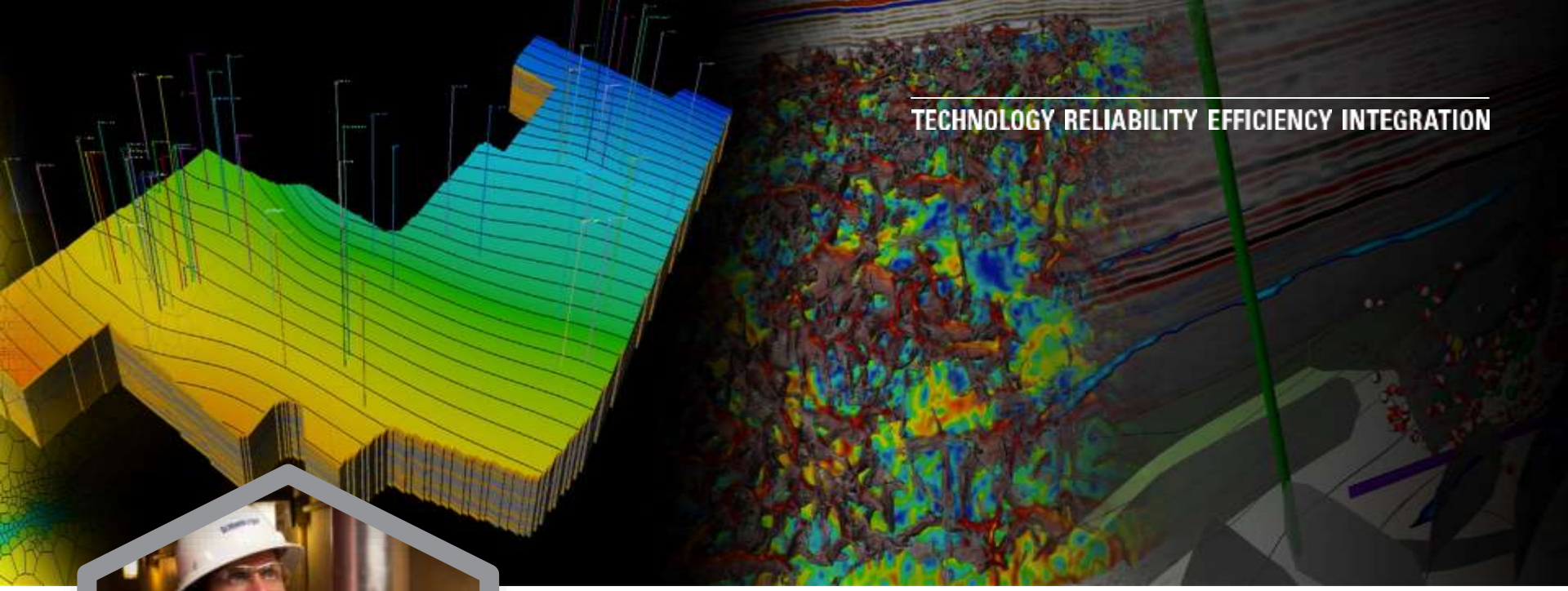


TECHNOLOGY RELIABILITY EFFICIENCY INTEGRATION

A Barrier to Placing a Primary Barrier

Name: Kevin Docherty
Position: NAL Domain Manager
Date: 22nd February, 2017

Schlumberger

Agenda

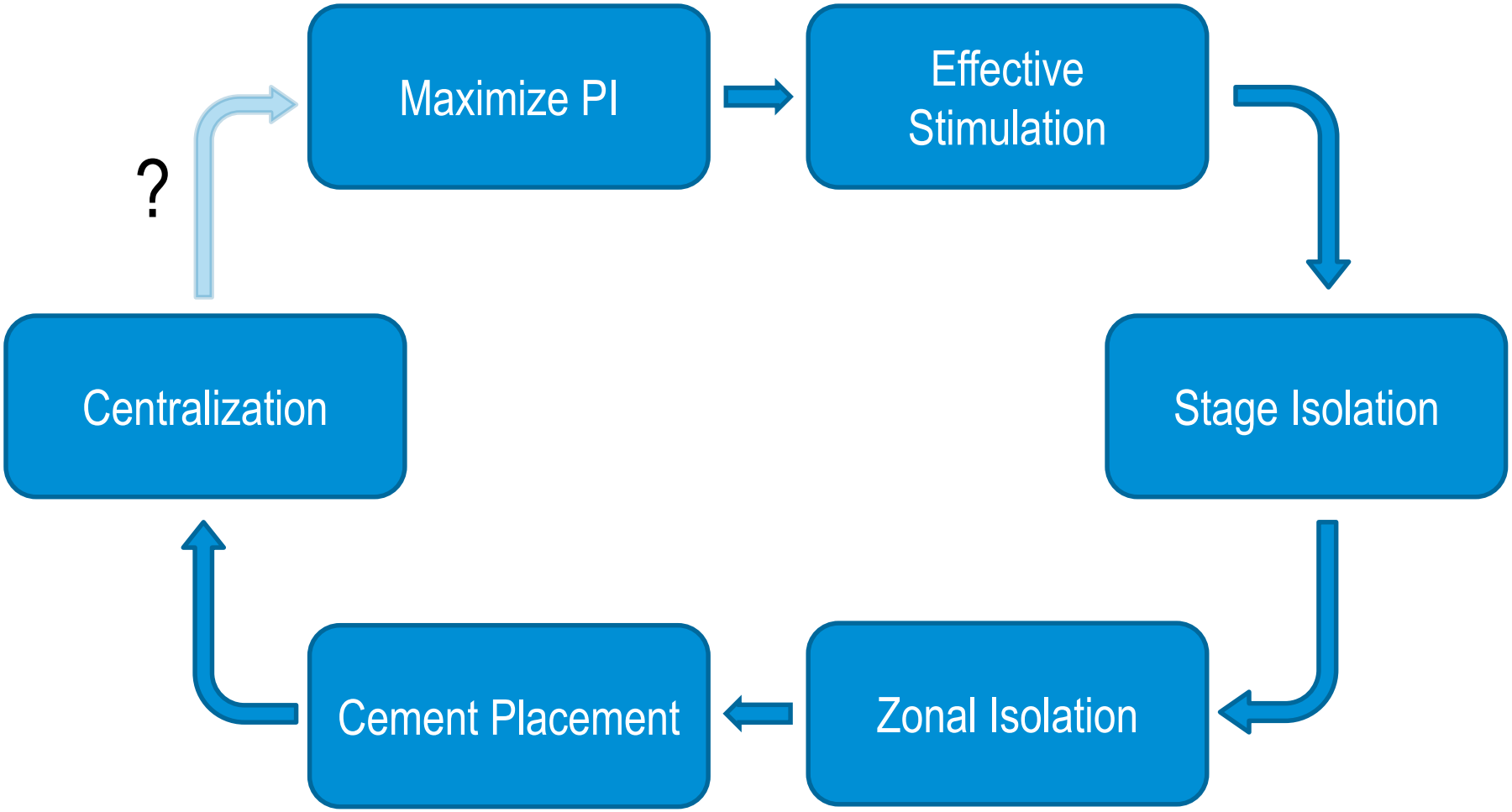
- Problem statement
- Deconstructing the path to success
- Maximizing production
- The path to effective stimulation
- The path to zonal isolation
- A barrier to placing a primary barrier
- Discussion

Problem Statement

How do we connect the dots between the well construction phase through to well productivity?

- Too many variables
- Too many dots to connect
- Must have's vs nice to have's
- Blurred lines of responsibility

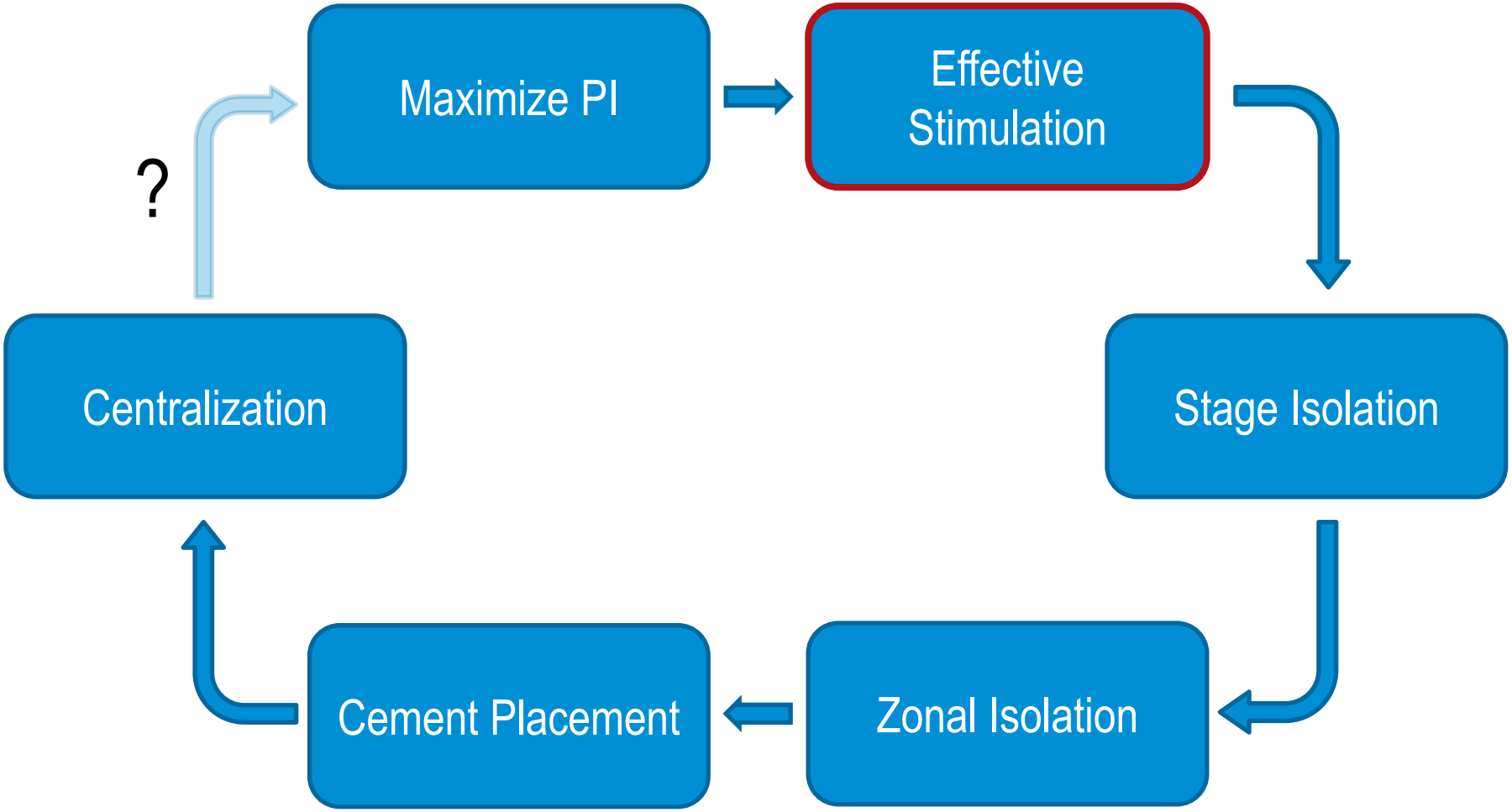
Deconstructing the path to success



Maximizing Production

- Wellbore placement
- Stimulation treatment
  - Contacting entire targeted interval
  - Maximizing the conductive flow paths
  - Cost effective
- Managing the reservoir

