DISTRIBUTED ACOUSTIC SENSING – "LISTENING" TO FRACTURE PLACEMENT

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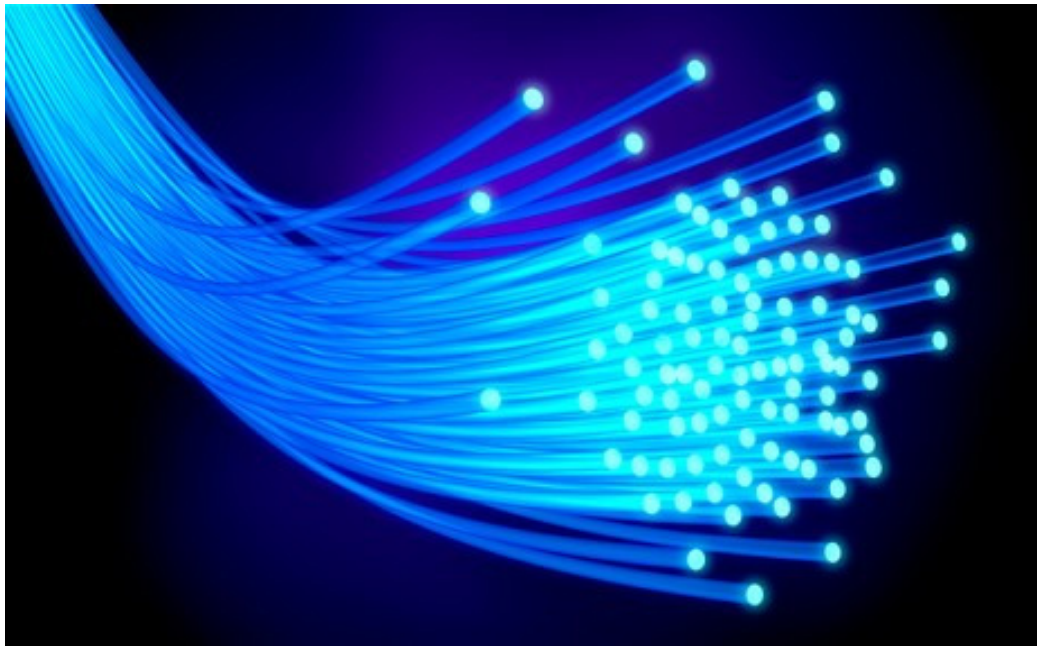
AGENDA

- What is DAS?
- Installation
- Completion Operations and Fibre Integrity
- Results and Interpretation
- Way Forward



WHAT IS DAS?

There are two ways of answering this question:

- Distributed Acoustic Sensing – DAS – is the ability to continually gather wellbore activity from toe to tree because almost everything which happens downhole has some element of vibration.
- Or, more technically, DAS, in its simplest form, is a method of collecting what is generically called acoustic data via a sensor.
  - In this case the sensor is a continuous optical fibre from the toe of the well to the wellhead.
  - Vibrational energy is passively 'converted' into an optical signal by inducing micro-strain into the optical fibre which affects the way light traveling along the fibre is reflected.
  - The resulting fringe pattern – a product of interferometry – is interpreted into energy levels at specific frequencies by surface electronics.

INSTALLATION

A DAS installation is performed much the same way as installing a control or TEC line. It is installed outside casing and protected across couplings, float collars and other downhole jewelry by clamps.

Centralizers are used to bias the installation to minimise drag introduced by any additional hardware

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INSTALLATION

For P&P completions the intended perforation locations need to be identified before installation. Completion Cable Protectors (CCPs) are installed where perforations are intended. CCPs are special protectors which not only provide protection against cable abrasion but also permit magnetic orientation.

Before completion a tool is run to 'map' the location of the CCPs in terms of true longitudinal and rotational position.

