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Digitizing Wellbore with Permanent Reservoir Monitoring and Flow Control : Is there a value ?

Varma Gottumukkala
Schlumberger

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Outline

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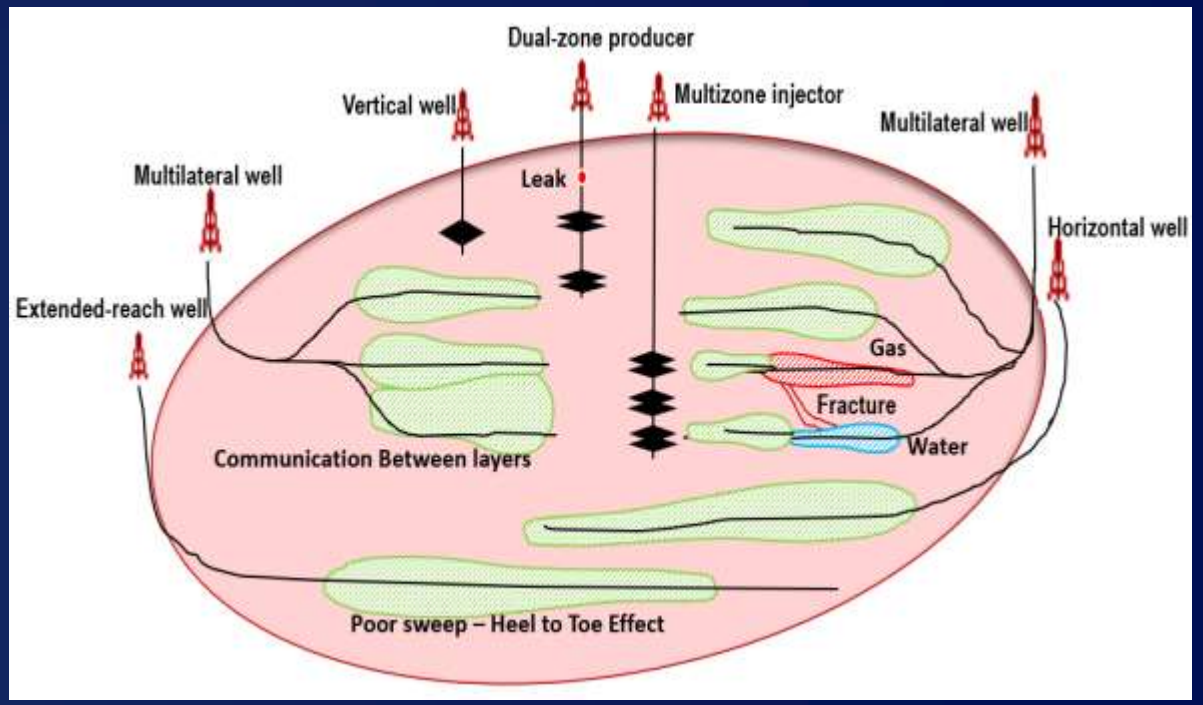
- Well production challenges
- Digital well completion
- Technologies – Monitoring, Flow Control, Digital Solutions
- Case studies
- Conclusions

Well Production Challenges

Drilling a well to target depth does not guarantee maximum oil production. Challenges include

- early gas/water breakthrough
- poor drainage/sweep
- well integrity failures (leaks)
- lack of downhole data
- need for intervention

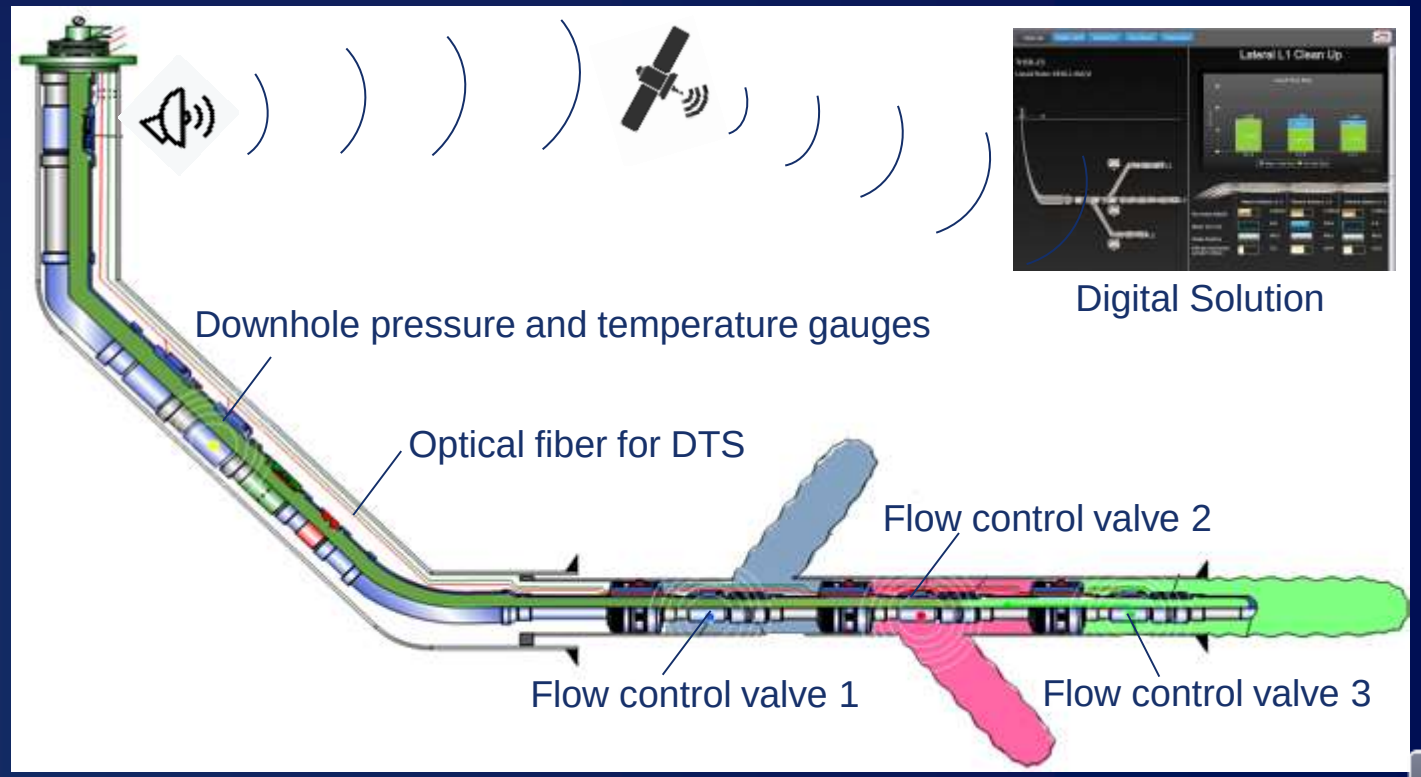
Well Types and Challenges



Digital Well Completion

Instrumenting a well with permanent monitoring and flow control valves to continuously measure pressure(P), temperature(T), flow rate(Q), fluid phases combined with digital solutions enables