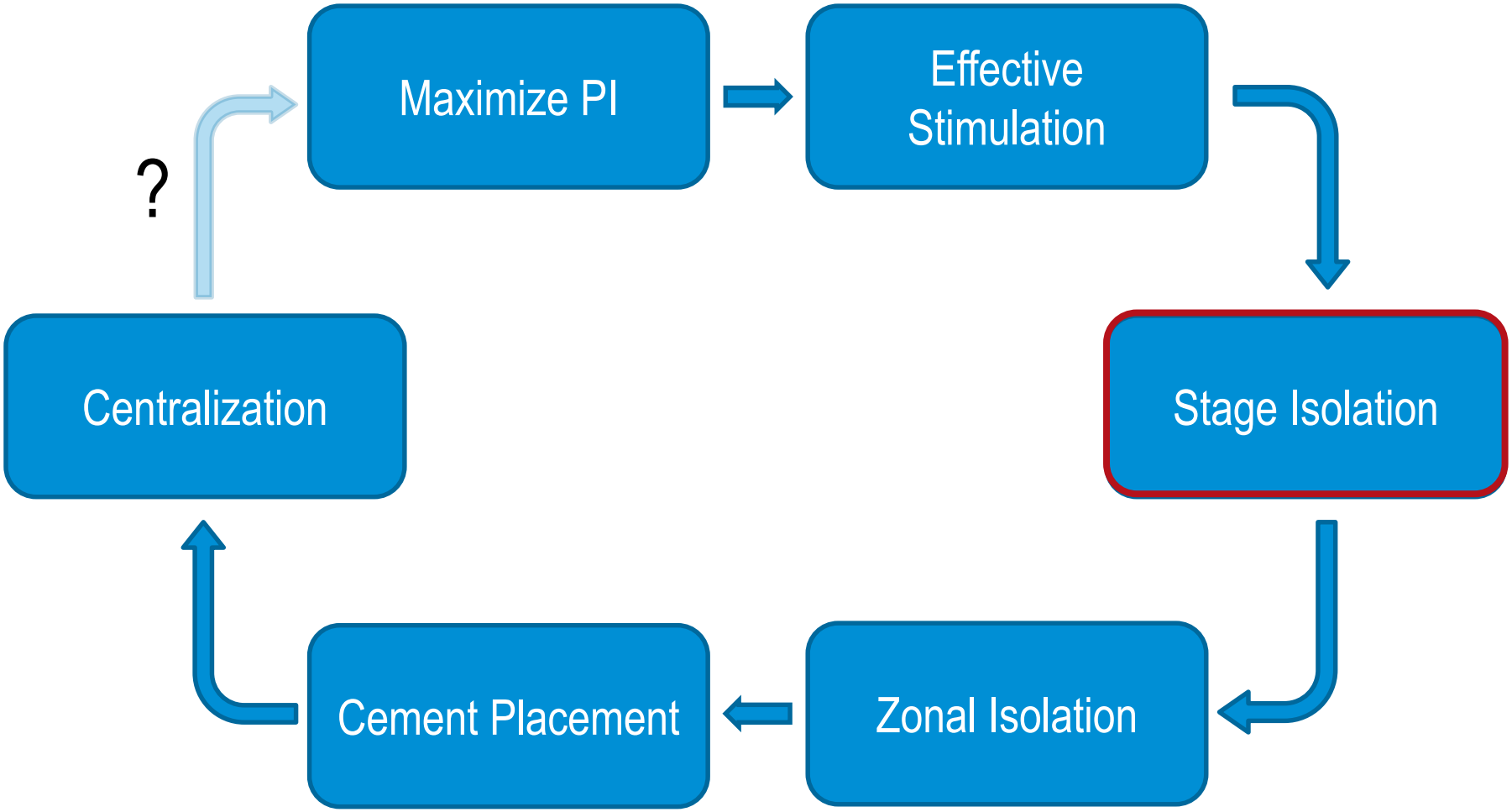
Deconstructing the path to success



The path to effective stimulation

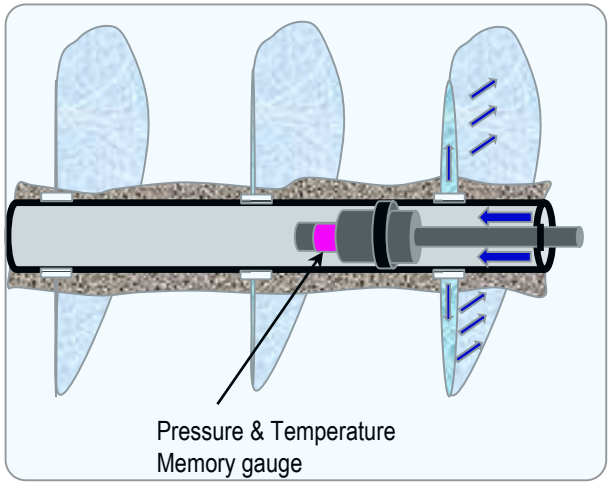
- Maximizing the conductive flow path
- Cost effective (ROI)
- Contacting entire targeted interval
  - Stage isolation inside pipe
  - Stage isolation in annulus
- Staying within reservoir boundaries
  - Stage isolation inside pipe
  - Stage isolation in annulus