COMPLETION OPERATIONS AND FIBRE INTEGRITY

By the time CWI moves onto location to perforate the well the following is known:

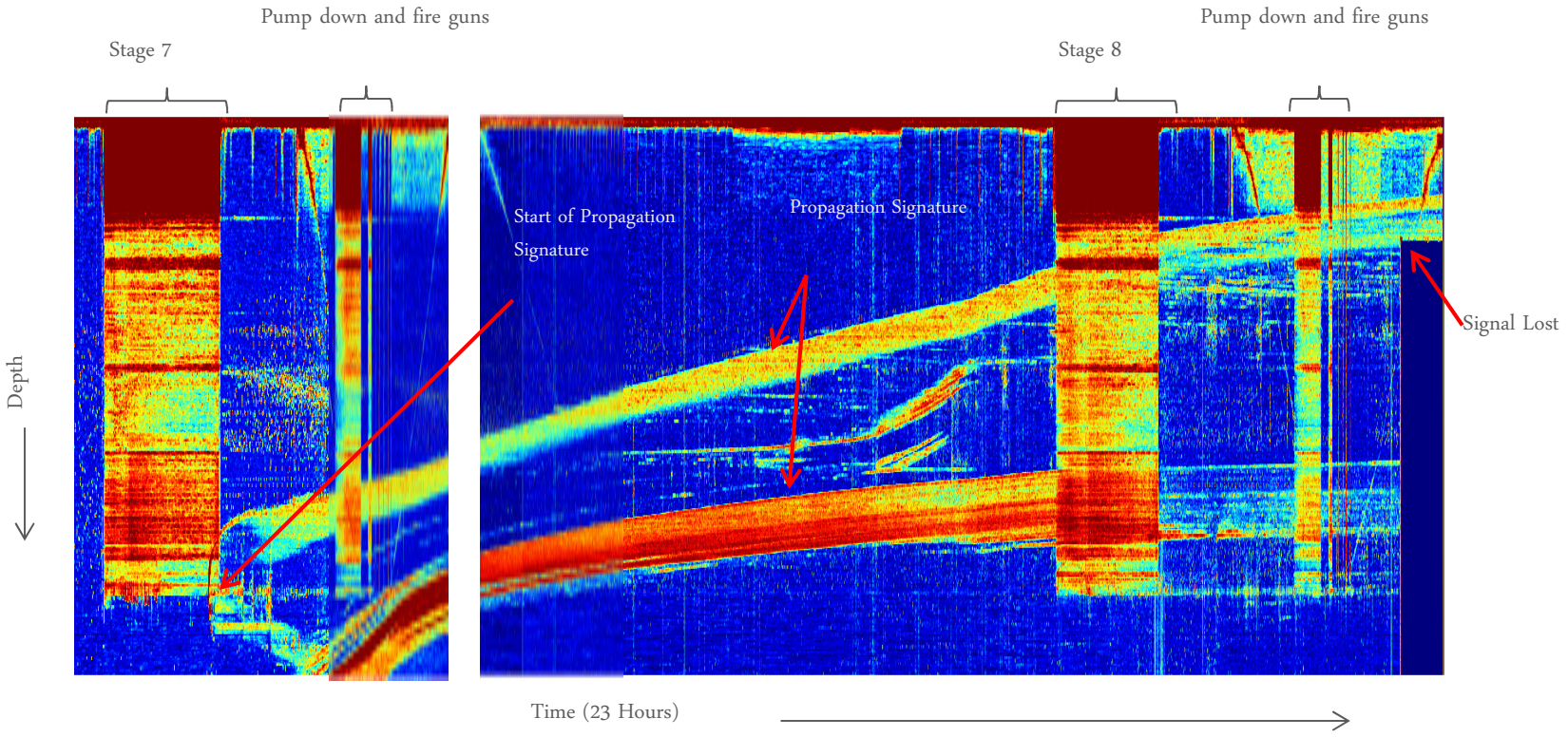
- Fibre condition is known to be good
- Location of all CCPs is known
- Stage length, perforations per stage and cluster size are defined

Not only has Shell developed best practices for installing fibre successfully but also for completing a well by using the following techniques:

- Run a dummy weighted gun to ensure orientation system works
- Only use zero-phased guns
- Actively monitor sand placement during frac to identify any anomalous behaviour

COMPLETION OPERATIONS AND FIBRE INTEGRITY

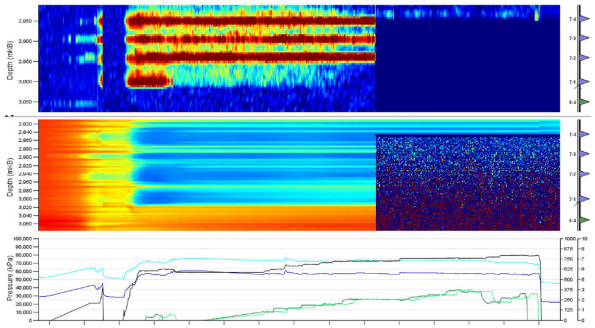
Integrity of the fibre is critical to the operation and fibres have been known to break and Shell, as the leader in fibre technology and application, has had its fair share of these!



