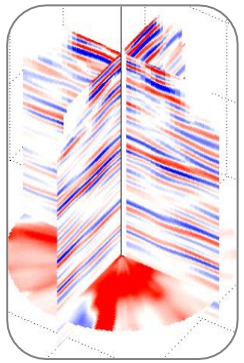
Flow profiling



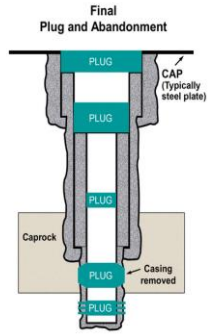
Xwell Microseismic & Strain



Repeat seismic 3D/4D



Well abandonment



DRILLING → COMPLETION → PRODUCT/RESERVOIR MANAGEMENT → WELL ABANDONMENT

Acknowledgements

We would like to thank the operators for their permissions to share the field trial results presented here.

Thank you

Questions?

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