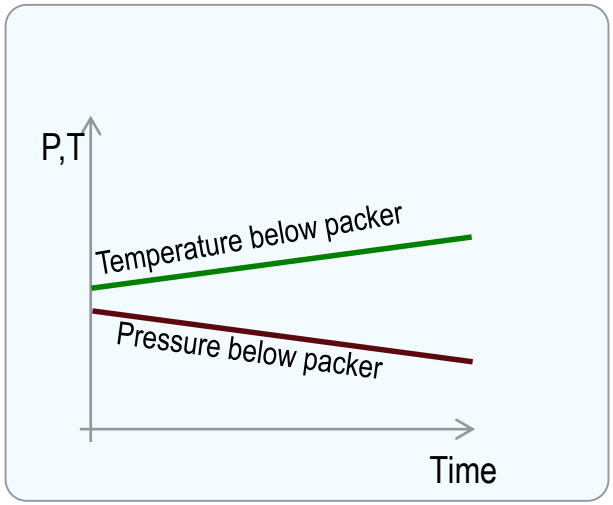
Deconstructing the path to success



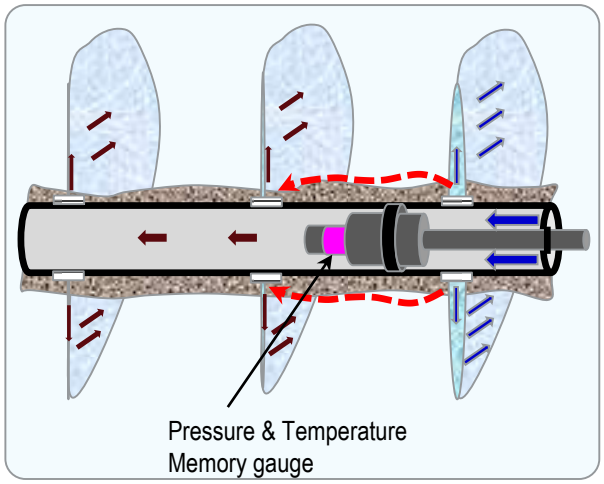
The path to effective stimulation

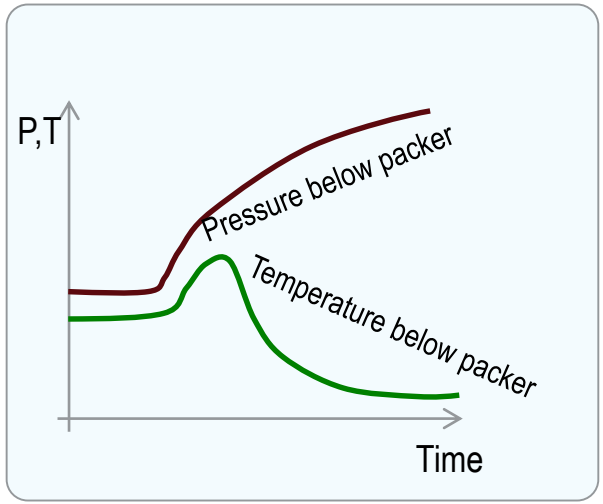
Ideal Case: No Communication



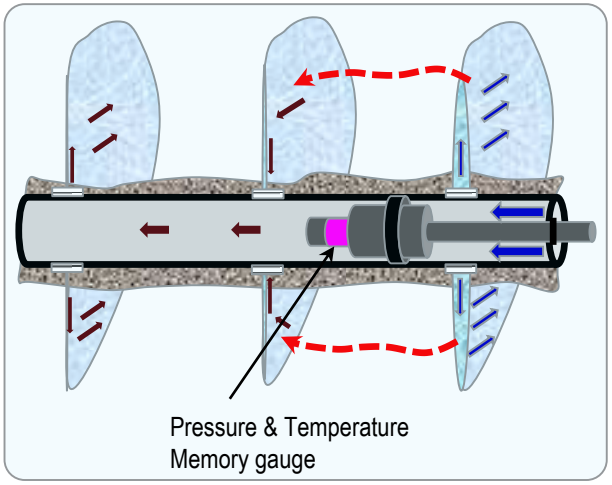


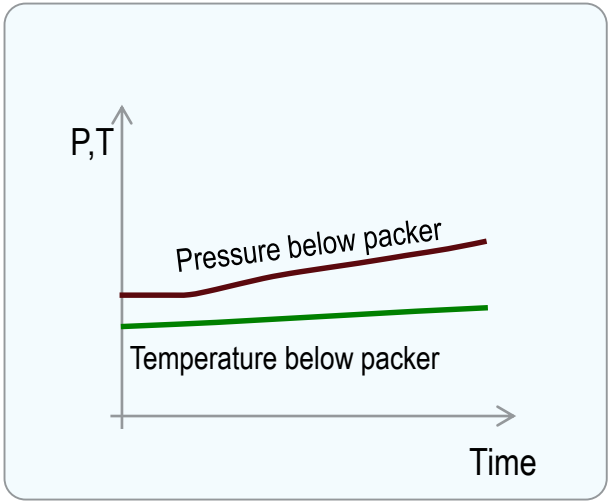
"Near-Wellbore" Communication



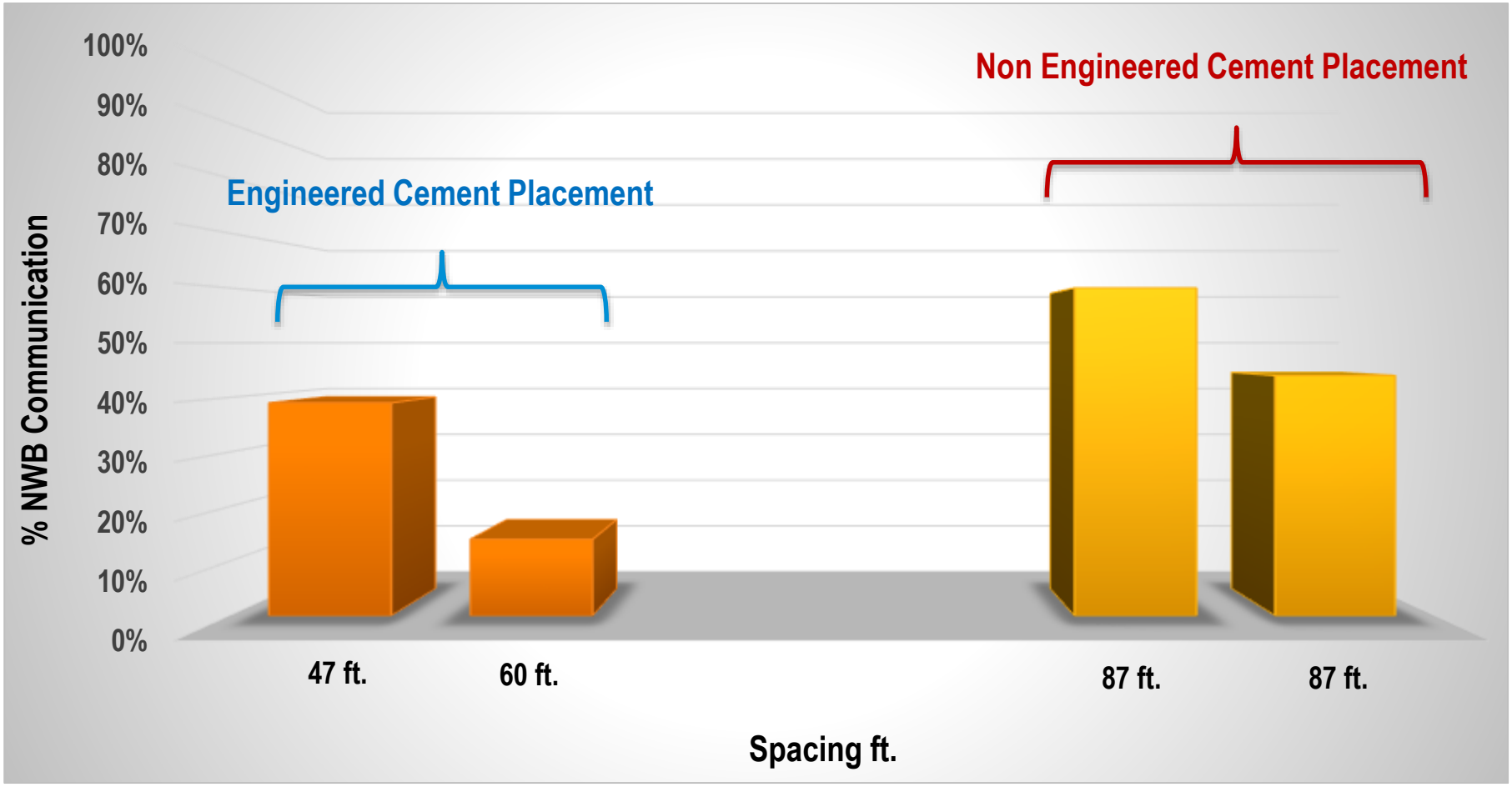


"Far-Field" Communication



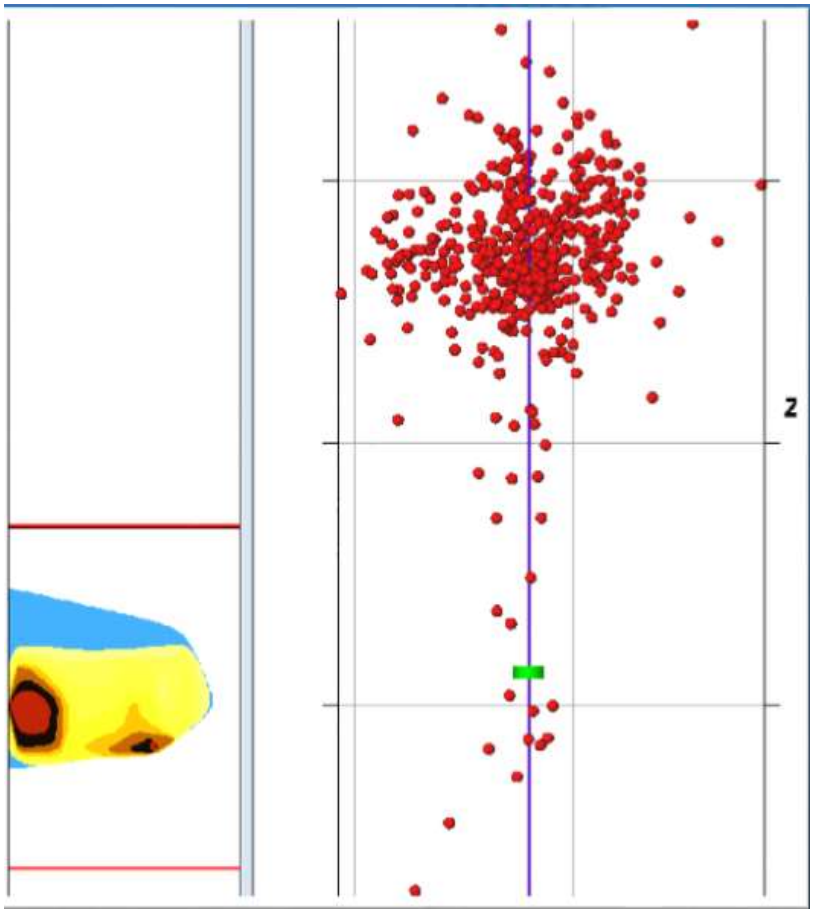


The path to effective stimulation

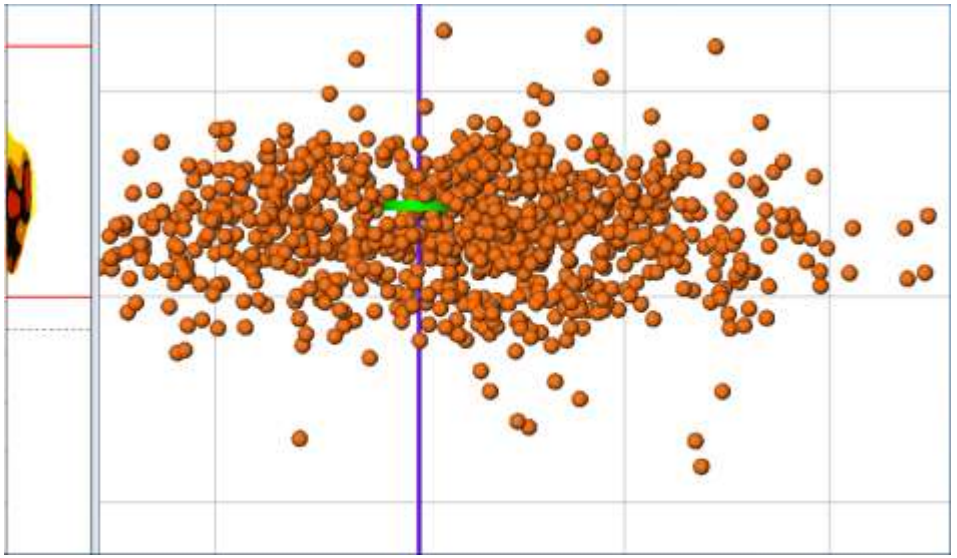


Engineered Placement → **Lower NWB Communication even w/ Shorter Spacing**

The path to effective stimulation



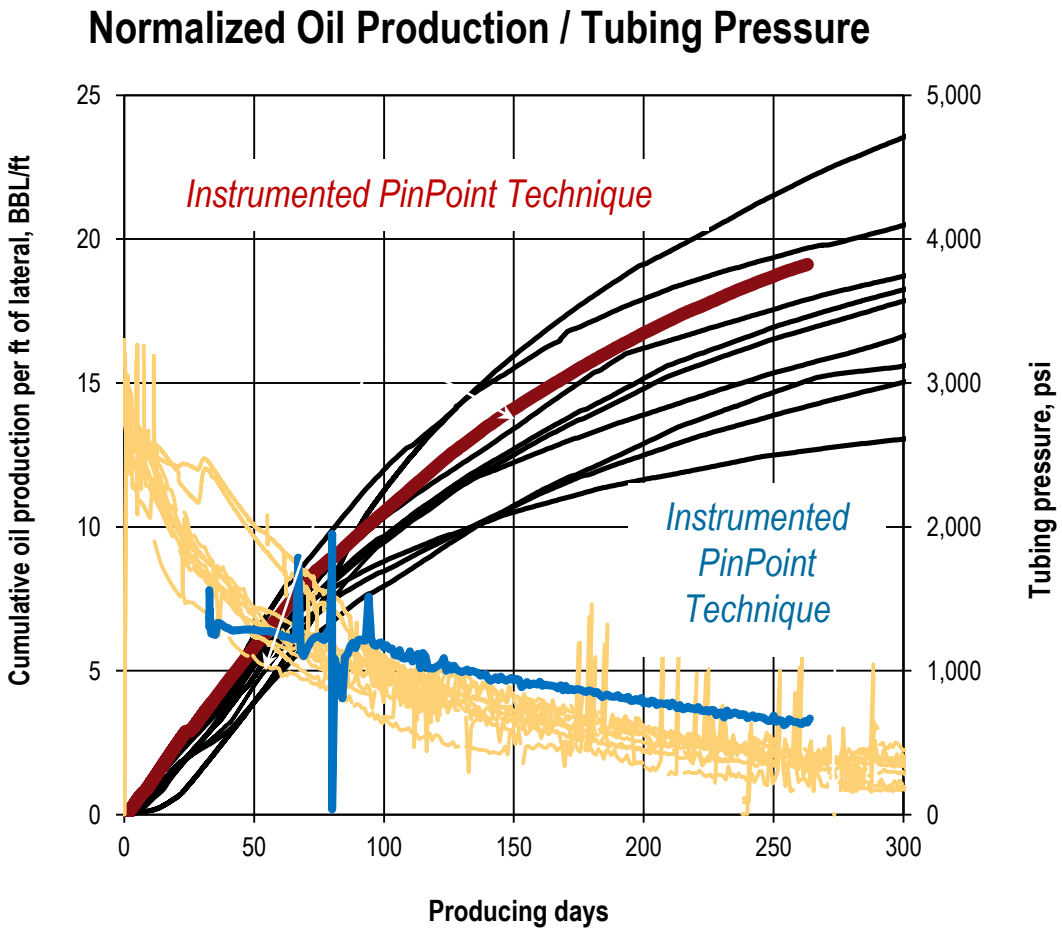
Micro-seismic is also a great tool for detecting stage isolation