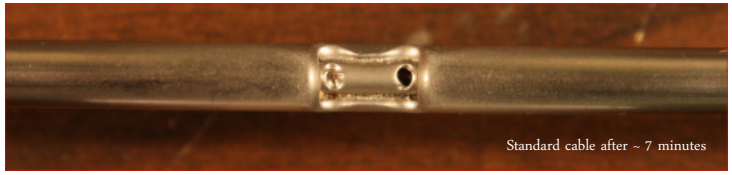
COMPLETION OPERATIONS AND FIBRE INTEGRITY

Failure typically occurs as a result of abrasion so Shell has:

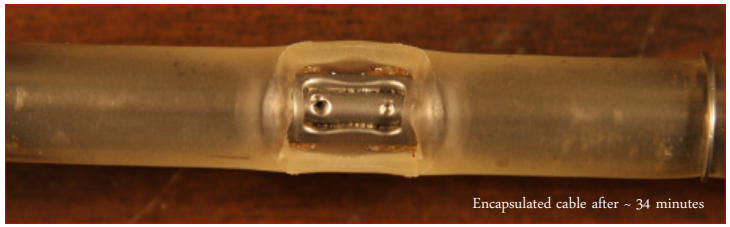
- Developed in conjunction with AFL a highly abrasion resistant polymer called StrataJac for encapsulation
- Introduced better CCP design



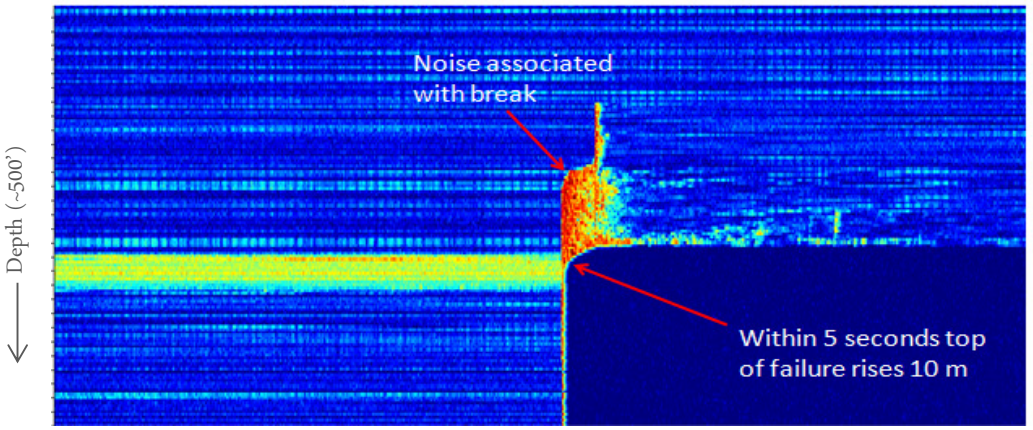
Testing has also shown that proppant velocity has a significant influence



Bare Cable (as deployed to date)



