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Development and Field Application of a Permanent Fiberoptic Wellbore Fluid Level Monitoring System

Chris Staveley, Smart Fibres Ltd., United Kingdom

PRESENTATION AGENDA

The Challenge:	- Production Optimization of Fractured Carbonate Reservoirs
Current Methodology:	- Periodic Wireline Gradio Surveys - Drawbacks with Current Methodology
New Methodology:	- Fiber Bragg Gratings (FBGs) - Distributed Pressure and Temperature Sensing (DPTS) with FBGs - Production Optimization using DPTS
Results:	- Field Data - Derived Value from Field Data

Current Status and Future Developments

THE CHALLENGE: FRACTURED CARBONATE RESERVOIRS

Typical Situation Faced by Petroleum Development Oman

- Very large reservoirs, multiple wells
- Thin oil rim with gas cap above and aquifer below
- Oil rim must align with the perforations in producing wells

But

- Oil is very mobile in carbonates – fractured / high permeability
- Leads to a dynamic oil rim

The Solution: **Production Optimization**

- Track the oil rim position across the reservoir
- Select which wells to produce and when
- Inject water or gas to control the oil rim position

So how to track the oil rim position?

PRODUCTION OPTIMIZATION: CURRENT METHODOLOGY

Measure fluid levels in well bores

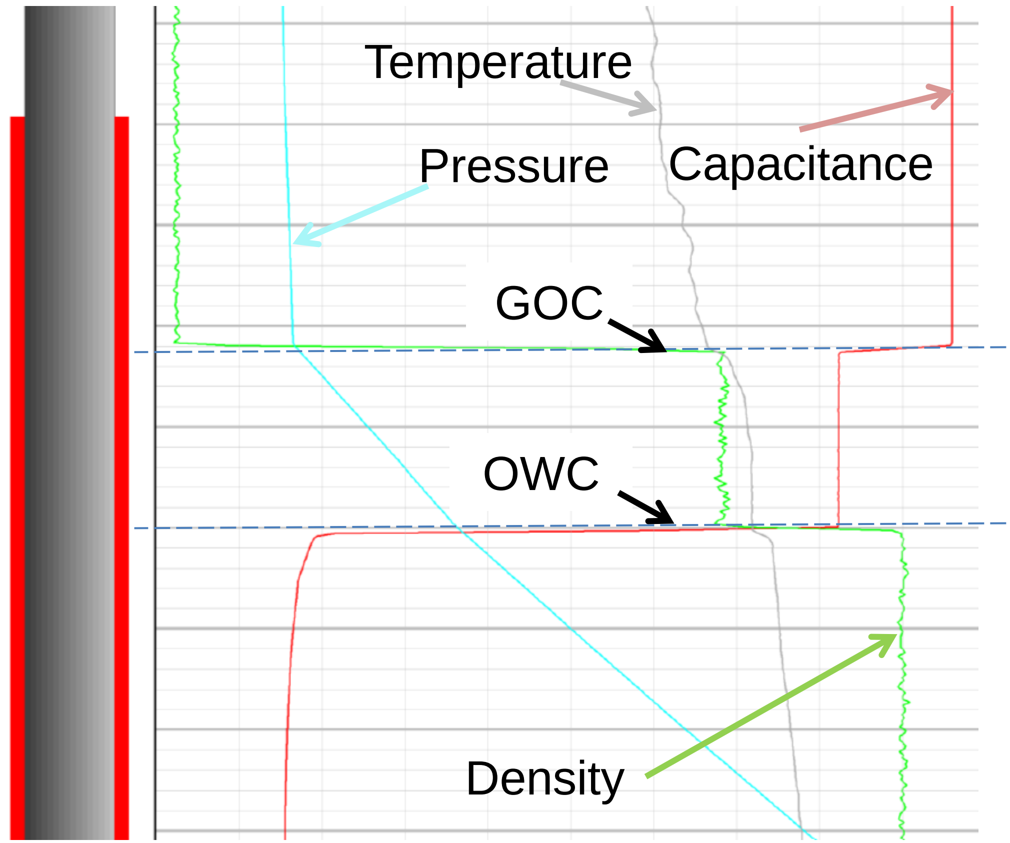
- Indicative of levels in the reservoir if perforated well casing and fractured, permeable formation

Use a Wireline Gradio Survey

- Multiple measurand (P, T, *C*, ρ) tool lowered into well

Sounds good – is it Effective ?