Poor stage isolation

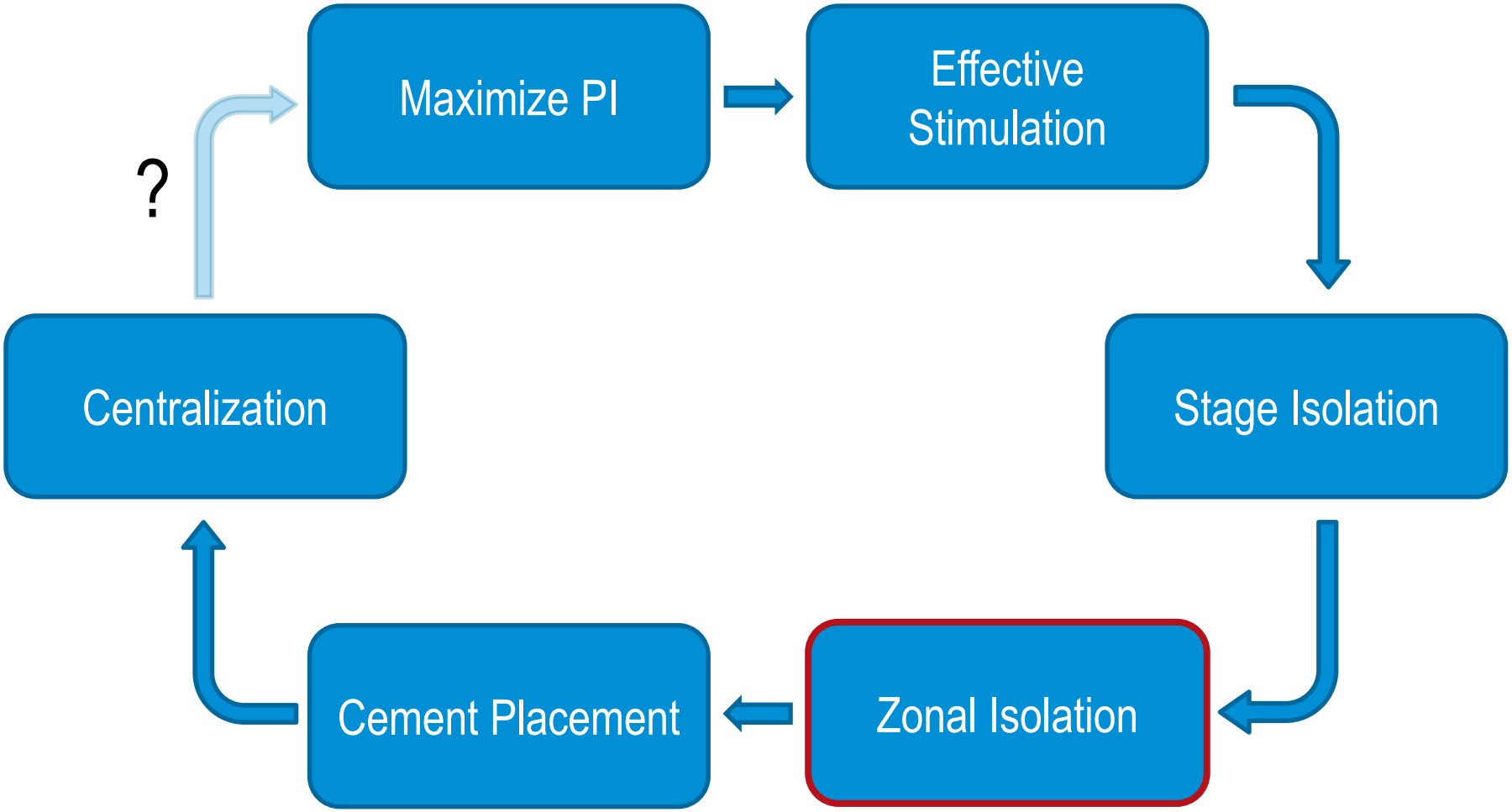
Good stage isolation

The path to effective stimulation



Higher production + Slower decline

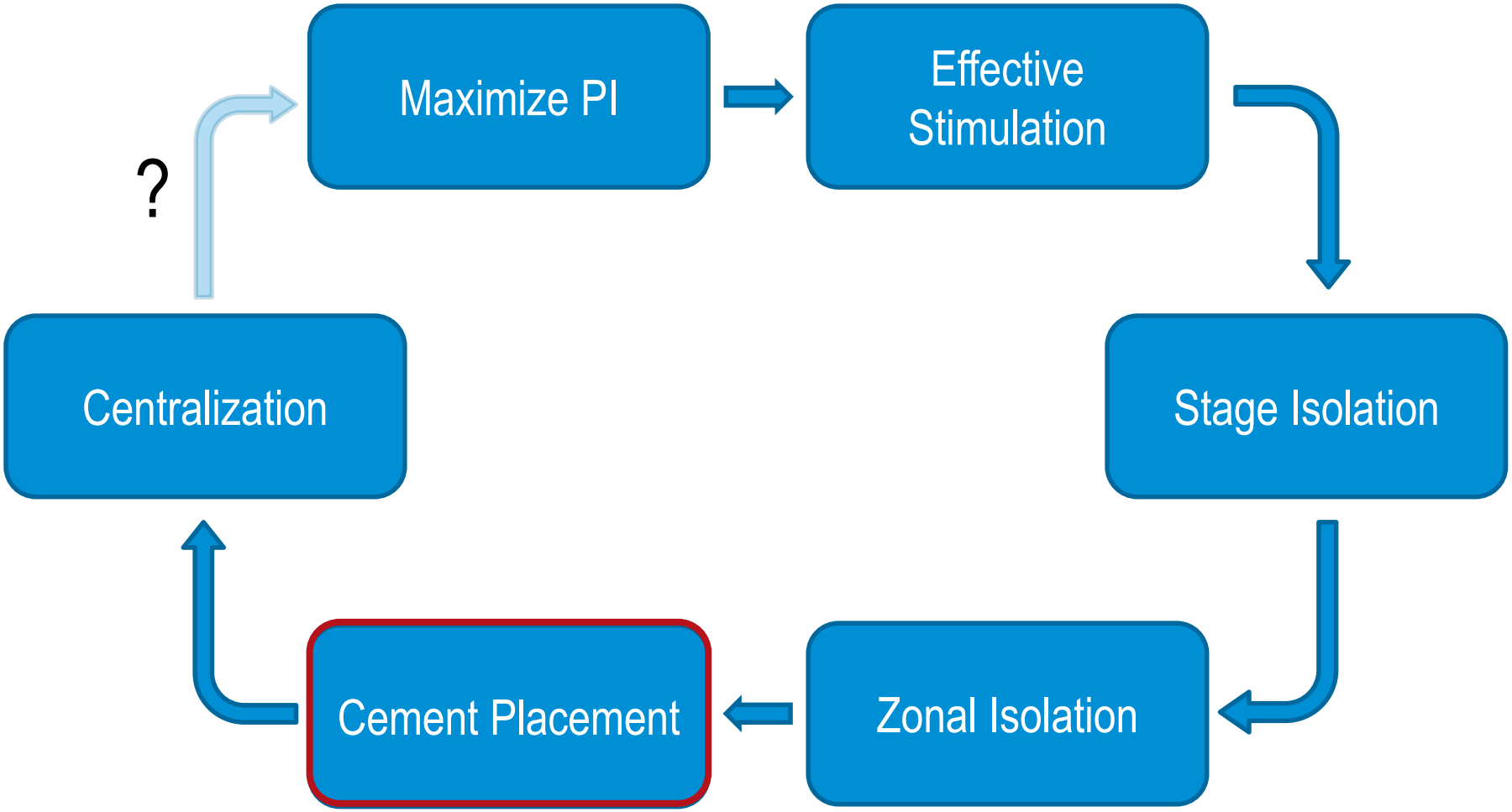
Deconstructing the path to success



The path to zonal isolation

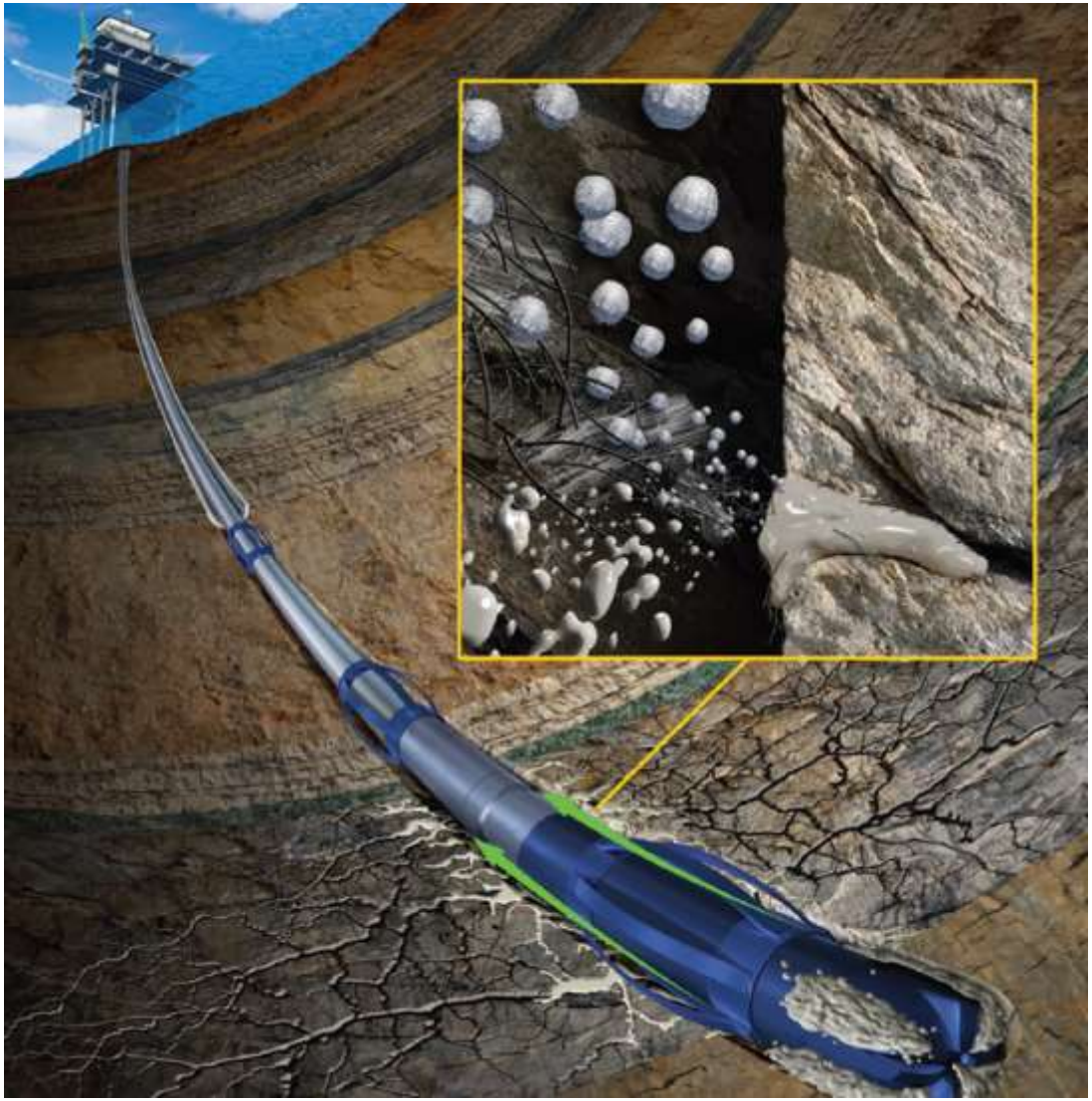
- Wellbore condition
- 3D Modeling
  - In pipe + annulus contamination simulated
  - 3D Stiff string vs soft string pipe modeling
  - High resolution centralization modeling along pipe
  - Pipe rotation simulated
  - Azimuthal flow simulated
- Competent Cement Evaluation
  - Validation