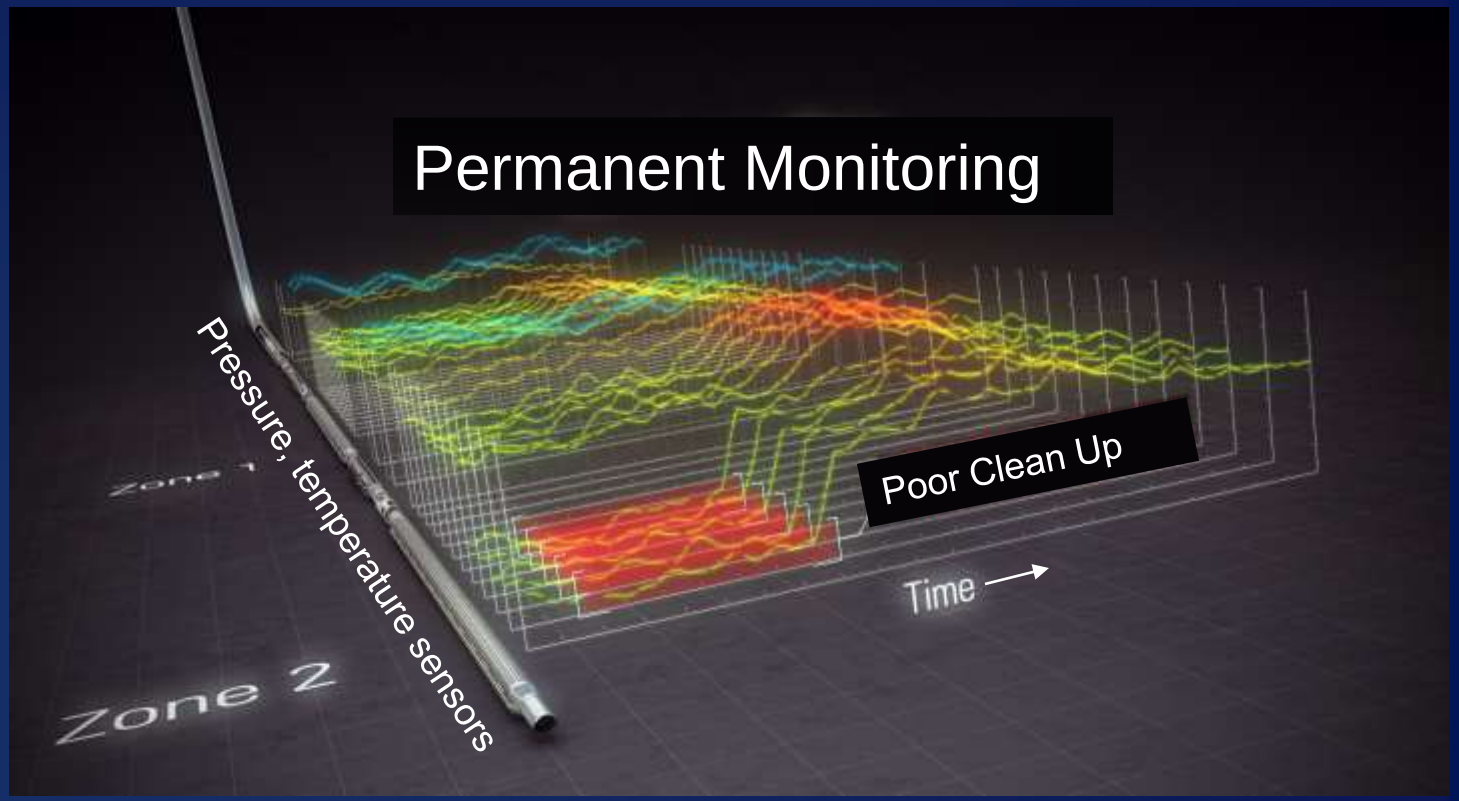
- production optimization
- reservoir management
- integrity monitoring
- well surveillance
- fewer interventions



Permanent Monitoring

What Is Permanent Monitoring?

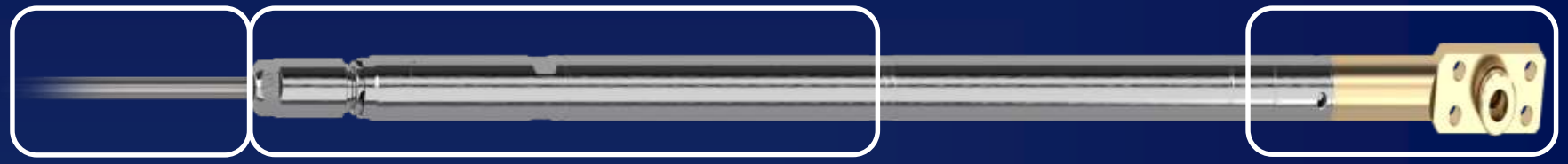
Continuous acquisition of downhole P, T, and other data across reservoir zones—at a single or multiple depths—over the life of the well



Downhole Gauges

Measurements: Pressure, Temperature

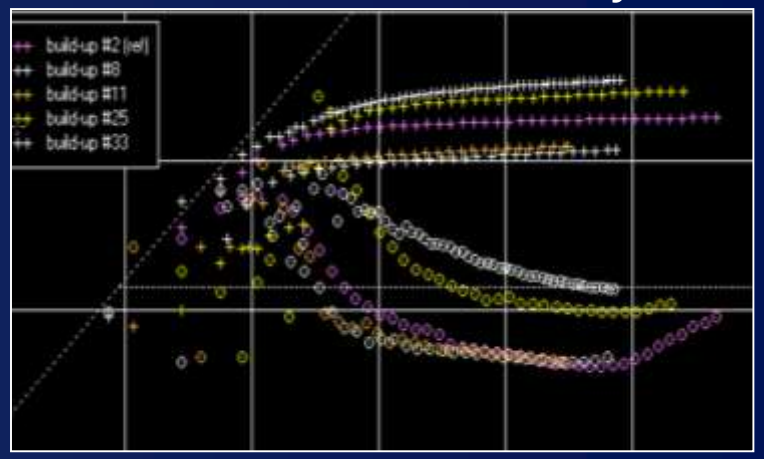
Deployment: Single point or multipoint, electric line



Applications

- Reservoir surveillance
- Permeability, skin, and drainage radius monitoring

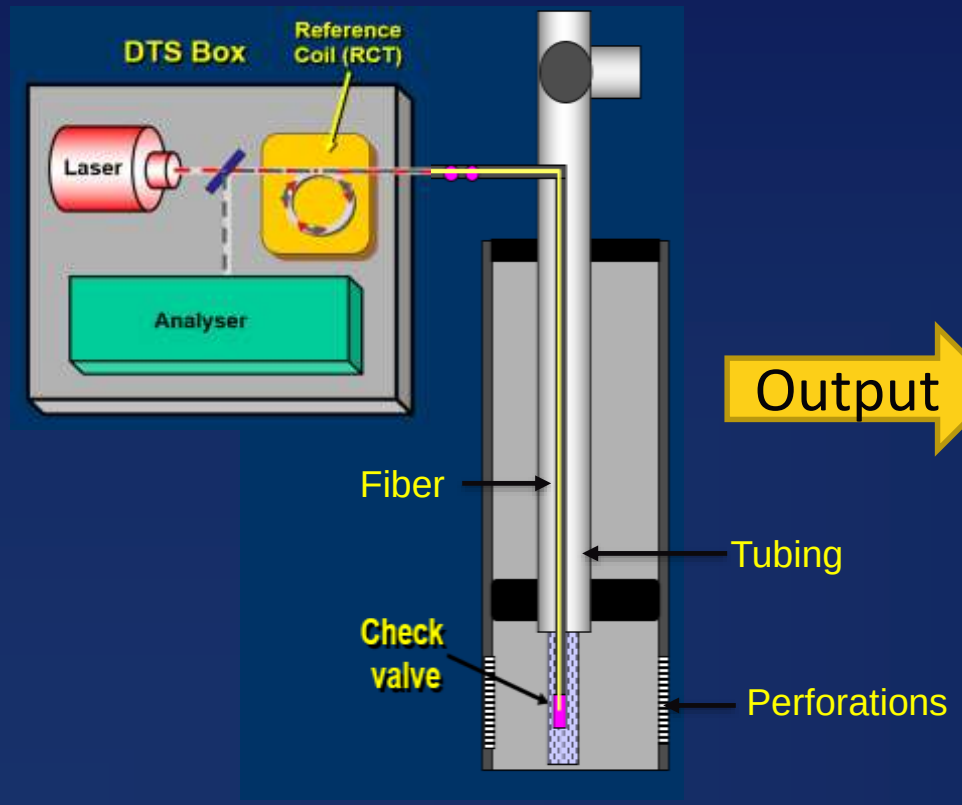
Pressure Transient Analysis



Optical Fiber

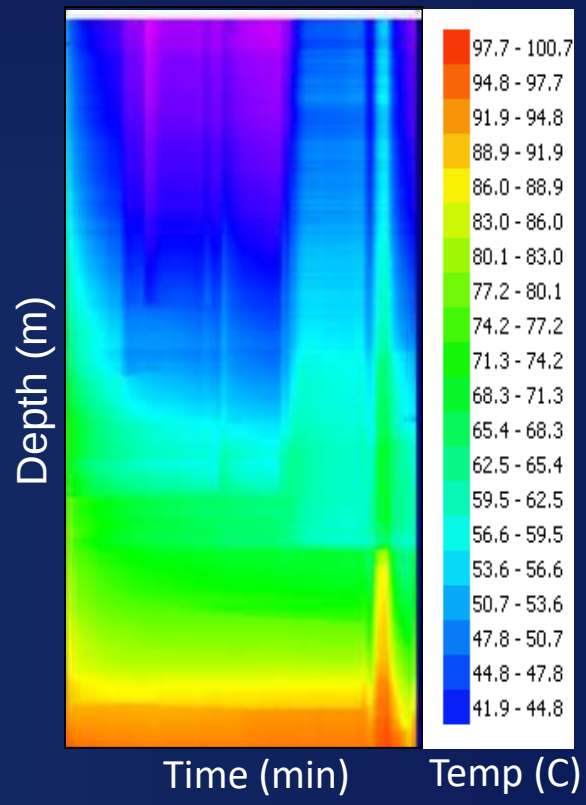
Measurements: Distributed temperature and acoustics