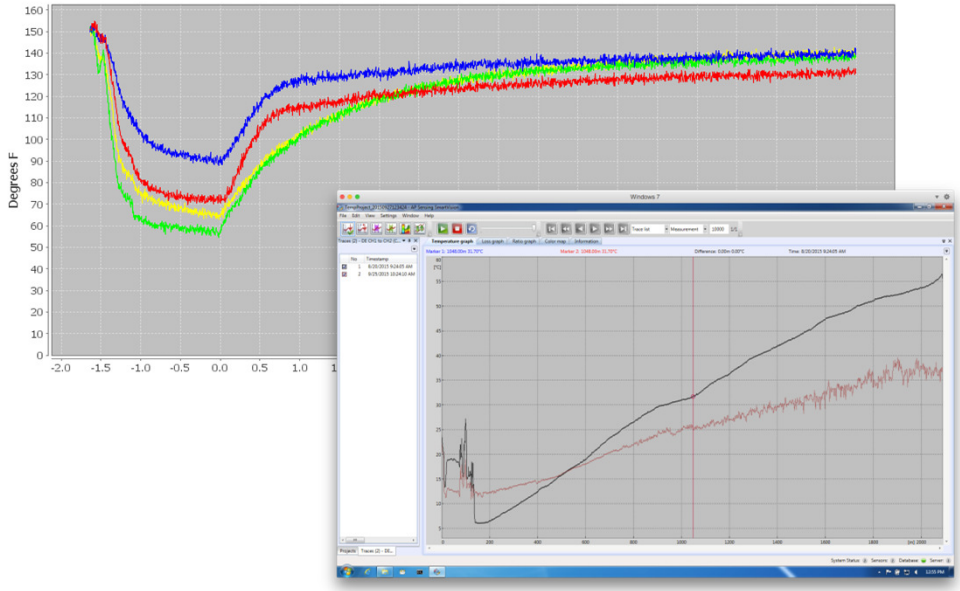
Encapsulated Cable

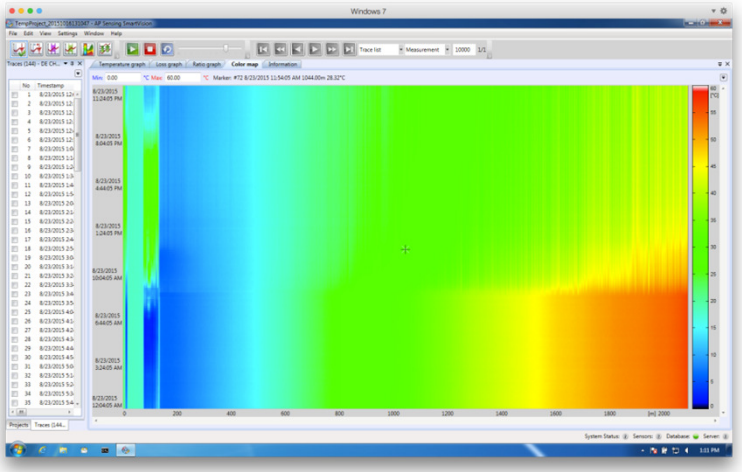


RESULTS AND INTERPRETATION

DAS and DTS can be installed into the same cable and these technologies are synergistic. DTS is well known and understood but when combined with DAS the information is more *quantitative*.