Deconstructing the path to success



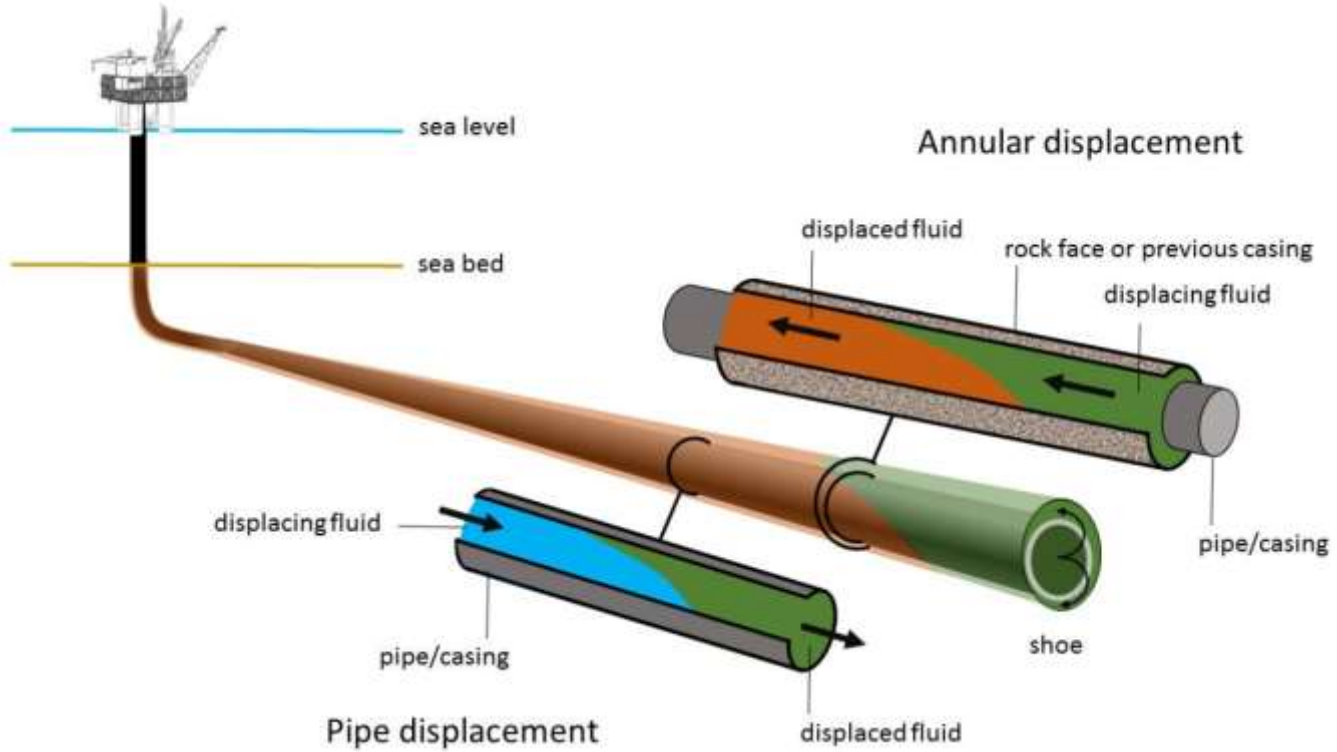
The path to zonal isolation – Wellbore Condition

- Stable wellbore
  - Rock stability
  - No influx
  - No losses
- Clean hole
- In gauge hole
- Minimized tortuosity
- Mud condition



The path to zonal isolation – 3D Modeling

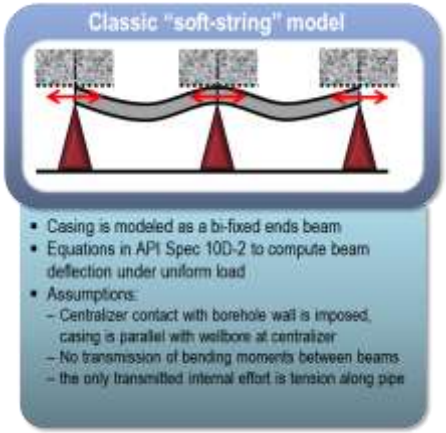
- Contamination both inside and outside pipe

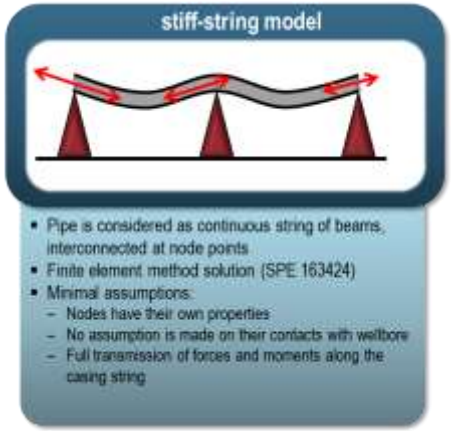


The path to zonal isolation – 3D Modeling

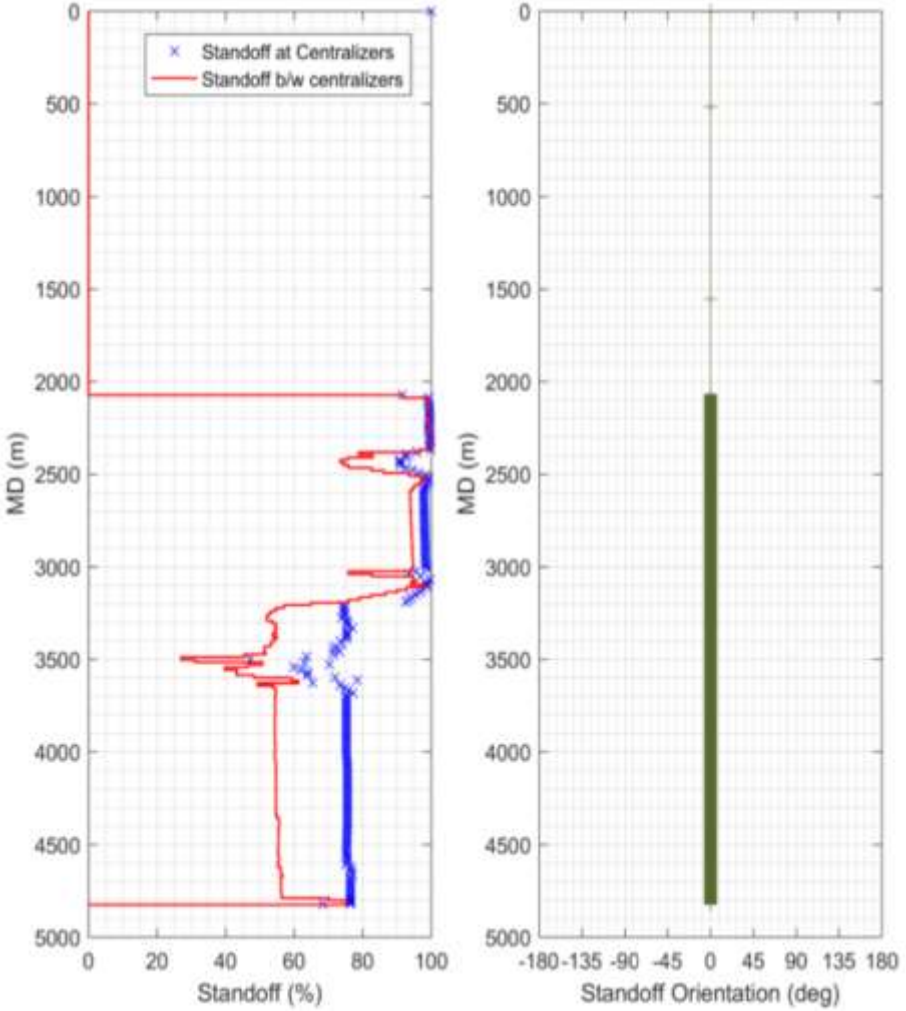
Stiff String vs Soft String Centralization Models

- Simulating centralization in the washed-out section
  - No wall contact is imposed
- Simulating centralization in a tortuous wellbore
  - No assumption that casing is parallel with wellbore at the centralization point
- Forces calculation is more realistic
  - Forces & moments are fully transmitted along the casing string
- No assumption that the casing is in tension
  - Buckling is simulated
- High resolution 3D pipe positioning output