Deployment: Clamped to tubing, casing, or pipeline

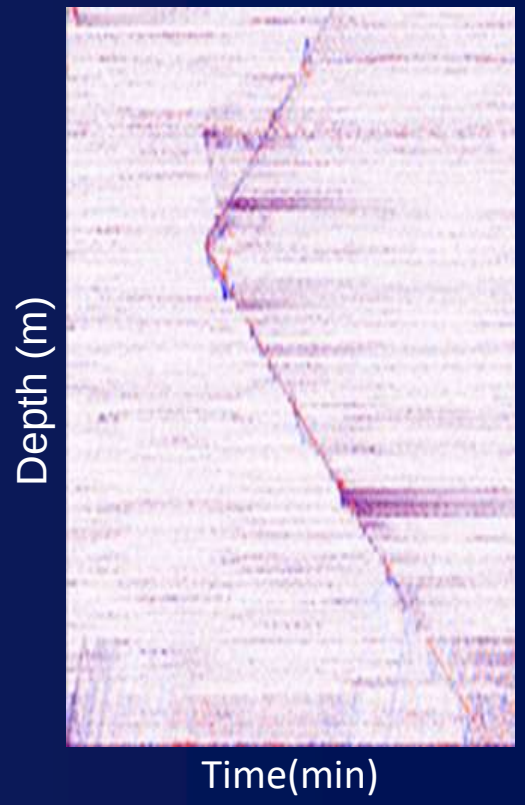


Output

Distributed Temperature Sensing (DTS)



Distributed Acoustic Sensing (DAS)



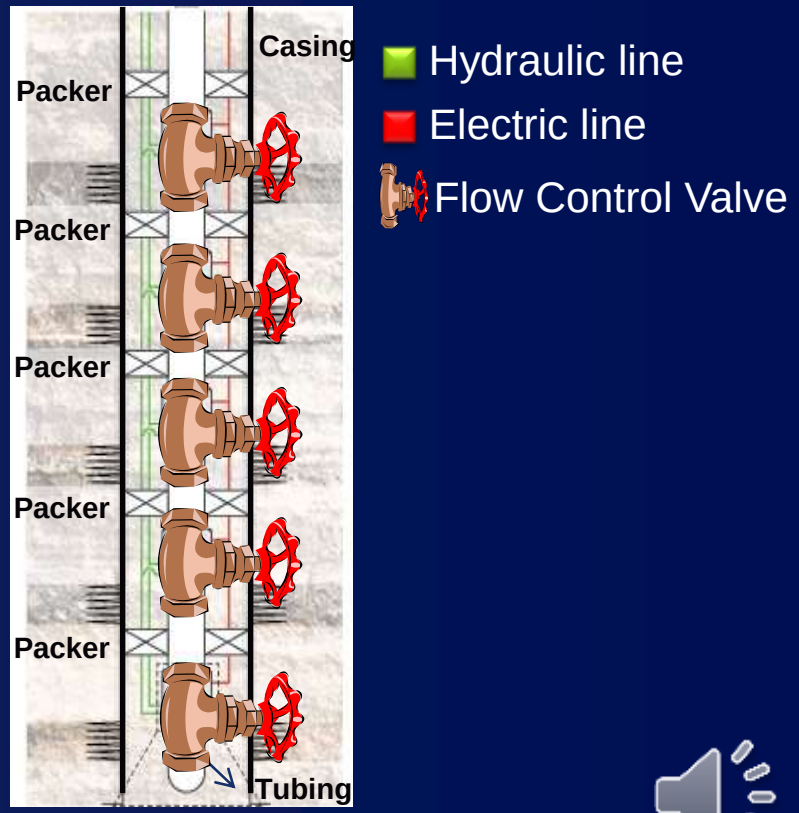
Flow Control

Flow Control Valves (FCVs)

Downhole control of reservoir inflow across single or multiple zones, with various options for chokes (e.g., on-off , 10-position, infinitely variable)

Deployment

- production tubing
- control lines to adjust choke positions
- remote actuation



Five-zone well with FCVs.

Types of FCVs

Hydraulic

- Valves actuated by <u>multiple</u> hydraulic control lines from surface

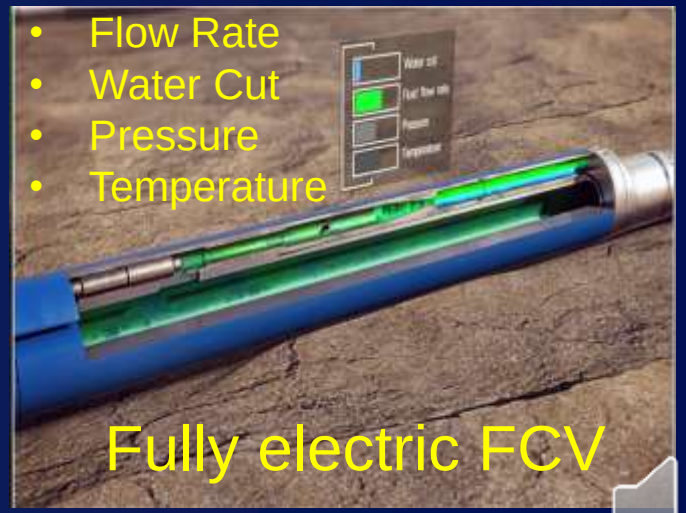
Electrohydraulic

- Valves actuated by <u>one</u> electric and <u>two</u> hydraulic control lines from surface

Fully electric

- Valves actuated by <u>one</u> electric line from surface

Electrohydraulic FCV



Digital Completion Deployment

Single Trip

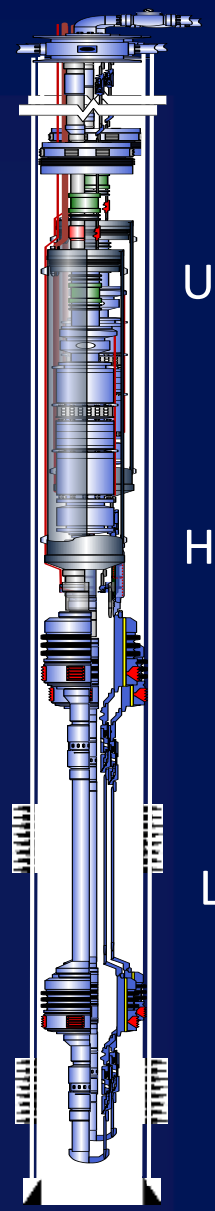
- Single/Multizone in one go

Multi Trip

- Run In Hole lower completion
- Sting in with upper completion
- Hydraulic and Electric Wet Mate