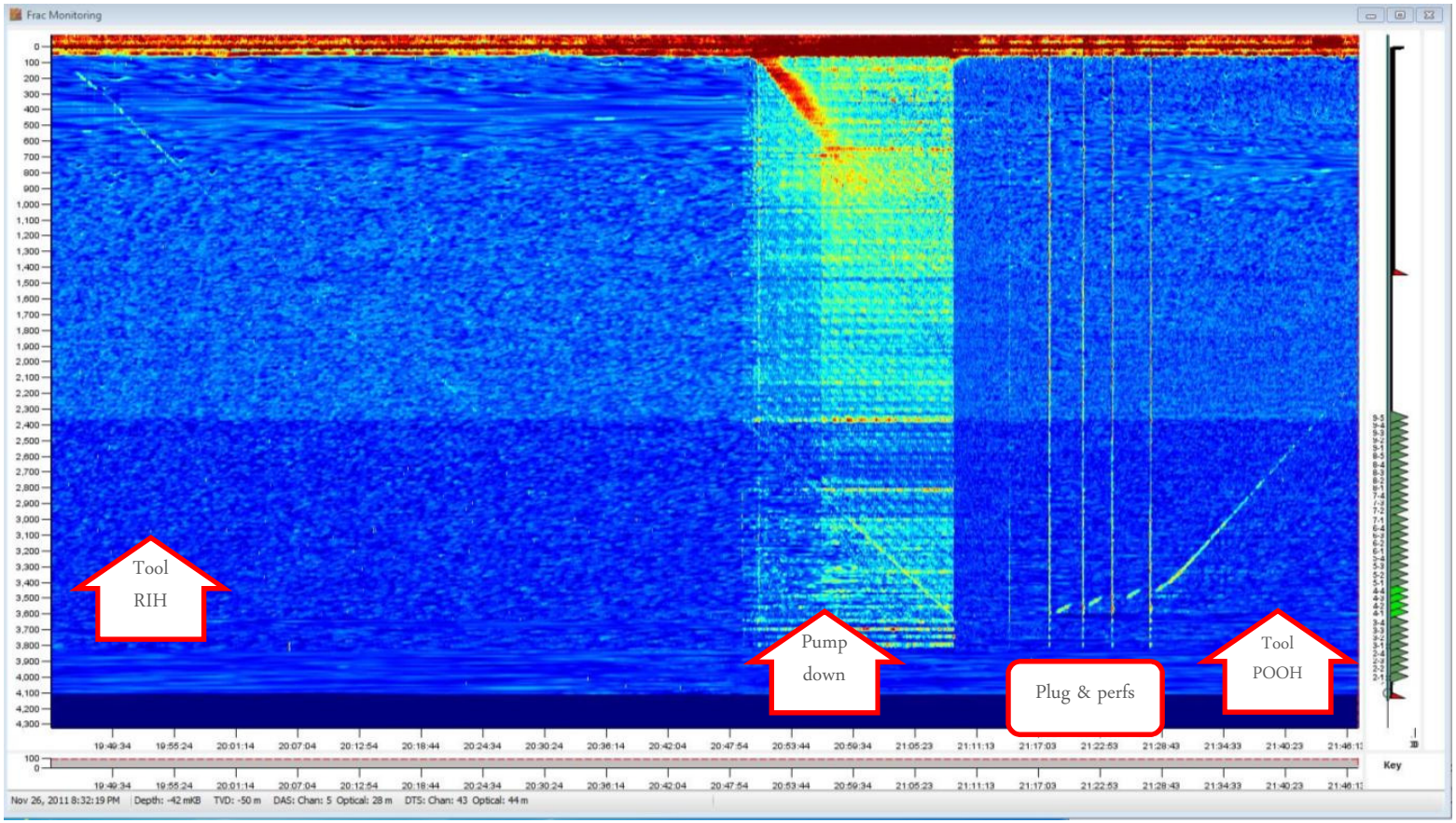
As a brief overview, DTS can be used to monitor cement curing, identify leaks, look at flow qualitatively, monitor fluid placement during frac and also monitor warm back to post frac.