- Sometimes not…



Example Gas - Oil - Water Interface

WIRELINE GRADIO SURVEY: DRAWBACKS

Data not real time

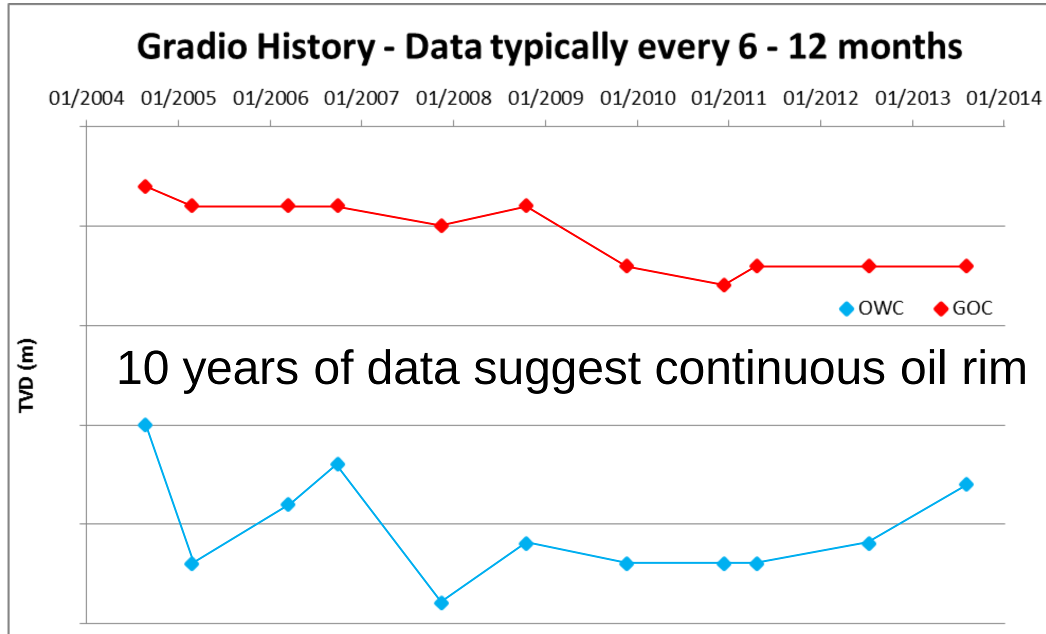
- True dynamic information missed…

Data accuracy questionable

- Differences between repeated gradio runs "orders of magnitude greater than the interpretation required" [1]

HSE Risks Involved

- Each survey requires a manned well intervention



[1] Shanks, David. April 2016. Digital Oilfield Monitoring Artificial Lift. SPE Webinar.

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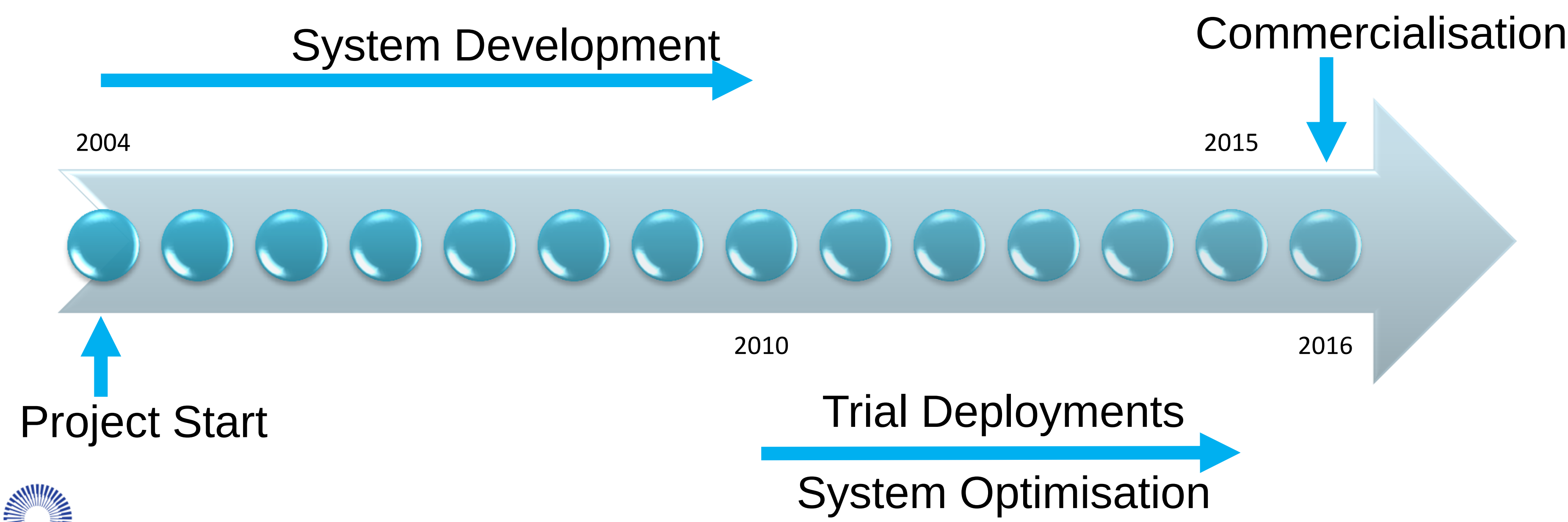
NEW METHODOLOGY: DISTRIBUTED PRESSURE SENSING WITH FIBER BRAGG GRATINGS