In- Lateral

- Deploy smart completions inside lateral

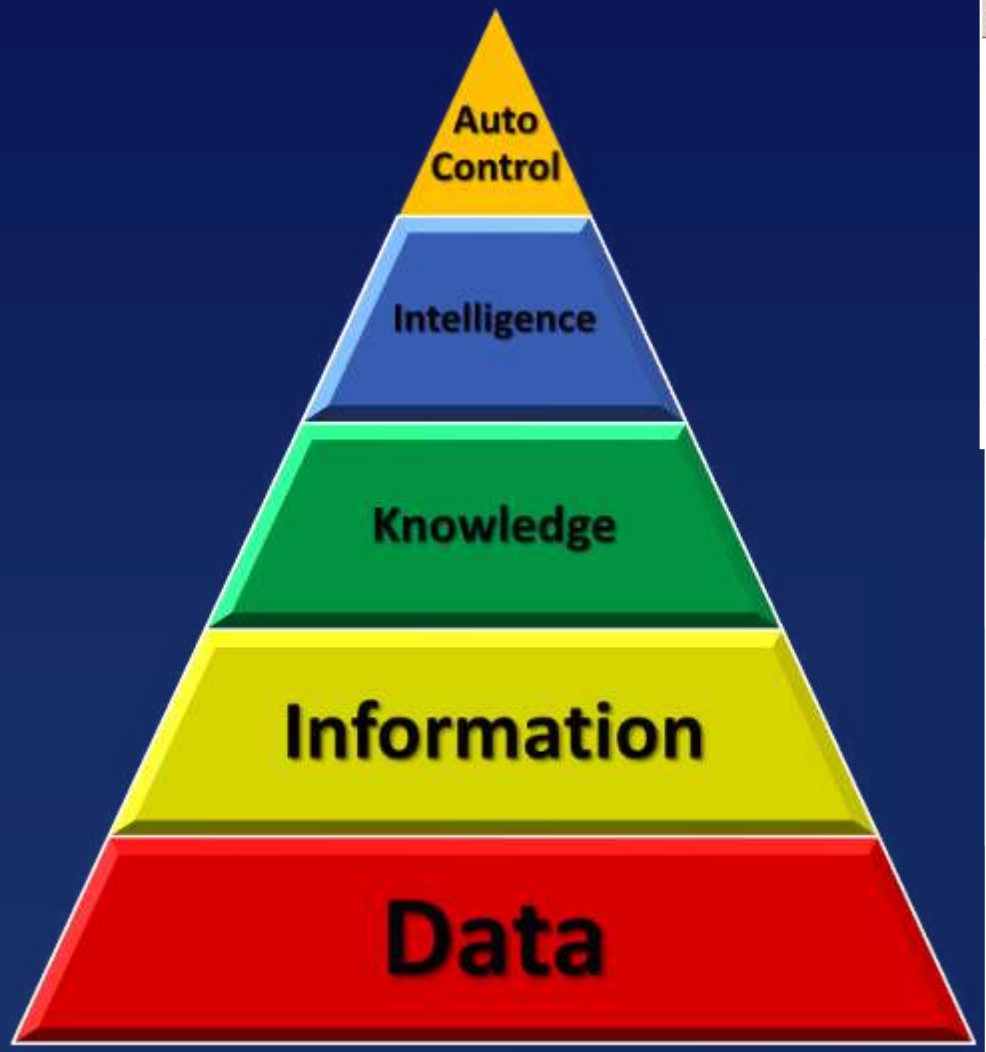


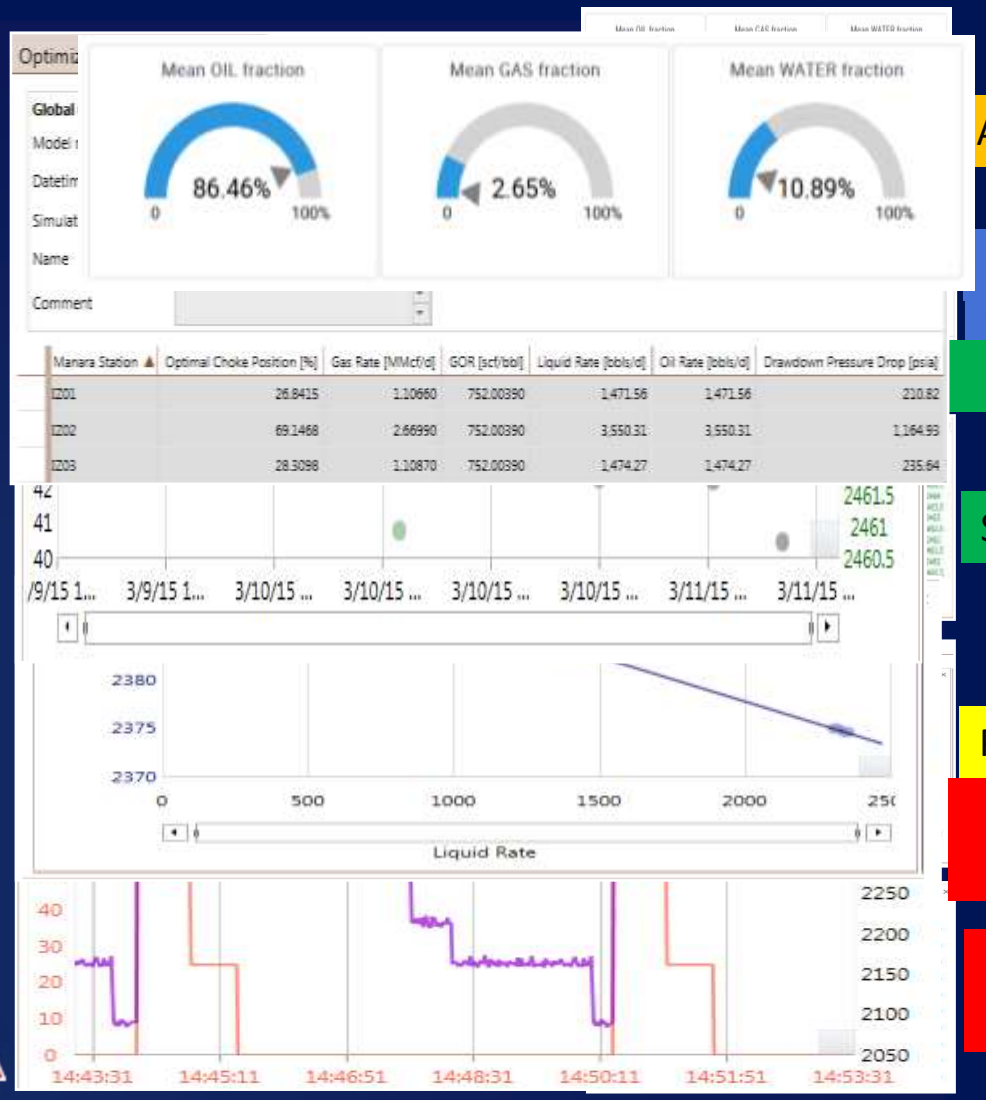
Upper Completion Stinger

Hydraulic/Electronics Communication

Lower Completion Receptacle

Digital Solution – Flow Control Valves





Auto control

Auto control

Optimal valve position

Optimal valve position

Skin; pressure depletion

Productivity index;
Reservoir pressure

Productivity index;

Flow Rate Estimate;
Pannulus, Ptubing, Area

Flow Rate Estimate;
Pannulus, Ptubing, Area

Reference : SPE 185513, 176648,186223

Digital Solution – Fiber Optics

Raw Data

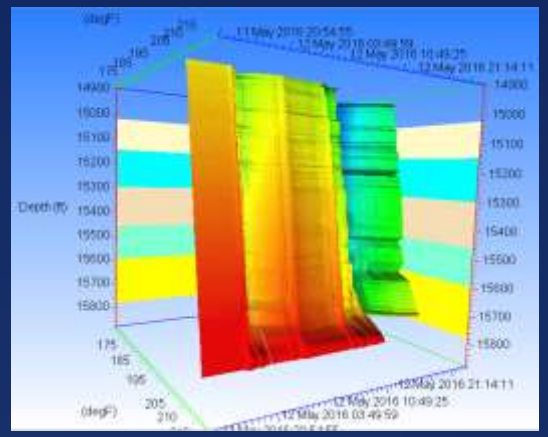
- Fiber optic data (DTS, hDVS)
  - Permanent installation
  - Coiled Tubing
  - Slickline

Forward well model

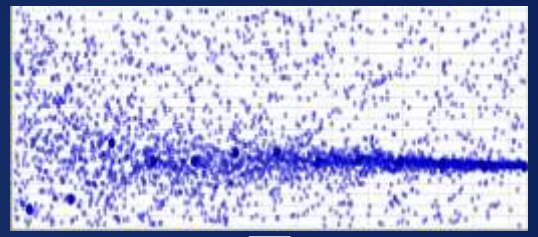
- Borehole (survey, completion)
- Reservoir model
- Transient Data Input(P,Q,T)