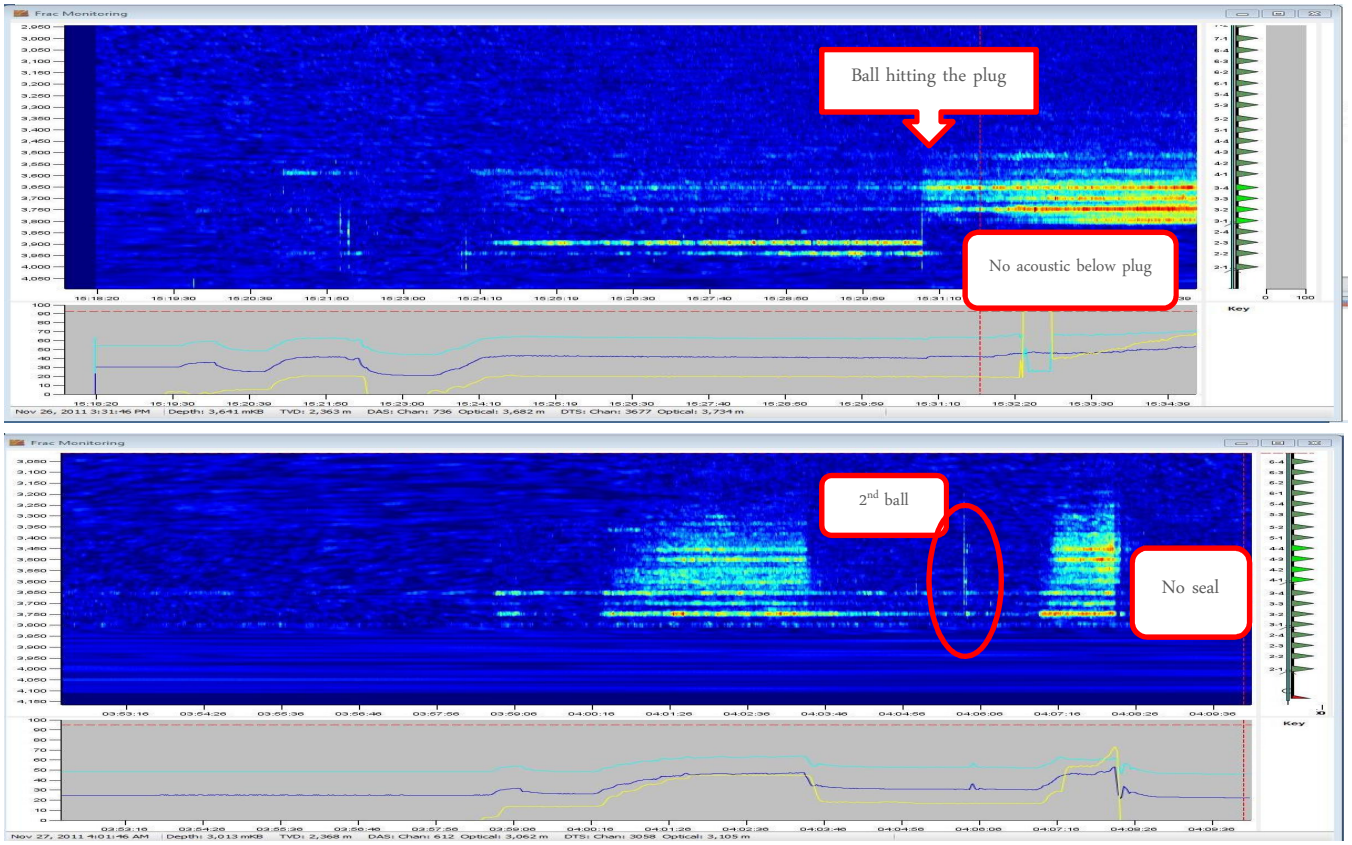
RESULTS AND INTERPRETATION

Before frac DAS monitoring can be, and is, used to actively monitor the stage perforation operation where tool running, plug setting and perforation.



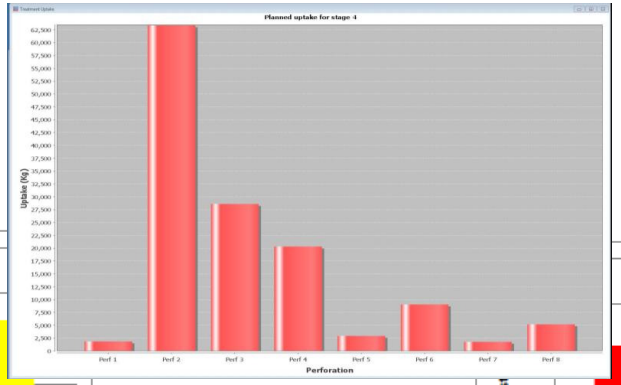
RESULTS AND INTERPRETATION

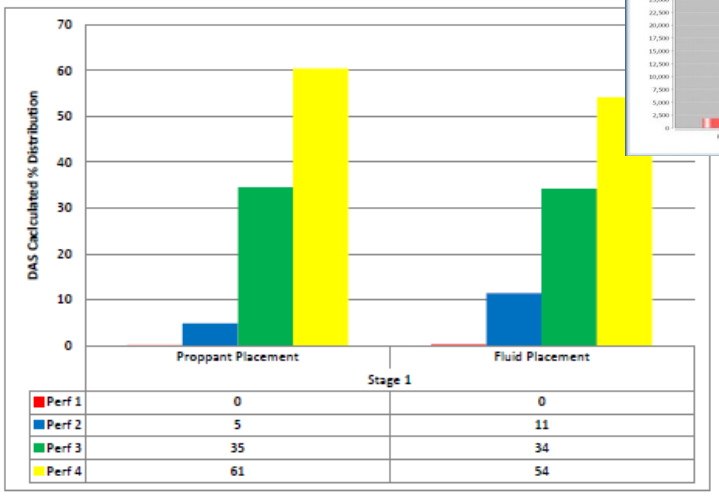
With P&P installations plug isolation is important and DAS, combined with DTS can indicate if a plug has sealed correctly or even if it is being displaced.