- A collaborative development project:
  - Shell Global Solutions – Project Initiators and Sponsor
  - Smart Fibres – Solution Developers
  - Petroleum Development Oman – Field trial hosts and first end user

- Project Timeline:



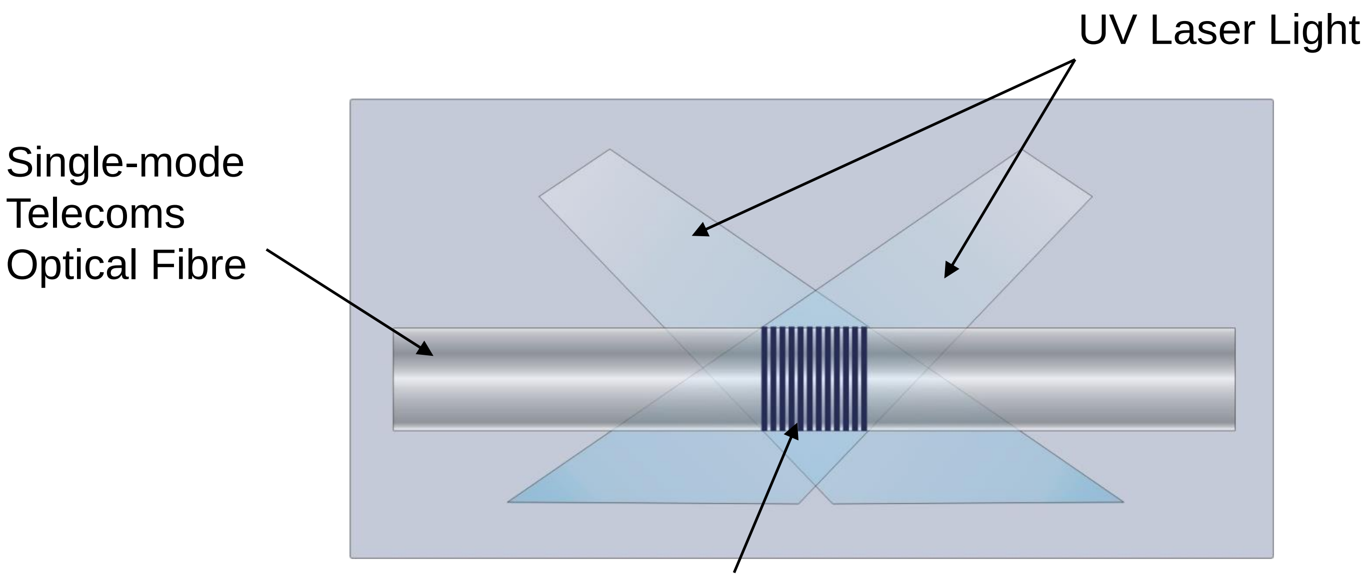
FIBER BRAGG GRATINGS

- A Fiberoptic Sensor
- Recorded with UV laser light – changes core refractive index
- Unique Bragg wavelength λ_B reflected according to the equation