Data process & visualization

- Conditioning, editing and display

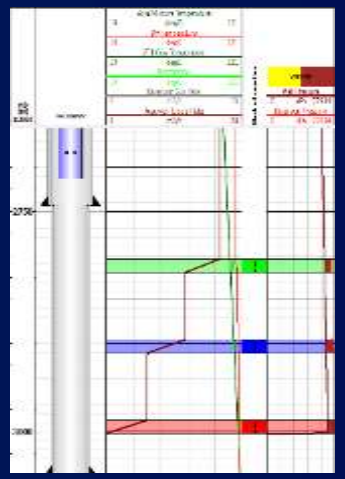


Compare & Optimize



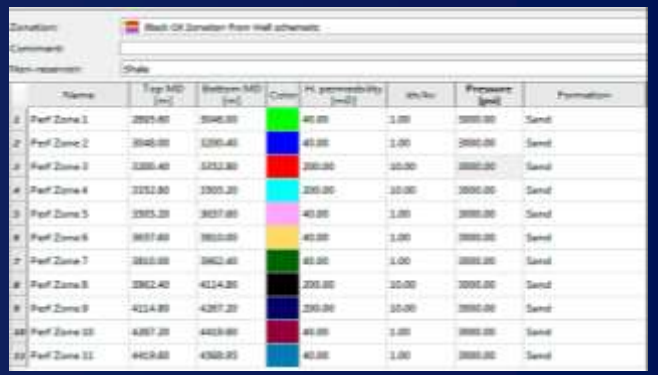
Interpretation

- Fluid breakthroughs
- Leak Identification
- Flow Profiling (PLT Log)



Results

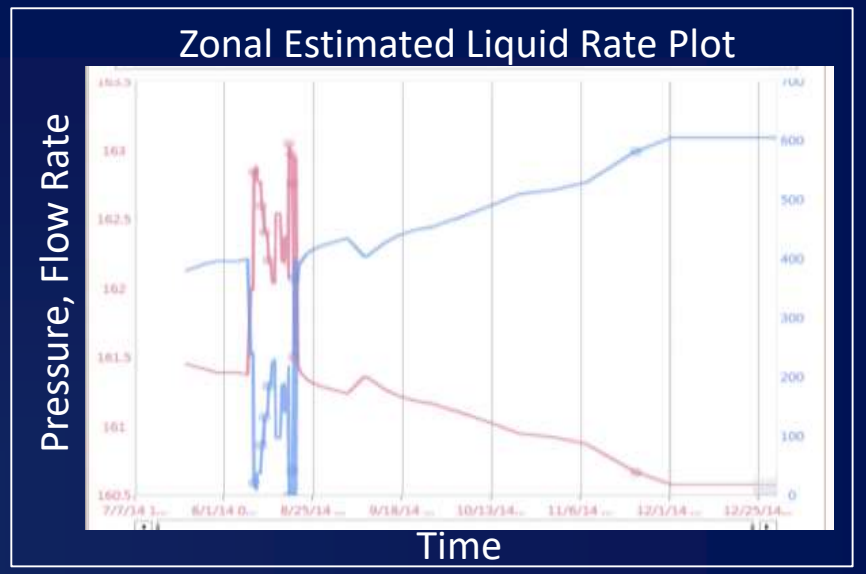
- Permeability & Skin
- Water Cut, GOR, Drainage Radius

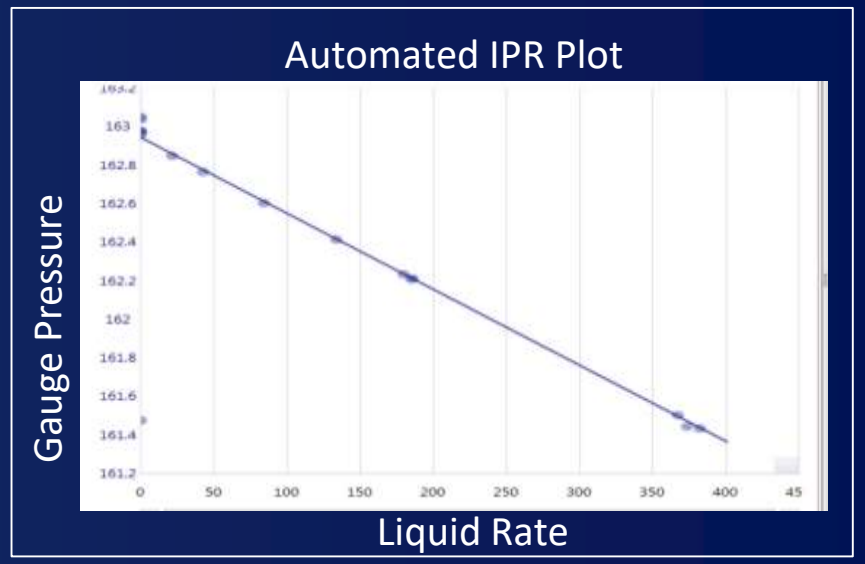


Case Studies

Vertical Well—Two-Zone

- Well completion
  - Commingled production : 2 zones
  - FCVs, PT gauges, ESP
- Back allocation
  - Estimate Q : Delta P across FCVs
- Production surveillance
  - Real-time IPR : zone
  - Water cut using dual gauges
- Production management
  - FCV position optimization : 15% production improvement

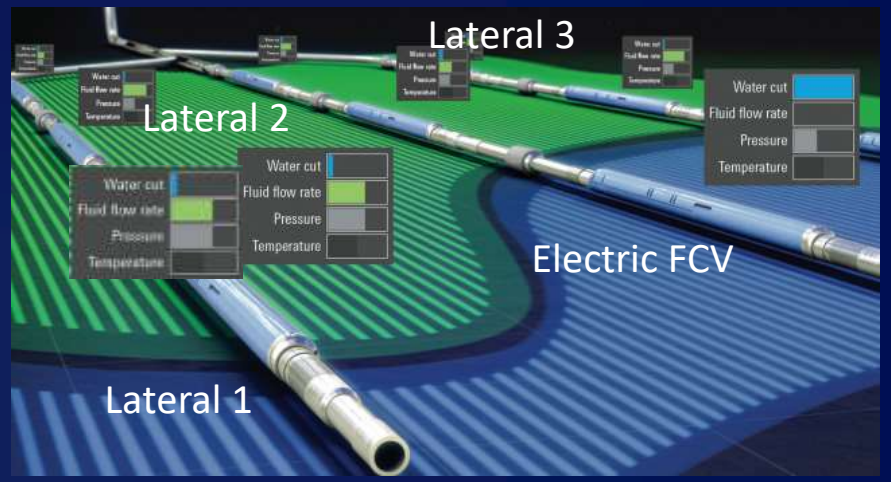




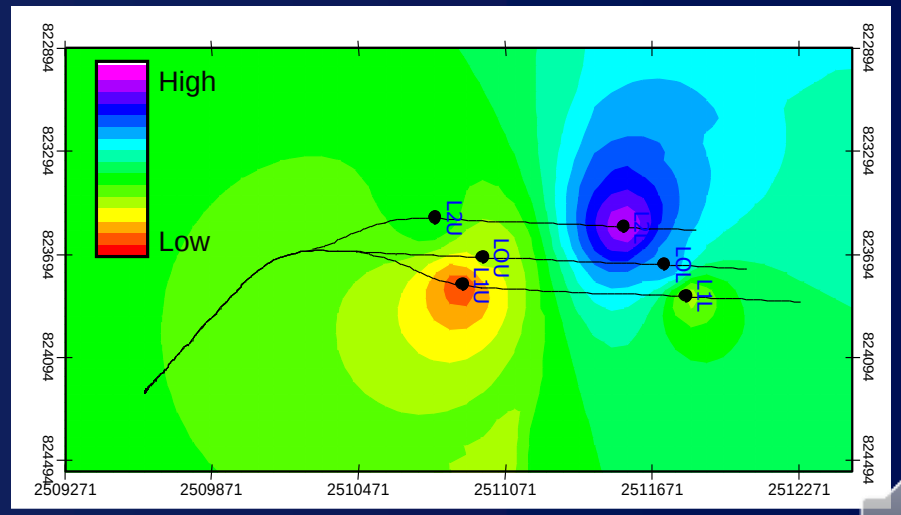
Reference : SPE 185513

Multilateral Well

- Well completion
  - Trilateral well: 30,000-ft contact
  - Six electric FCVs, two per lateral, multitrip
- Permanent measurements
  - P, T, water cut, downhole flow rate
- Reservoir surveillance
  - Uneven sweep and drainage
- Production management
  - FCV optimization : enable production from tight zones