RESULTS AND INTERPRETATION

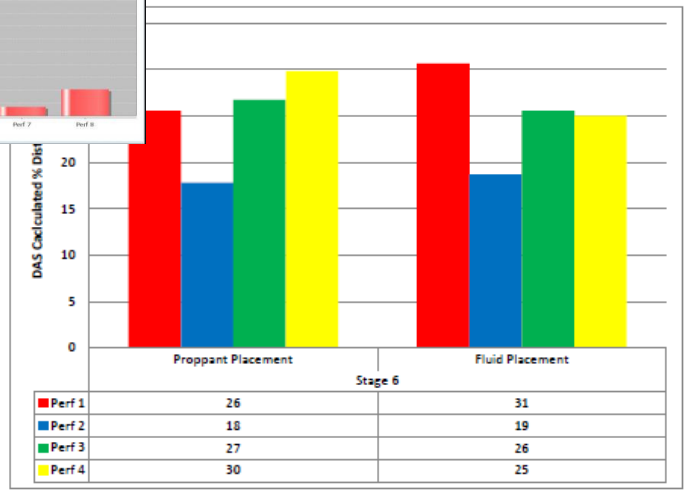
The greatest benefit however is in hydraulic frac monitoring because although we know how much sand is put away, this technology now allows a better indication of *where* the sand is going to a perforation cluster granularity. This is especially important in determining perforation efficiencies.





	Proppant Placement	Fluid Placement
Perf 1	0	0
Perf 2	5	11
Perf 3	35	34
Perf 4	61	54

Figure 1: DAS Calculated Placements – Stage 1



	Proppant Placement	Fluid Placement
Perf 1	26	31
Perf 2	18	19
Perf 3	27	26
Perf 4	30	25

Figure 1: DAS Calculated Placements – Stage 6

RESULTS AND INTERPRETATION

DAS and DTS provide real-time data during operations which can be used dynamically but it also provides the opportunity to improve operations for upcoming wells

- It can and has enabled Shell to optimise cluster spacing, stage spacing and wellbore spacing.
- It can identify where potential diverters can be used in known formation geometries
- It can help in any planned re-frac operations

WAY FORWARD

Already DTS/DAS is providing:

- Cement curing profiles
- Casing integrity
- Tool deployment monitoring
- Full wellbore monitoring
- Plug isolation
- Flow diversion
- Real-time proppant placement
- Cooling and warm back data
- VSP data
- Cross-well communication monitoring

Additionally; in Groundbirch Shell has:

- been successfully monitoring flow at individual perforation level continuously for over a year.
- implemented perforation/stage data gathered on this well to modify perforation methodologies in a subsequent well in the same asset

WAY FORWARD

Although fibre reliability is increasing it is still perceived as high risk and costly. With that in mind Shell is leading the way to remove the fibre from a specialist category to a commodity category with the aim of reducing the installation cost to be competitive with micro-seismic installations and PLTs.

Shell has already:

- Reduced drilling and completions costs by over 50% in the last two years by better project management and careful design of mechanical hardware
- Has plans to further reduce the installation costs by another 50% over the next few years

This will make fibre more accessibly and the data more valuable but the technology is also developing ...

WAY FORWARD

DAS technology continues to find applications. What was once a specialized technology is finding outlets in all types of applications. Applications likely to become available in the near future are:

- Higher resolution devices of ~ 1m of better
- Better signal to noise ratio Micro-Seismic systems to compete with traditional geo-phones

This will result in the ability to have a permanent high resolution micro-seismic system and the ability to perform PLTs on a regular basis without the need for intervention, delayed production and value hysteresis/distortion

In terms of application, DAS is already being deployed off-shore and will eventually be installed sub-sea, where even small improvements in production efficiency has a large impact on profitability

MORE INFORMATION

If you need more specific information on system design, installation and completion, feel free to contact either myself or Alan Reynolds – Project Execution Manager:

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