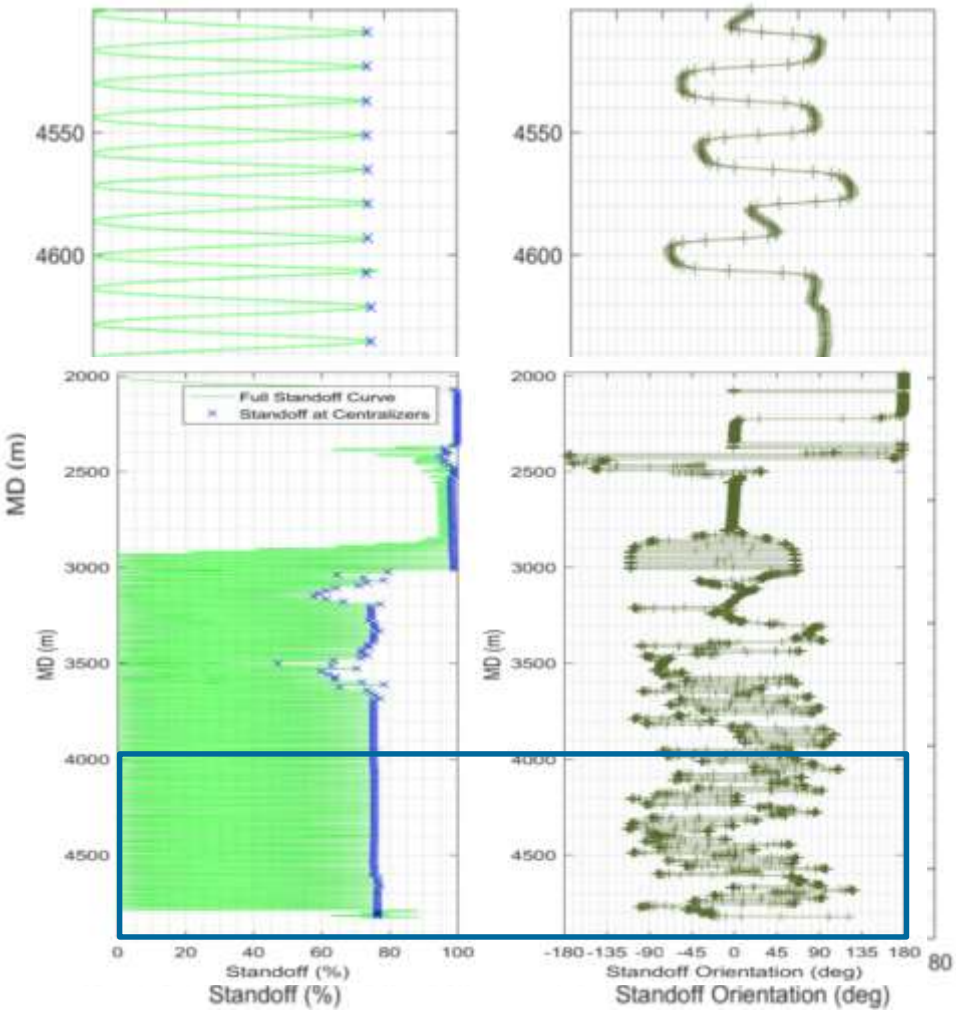




The path to zonal isolation – 3D Modeling

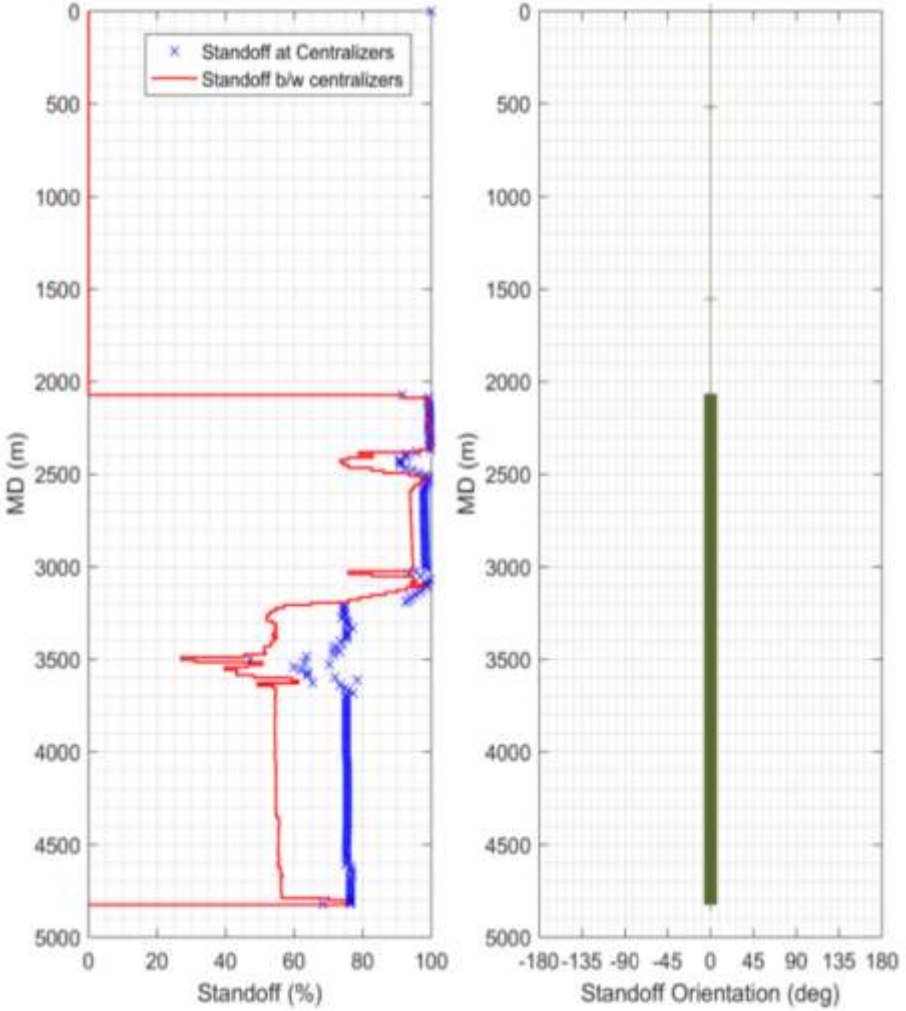


Soft String Model

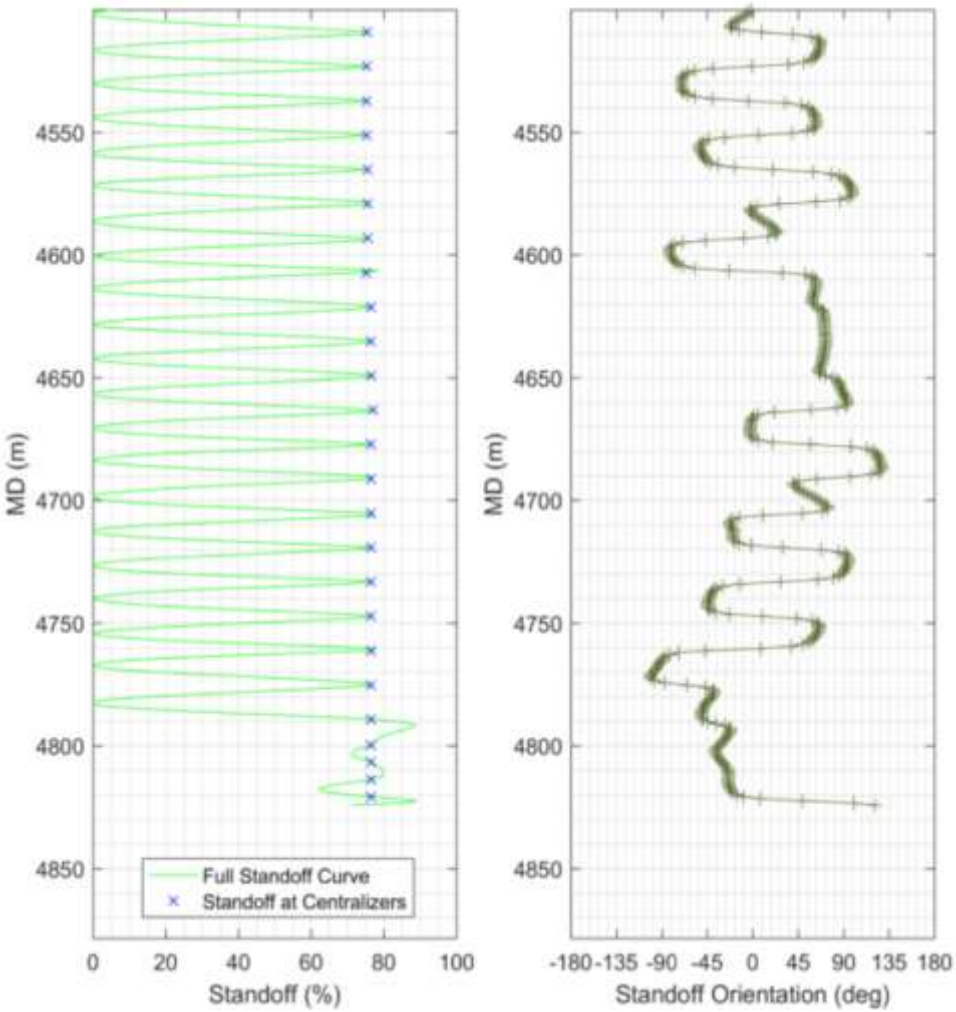


Stiff String Model

The path to zonal isolation – 3D Modeling

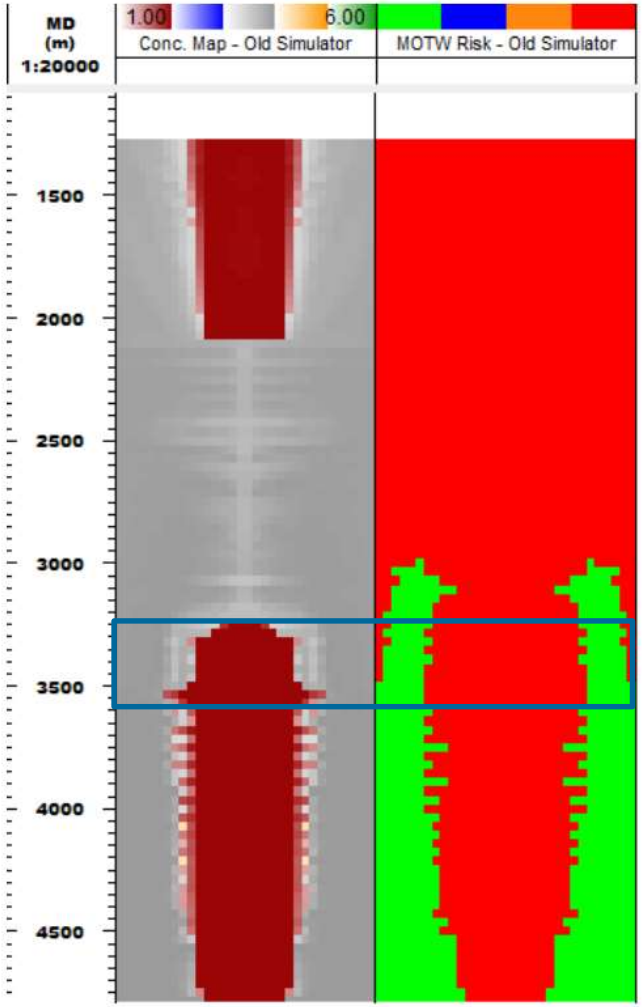


Soft String Model

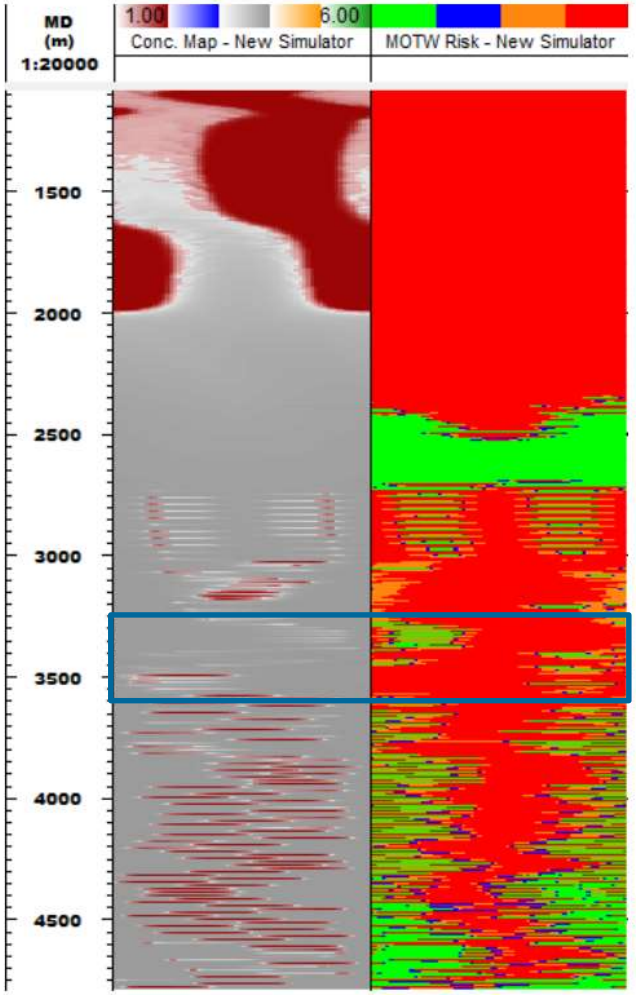


Stiff String Model

The path to zonal isolation – 3D Modeling

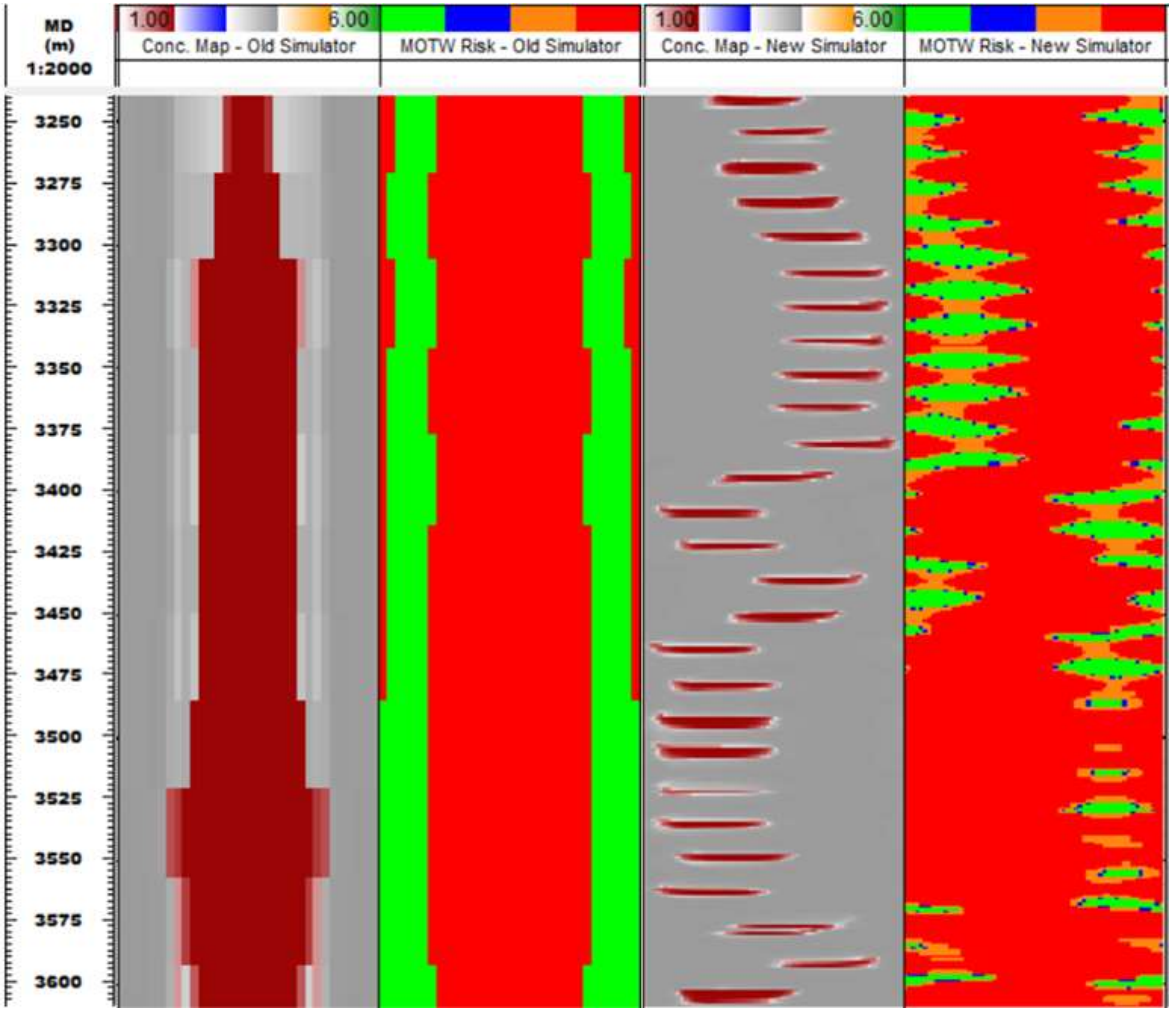


2D Model