Well Completion

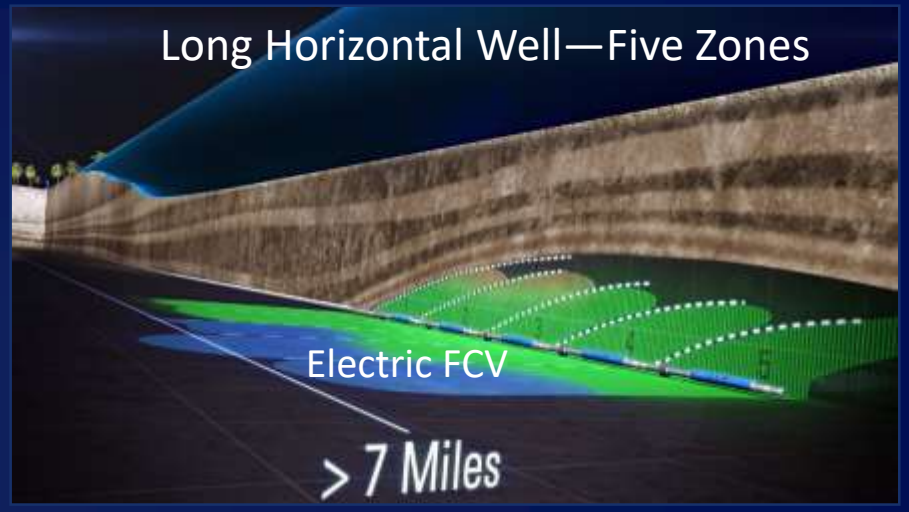


Reservoir pressure map

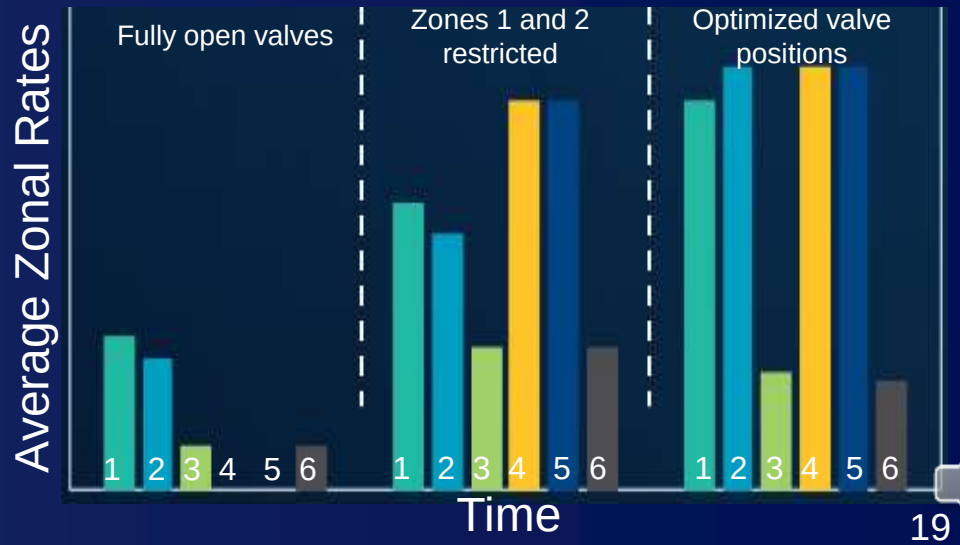
Reference : JPT, Sep 2016

Extended-Reach Well

- Well completion
  - Total well length: 40,000 ft
  - Six electric FCVs : five reservoir zones
- Permanent measurements
  - P, T, water cut, downhole flow rate
- Production management
  - High-flow zones choked back, drawdown increased in low-flow zones
- Reservoir characterization
  - Perform pressure buildup by zone : eliminate production deferment

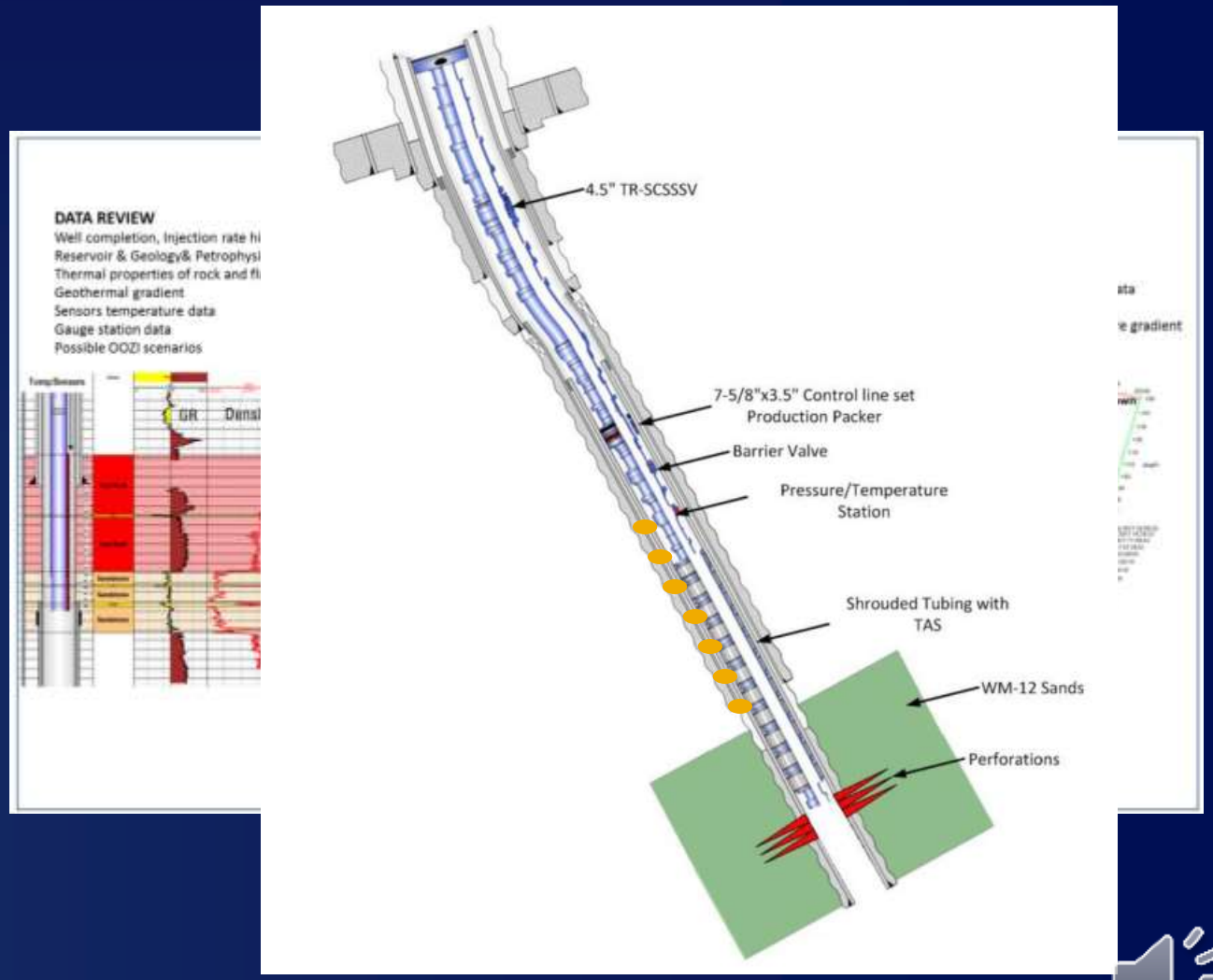


Well Flowback Optimization



Deepwater Injector Well

- Well completion
  - Deviated well: 20,000ft MD
  - Distributed temperature sensors
- Permanent measurements
  - Array of temperature sensors:120
- Reservoir surveillance
  - Permanent injection profile
  - Well integrity
- Production management
  - Flowback optimization via surface choke adjustments