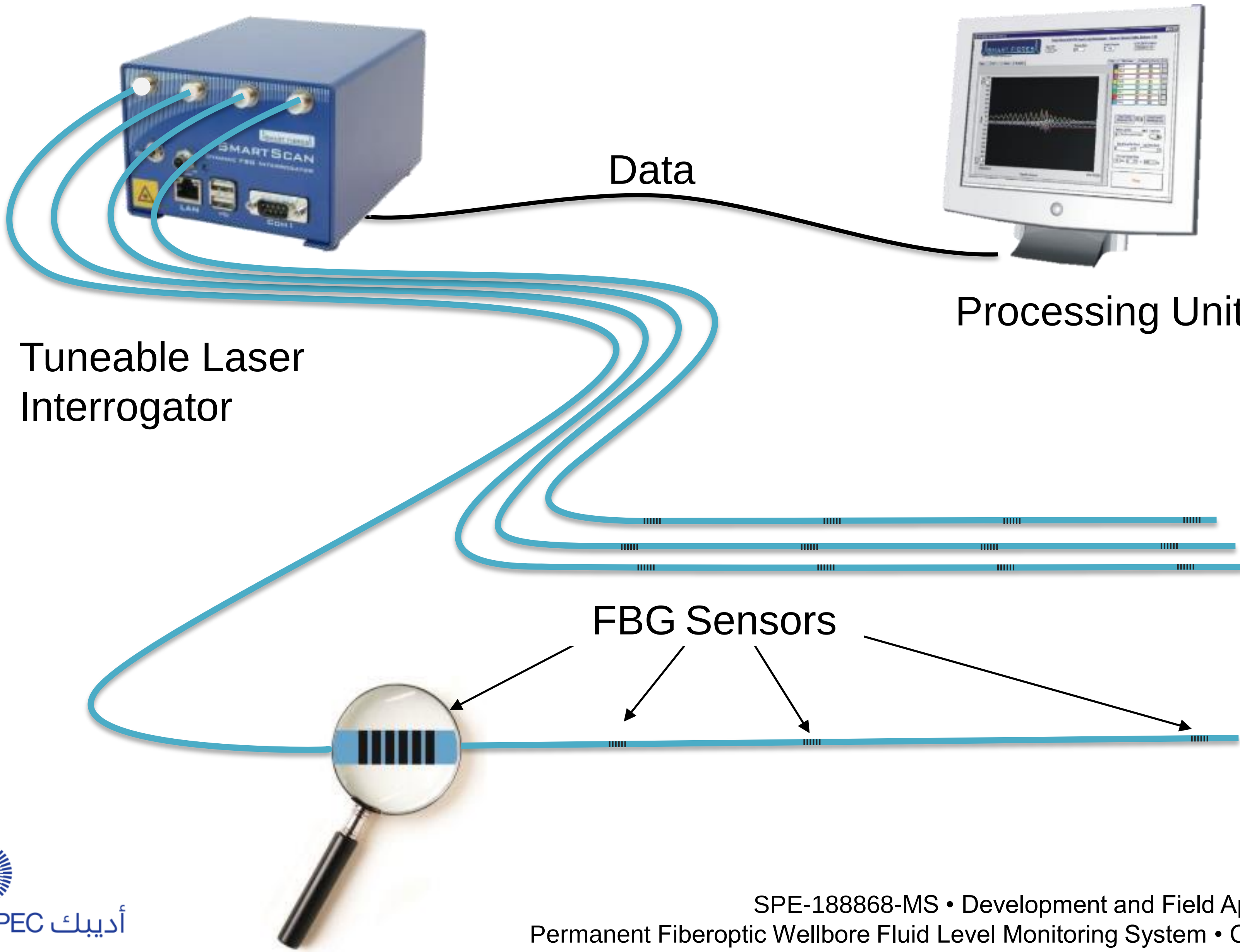
$$\Delta\lambda_B = \lambda_B(1-\rho_\alpha)\Delta\varepsilon + \lambda_B(\alpha+\xi)\Delta T$$