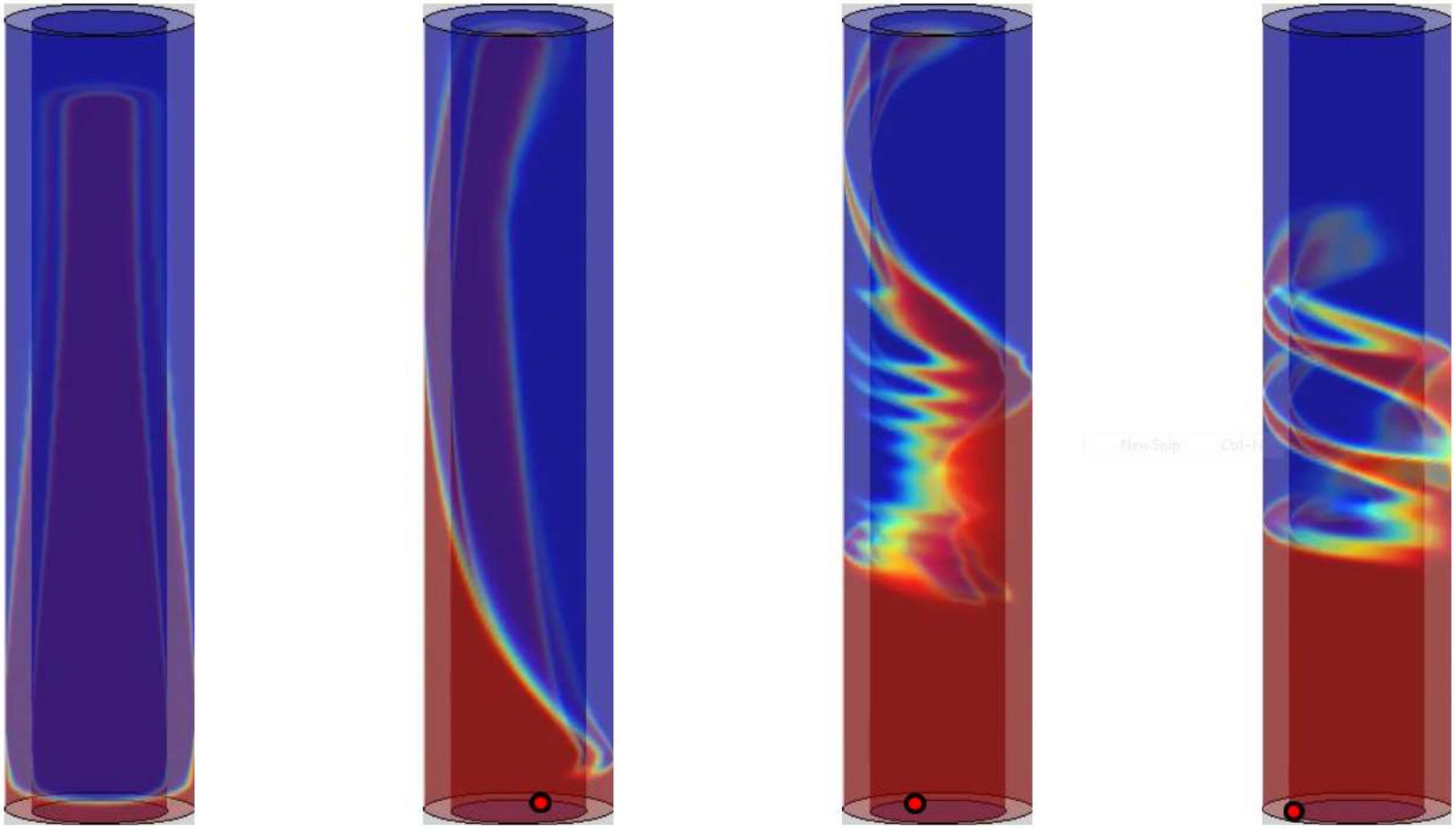
3D Model

The path to zonal isolation – 3D Modeling



2D Model 3D Model

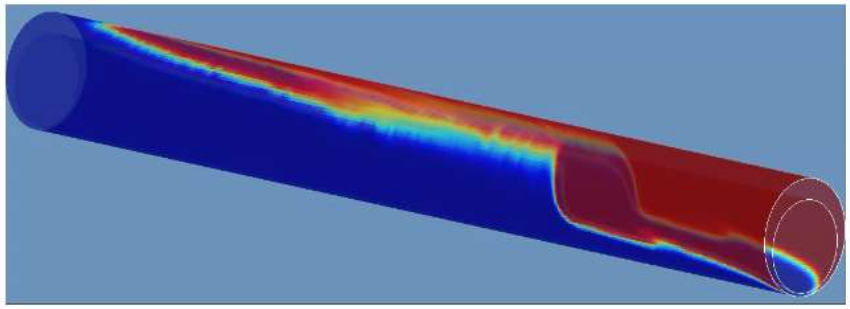
The path to zonal isolation – 3D Modeling



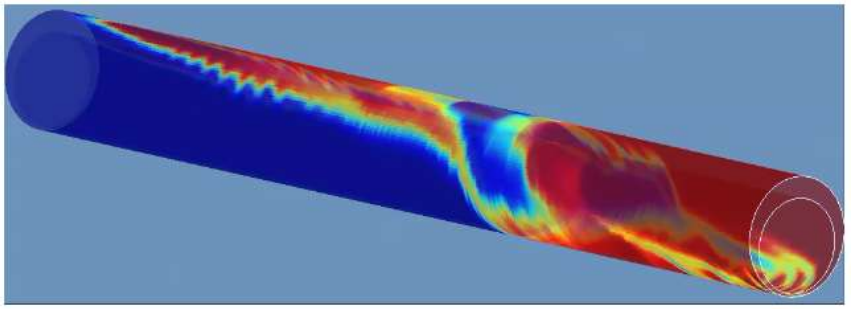
The path to zonal isolation – 3D Modeling

Azimuthal Flow

- Buoyancy driven azimuthal flow is common in highly deviated wells
- Azimuthal flow significantly effects cement placement
  - Must be simulated in highly deviated wells