Source: SPE 192870

Digital Completions: Summary

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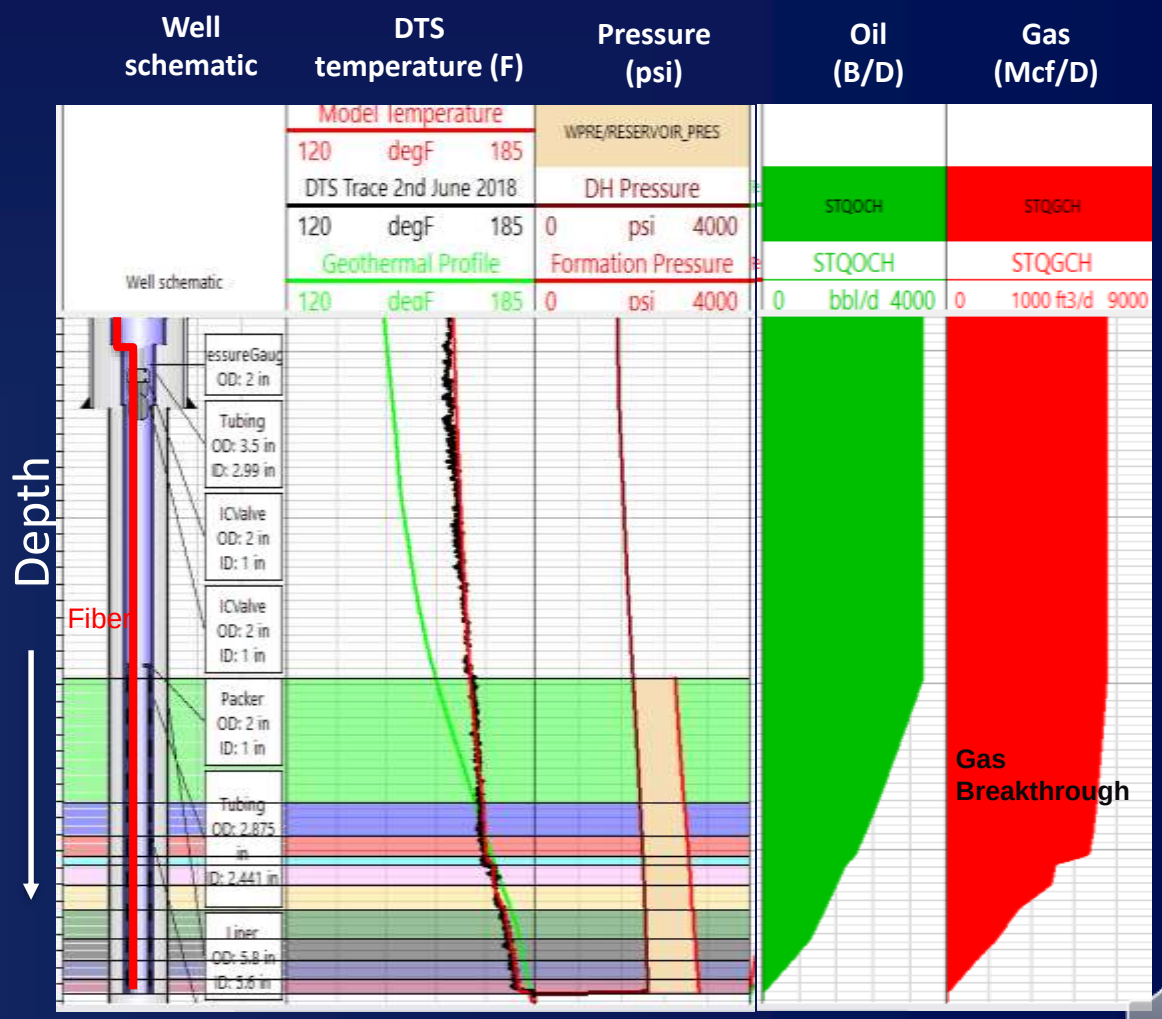
- Identify and prevent early gas/water breakthrough
- Manage drawdown: Control flow from each reservoir zone
- Optimize production and sweep
- Establish production profile across the reservoir
- Minimize interventions

Horizontal Well - Fiber Optics

- Well details
  - Horizontal oil producer
  - 1,900-ft pay zone, sandstone
  - Fiber with tailpipe
  - DTS measurement

- Results
  - Temperature match : actual vs model
  - Oil and gas production profile
  - Identification of gas breakthrough



Unconventional Fracturing - Fiber Optics

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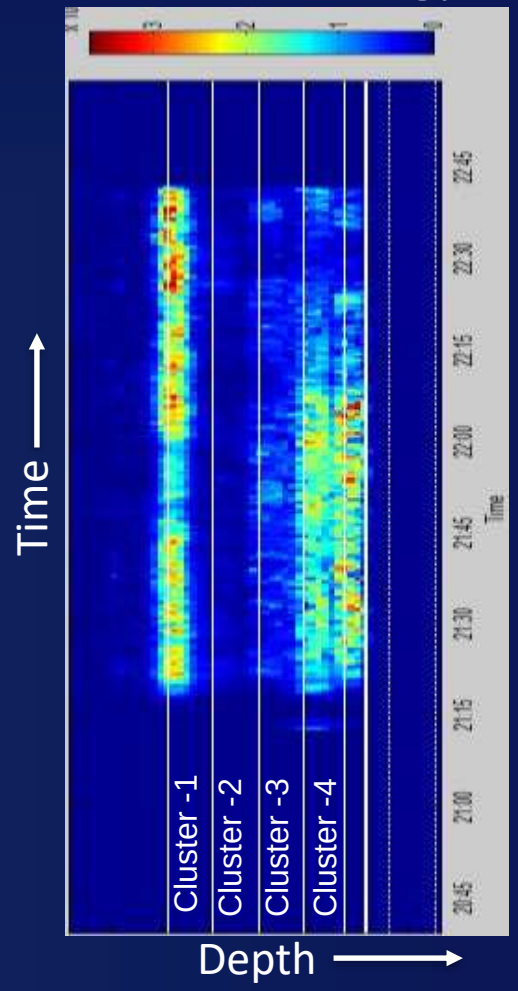
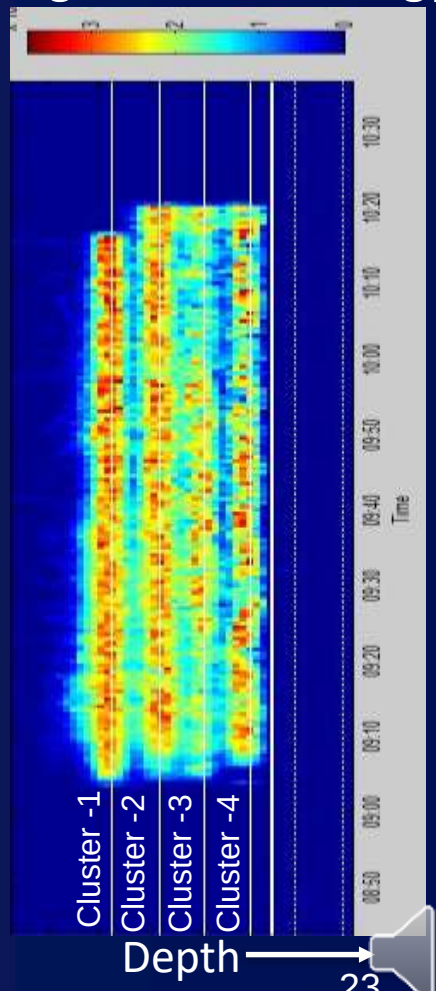
- Well details
  - Plug and perforations, unconventional
  - Horizontal length 13,000 ft
  - Fiber behind casing
  - DAS measurement
- Results
  - Stage 10: cluster 2,3, not fractured – low energy
  - Stage 18: used diverter, all clusters fractured – high energy