Bragg Wavelength Change   Strain Change   Temperature Change

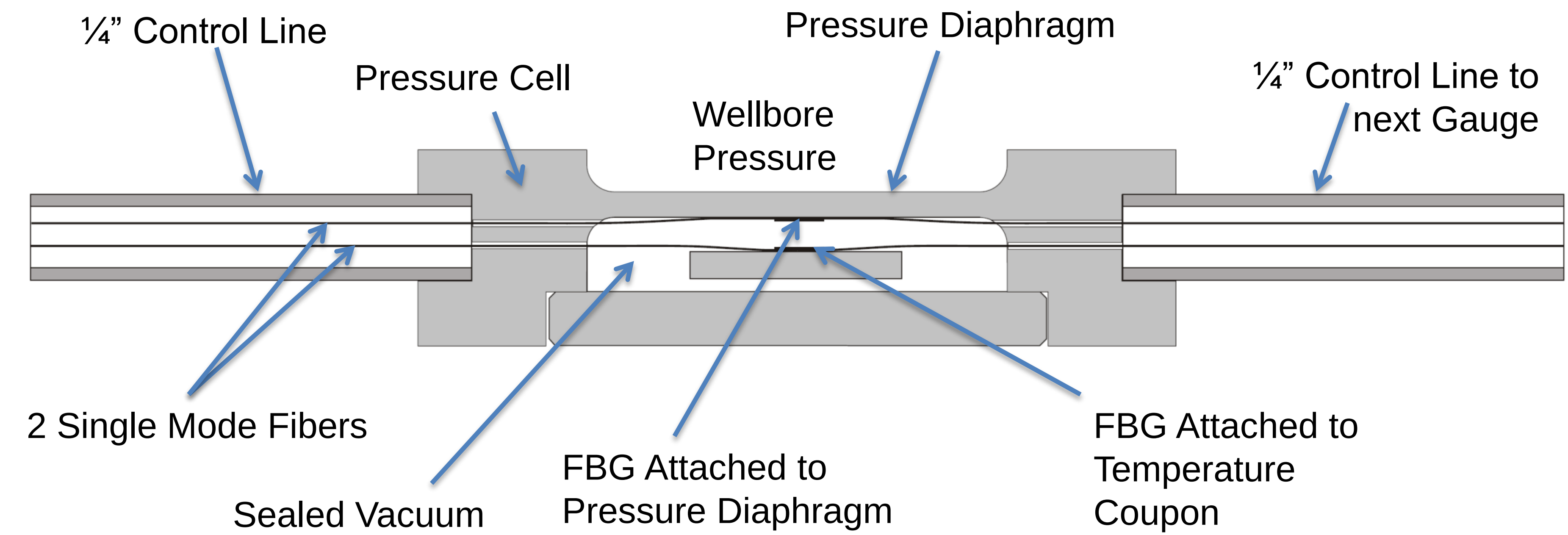
- Bragg wavelength Varies with strain and temperature

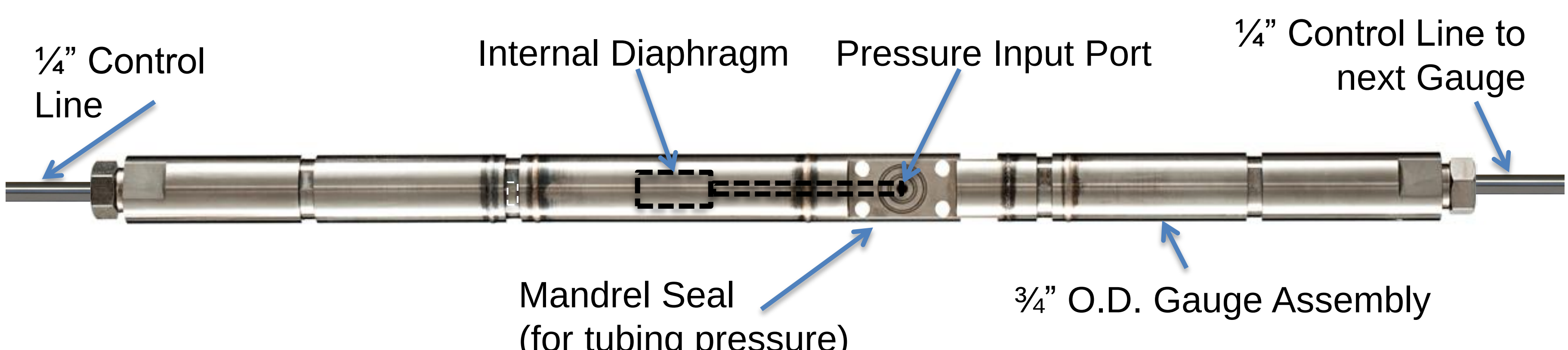


FIBER BRAGG GRATING SENSING SYSTEM ARCHITECTURE

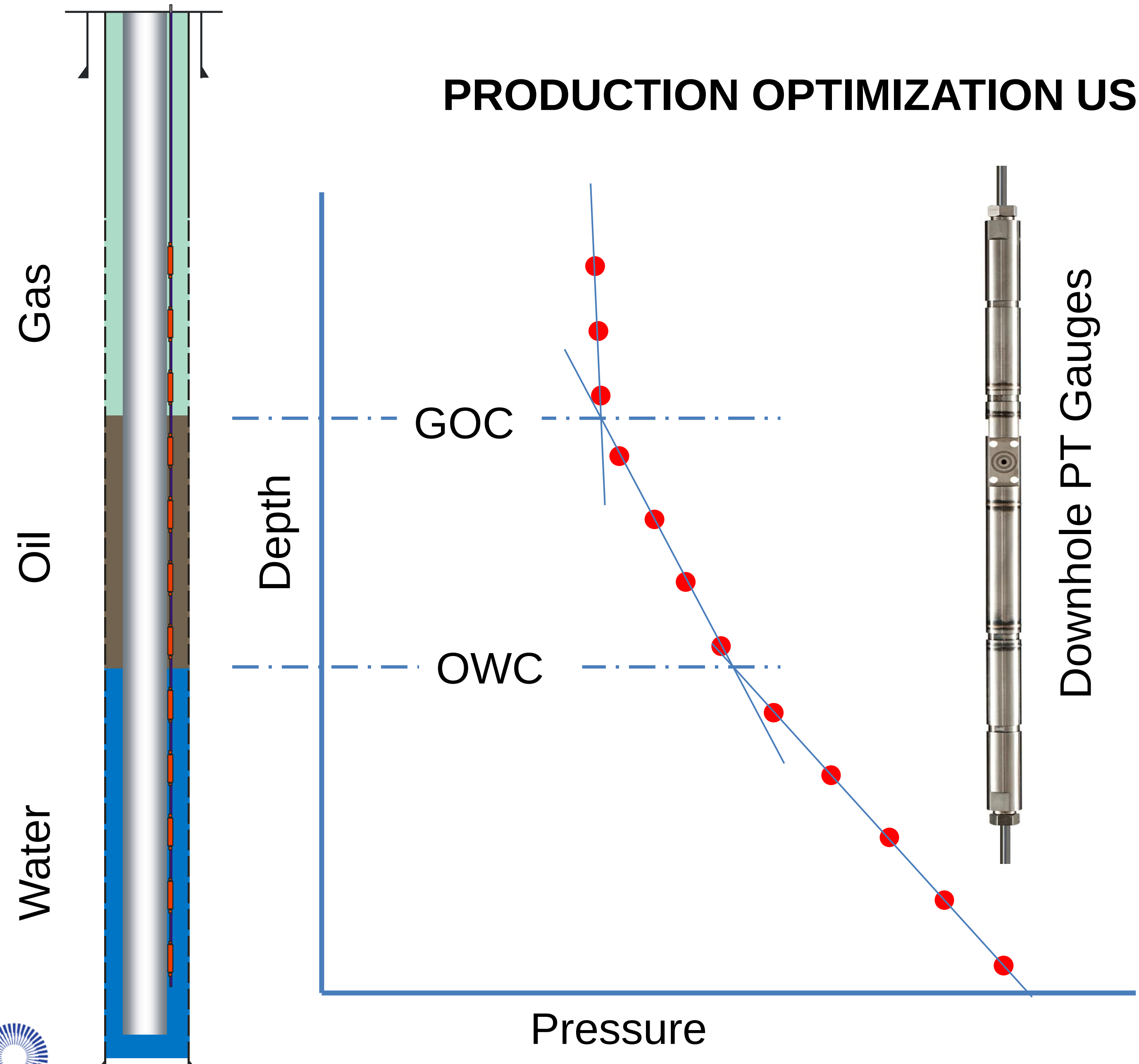


PRESSURE / TEMPERATURE SENSING WITH FBGS





PRODUCTION OPTIMIZATION USING DPTS

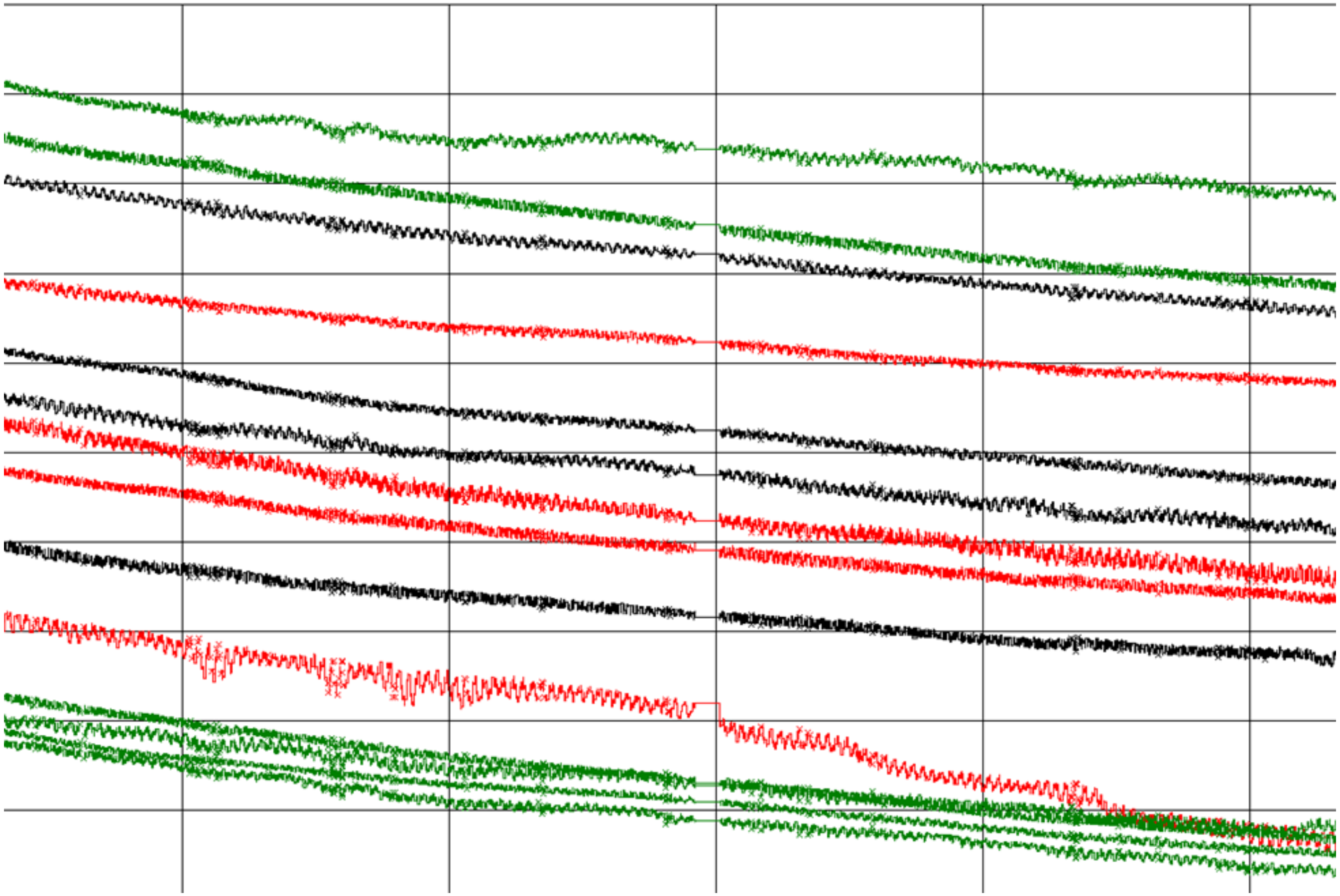


Pole Mounted
Surface Instrument

DPTS SPOOLED DEPLOYMENT METHOD

1. Tested DPTS gauge array delivered to well site
2. Gauge array run over large diameter sheave
3. Gauges fixed to tubing string with steel clamps
4. Solar Powered Surface instrumentation radios P/T data to PDO server
5. Software on PDO server calculates fluid interfaces