Stage 10: DAS Energy

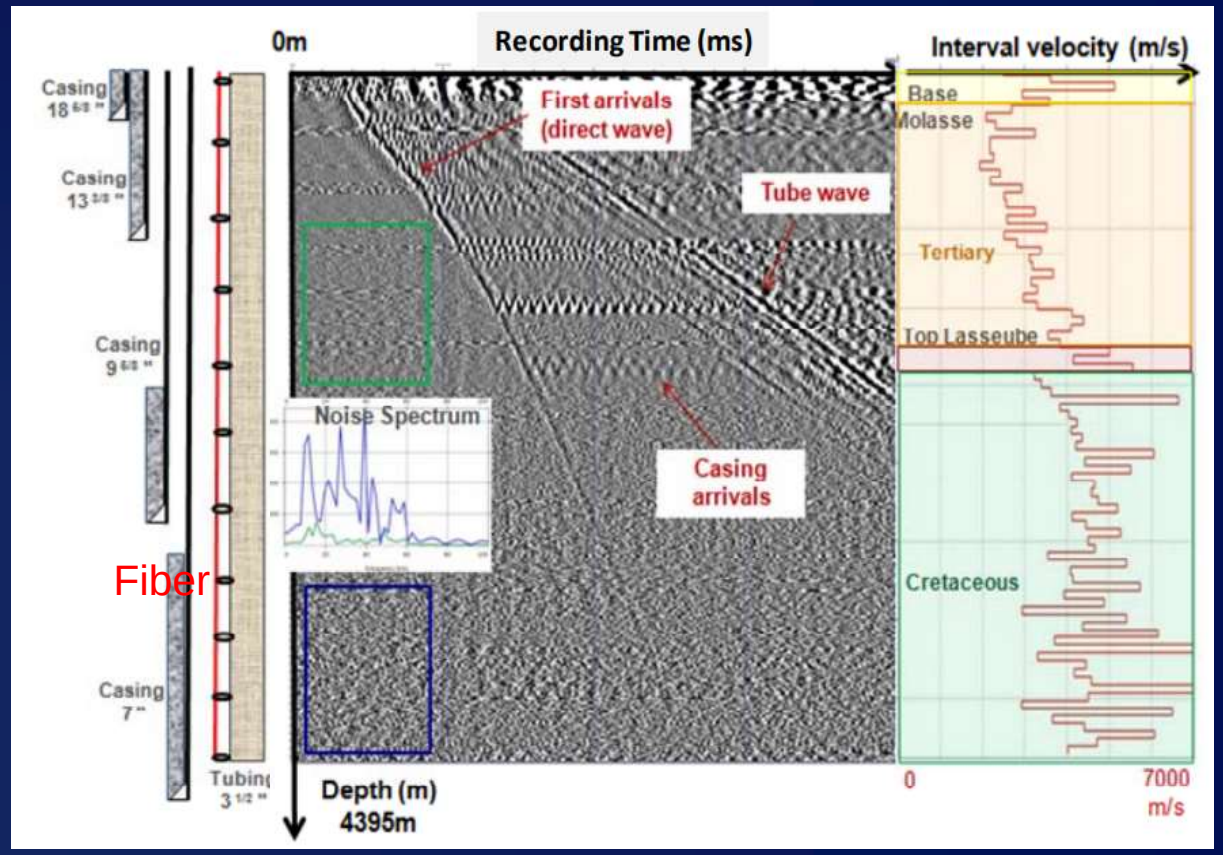


Stage 18 : DAS Energy



Fiber Optics—VSP Monitoring

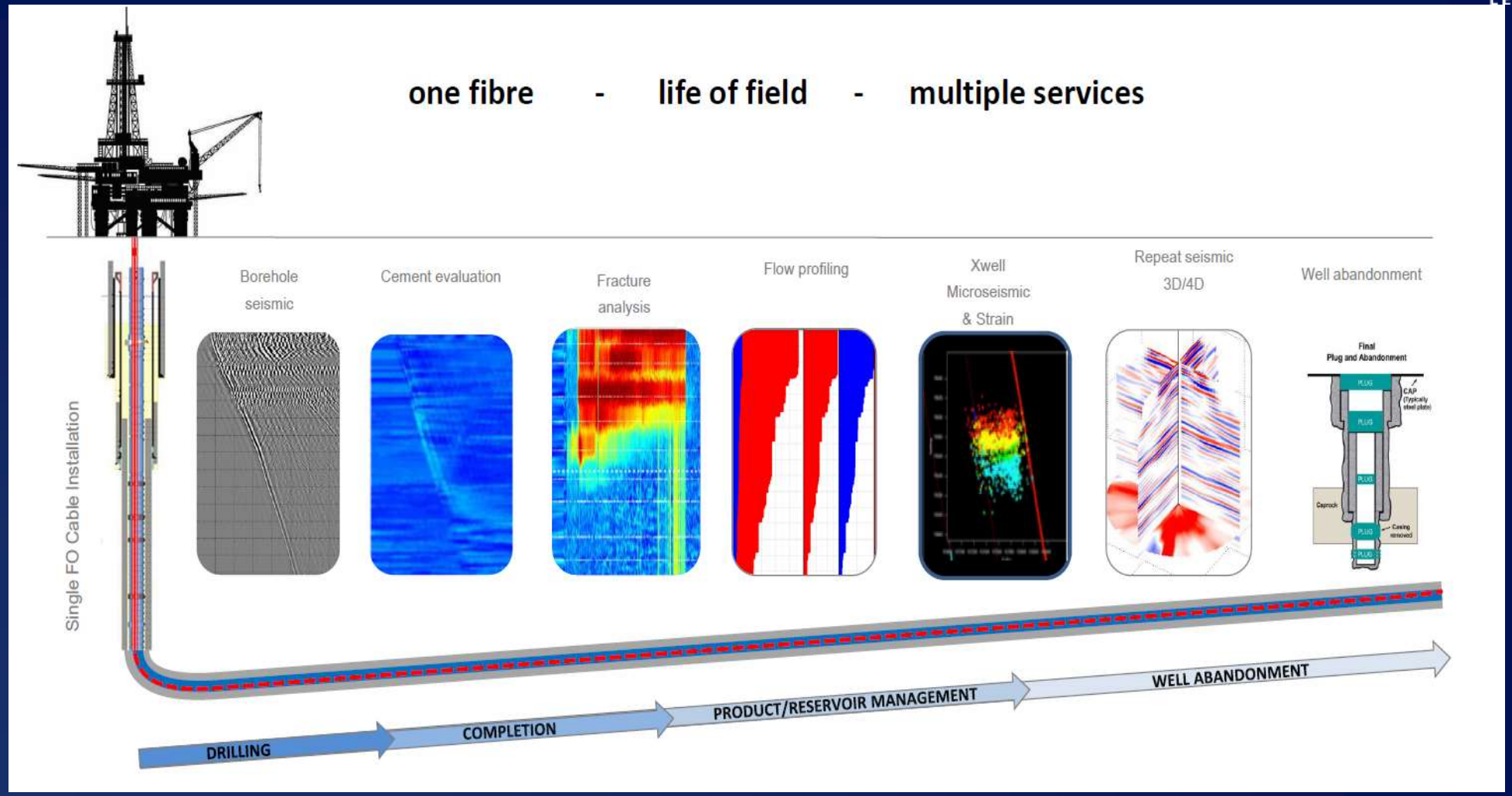
- Well details
  - Oil well
  - Depth 4,395 m
  - Fiber strapped to tubing
  - DAS measurement
- Results
  - Vertical seismic profiling (VSP) with arrivals
  - Layer identification and use for surface seismic depth correction



Distributed Acoustic Sensing : single sweep record at well head, derived VSP after 20 sweep stacking

Source: SPE 161609

Summary: DTS and DAS



Source: SPE Workshop, Denver, 2018. Craig Milne, Jacques-Olivier Gaudron, Douglas Makhija, Jeroen Burgers, Tom Parker, and Mahmoud Farhadiroushan.

Economics

Well Type	Zones	Digital Completion Well Cost	Estimated Savings
Vertical	Single	1.2X	-0.1X
Vertical	Multi	1.4X	0.1X
Horizontal	Single	2.5X	0.3X
Horizontal	Multi	2.5X	0.5X
Multilateral	Multi	3.2X	0.8X
Extended reach	Multi	4X	X
Deepwater	Single	22X	3X

Conclusions

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- Real-time production management and improved reservoir recovery
- Fiber-optics provide permanent reservoir surveillance opportunities
- Downhole hardware should be combined with digital solutions to realize value
- Digital well completions enables reduced well count targeting multiple drains from single well minimizing over all field development costs
- Economic value improves for wells targeting more than one production interval

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