DPTS PRESSURE FIELD DATA

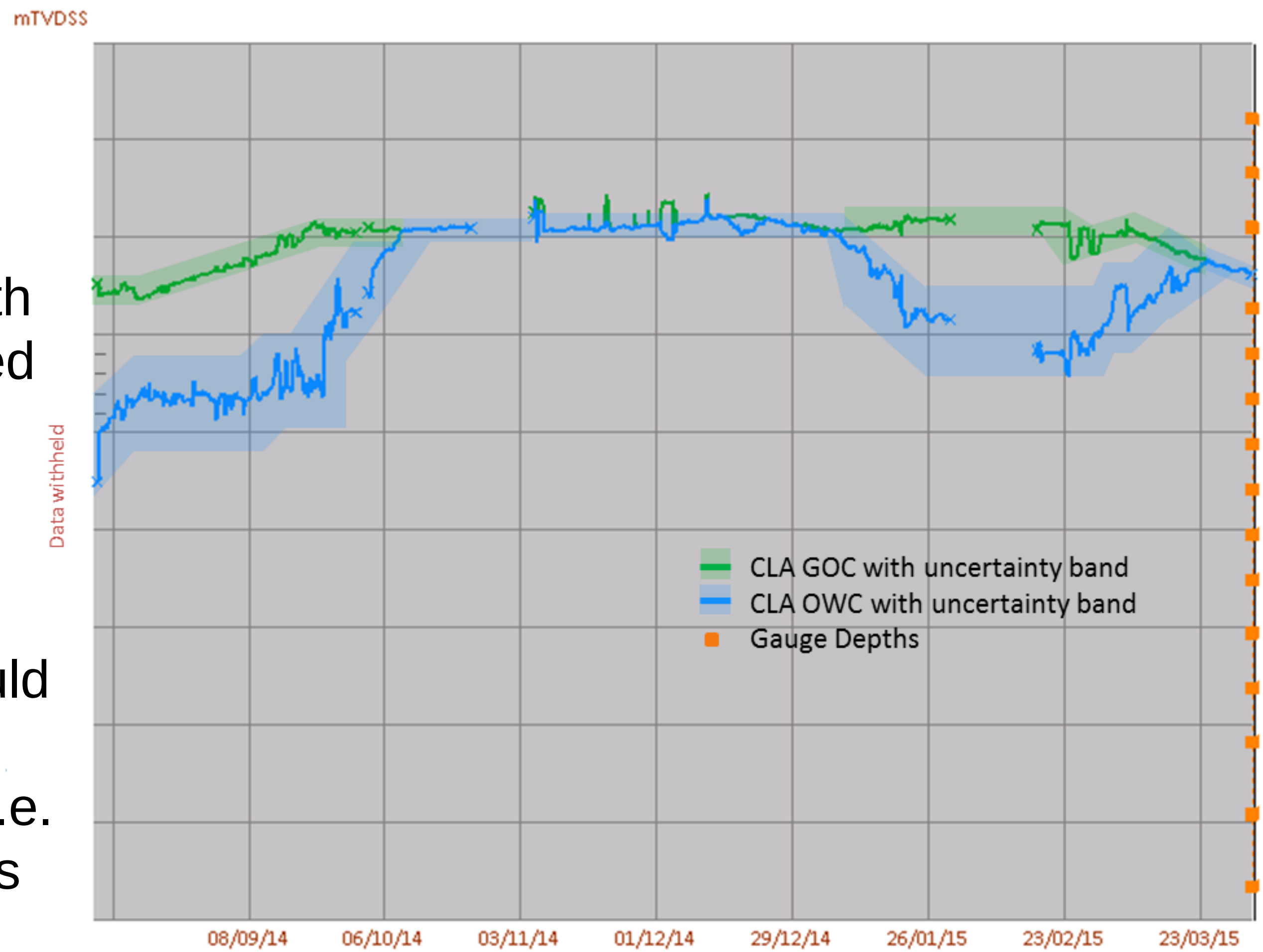


- Showing pressure reported from 14 deployed gauges over 5 months
- Very stable data (dP in gas phase ~1kPa = 0.15psi)
- Relative gauge movement correlates with reported change of phase

DPTS FLUID CONTACTS FIELD DATA

Field Data from PDO Carbonate Reservoir, 2014/15

- Result from well with 15 Gauges deployed
- 6 months of data shown
- Oil rim disappears twice
- Gradio method would give 1 datapoint in this time window - i.e. it completely misses this behaviour



PRODUCTION OPTIMIZATION USING DPTS: DERIVED VALUE

Improved Reservoir Understanding

- Gradio survey policy inconclusive. Real-time monitoring required

Production Improvement

- More than 100 m^3/d production increase estimated

Avoid Production Deferment

- *e.g.* prior loss of oil rim led to production loss of ~500 m^3/d for 6 months

OpEx Reduction

- One time cost of permanent DPTS system vs. repeated gradio survey costs

HSE Risk Reduction

- 1 well intervention for DPTS vs. repeated gradio survey interventions

System Expansion Capability

- DPTS fibre could also be used for DAS, VSP or DTS

CURRENT STATUS AND FUTURE DEVELOPMENTS

Current Status

- Numerous DPTS deployments with PDO for fluid contact monitoring in sweet and sour service fields
- Further DPTS deployments with other operators for other applications, both annular and tubing pressure measurements

Future Developments

- Increased gauge operating temperature from 400^{o}F / 204^{o}C to 600^{o}F / 316^{o}C service (for thermal recovery wells)
- Reduced gauge diameter from ¾” to ~¼” (for space critical applications)
- Integration of Quasi-Distributed Acoustic sensing (QDAS) between gauges

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