No Azimuthal Flow



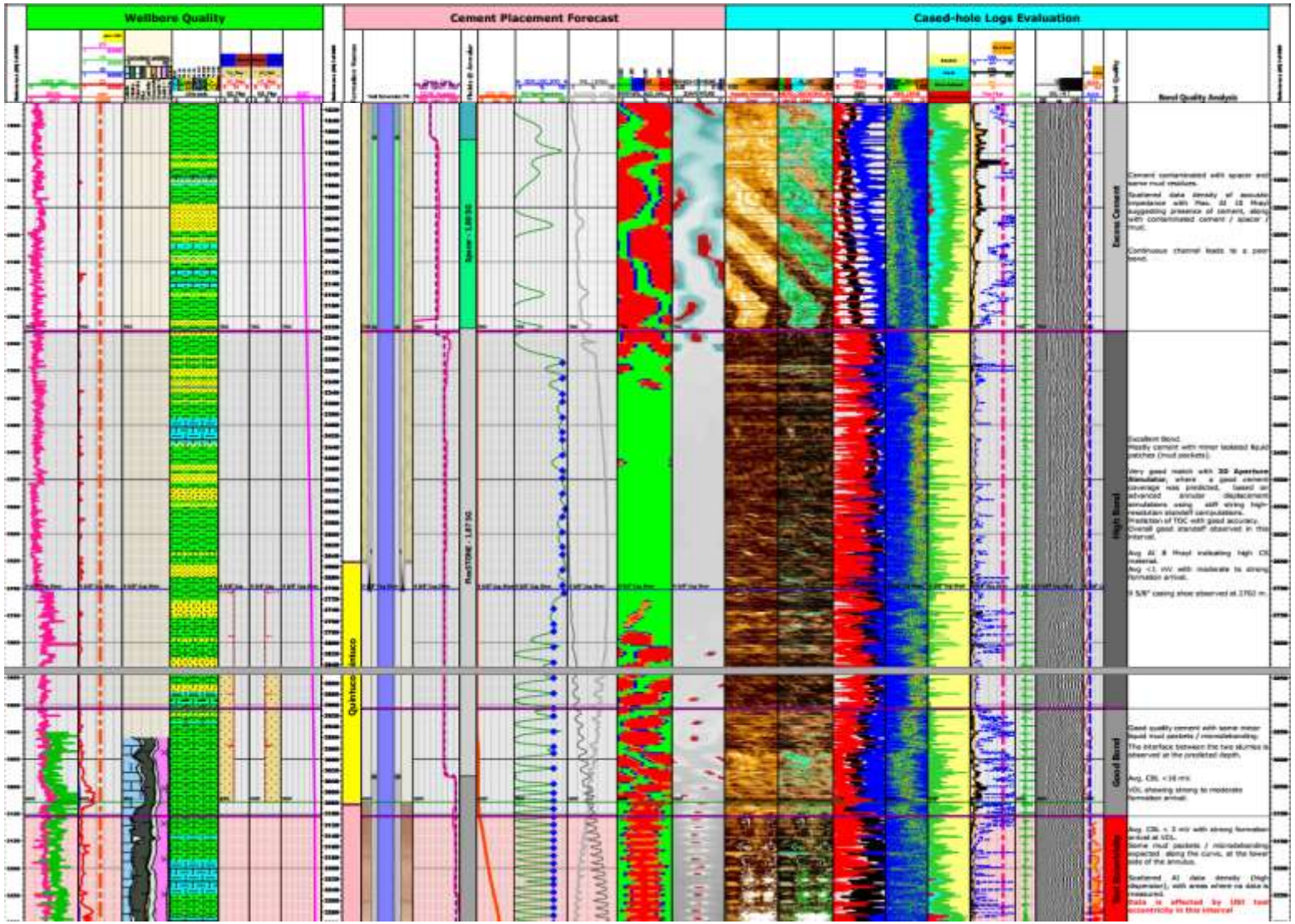
Azimuthal Flow

The path to zonal isolation – Cement Evaluation

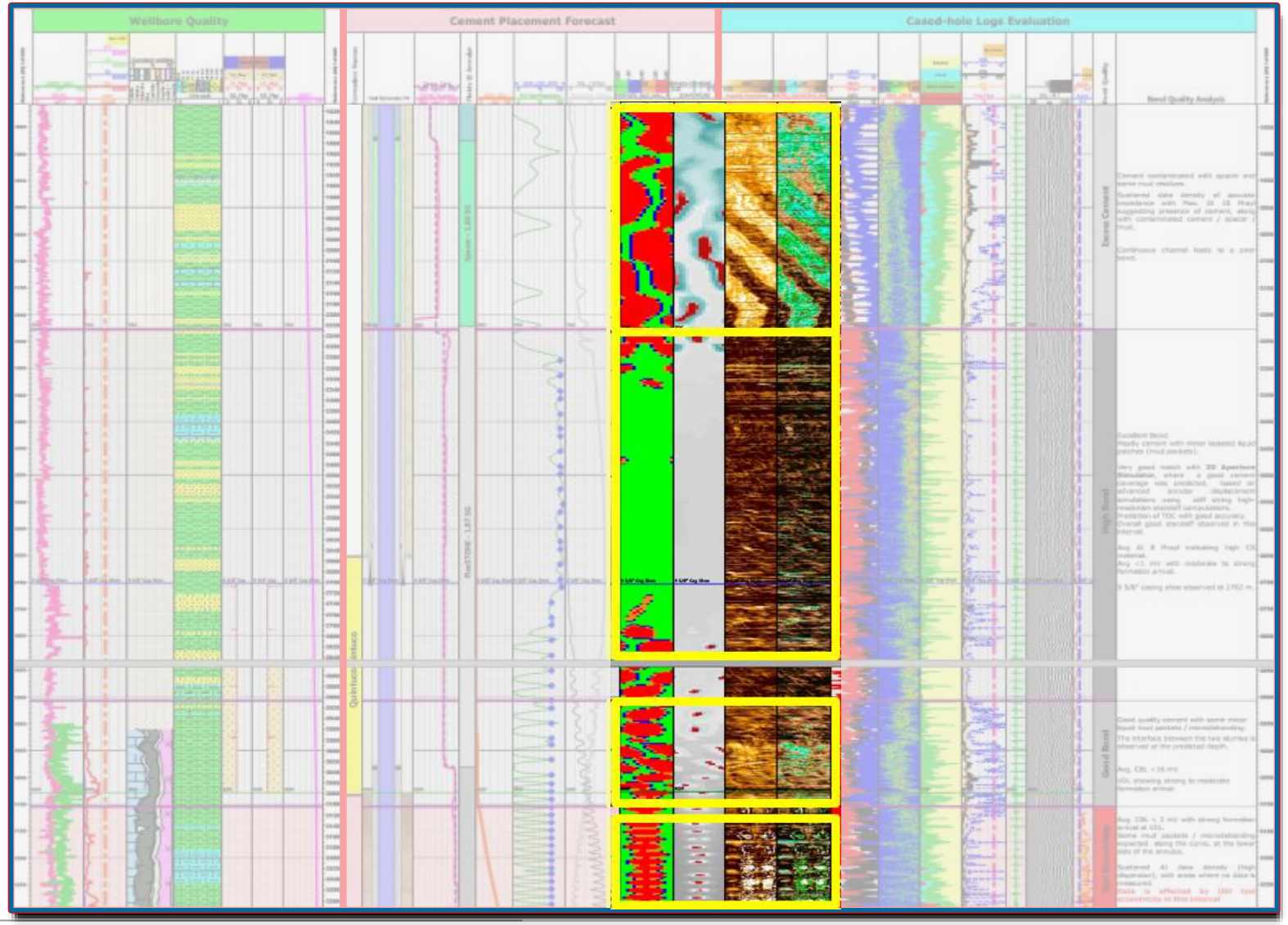
Next Generation Cement Evaluation

- Professional training
  - Stop relying on one or two global guru's to interpret bond logs
  - Wireline and cementing experts train together
  - Train all aspects of cement evaluation
    - Post job playback simulations
    - Pressure matching
    - Fluids QA
    - Bond logs
- Professional software tools
  - Enable all relevant data to be displayed in one layout

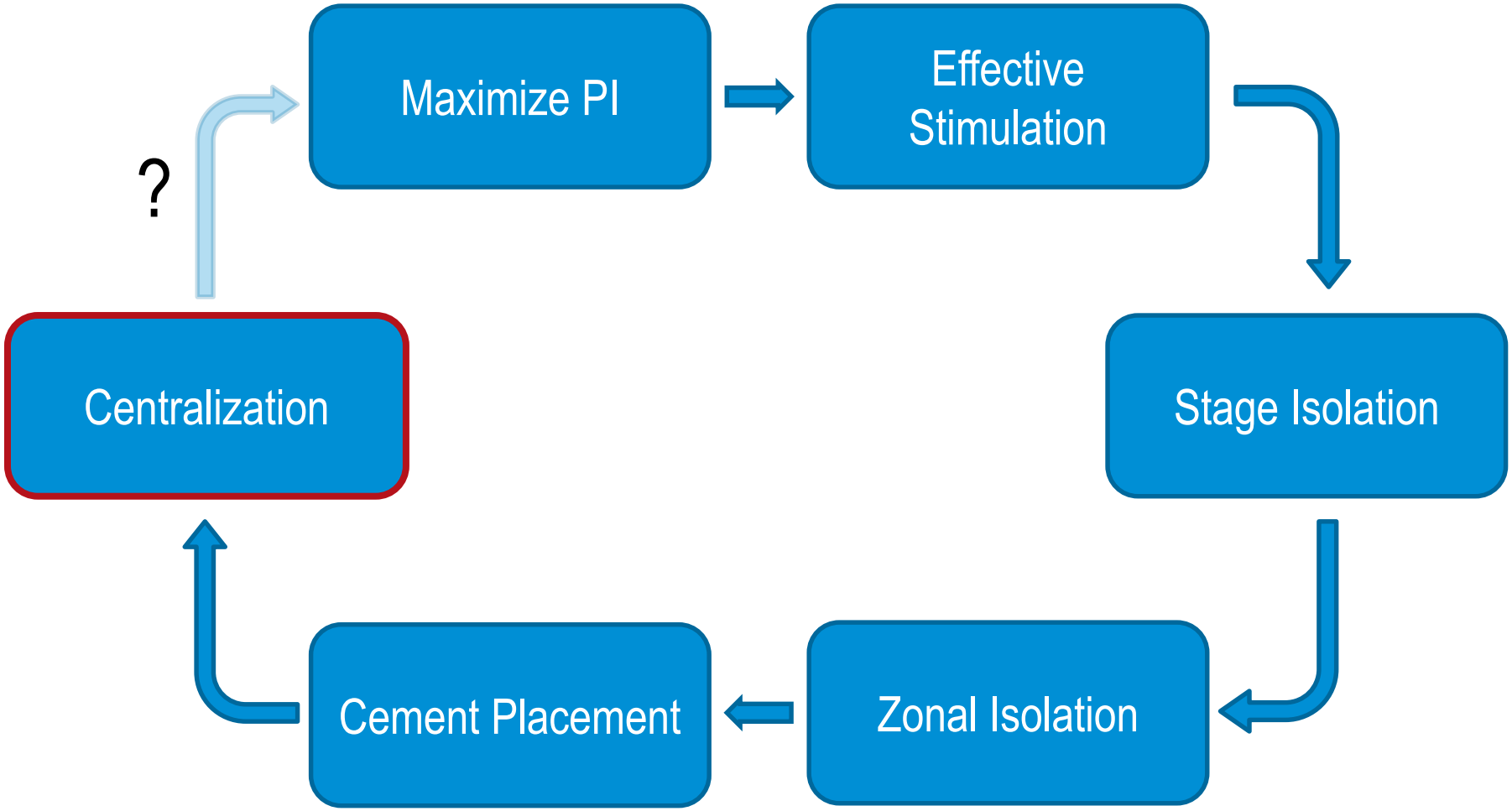
The path to zonal isolation – Cement Evaluation



The path to zonal isolation – Cement Evaluation



Deconstructing the path to success



A barrier to placing a primary barrier – Centralization!

What are the “hang ups” to using centralizers?

- Getting pipe to bottom?
- Cost?

How should we approach these barriers?

- Use the right design tools and knowledge to guide your decisions

A barrier to placing a primary barrier – Centralization!

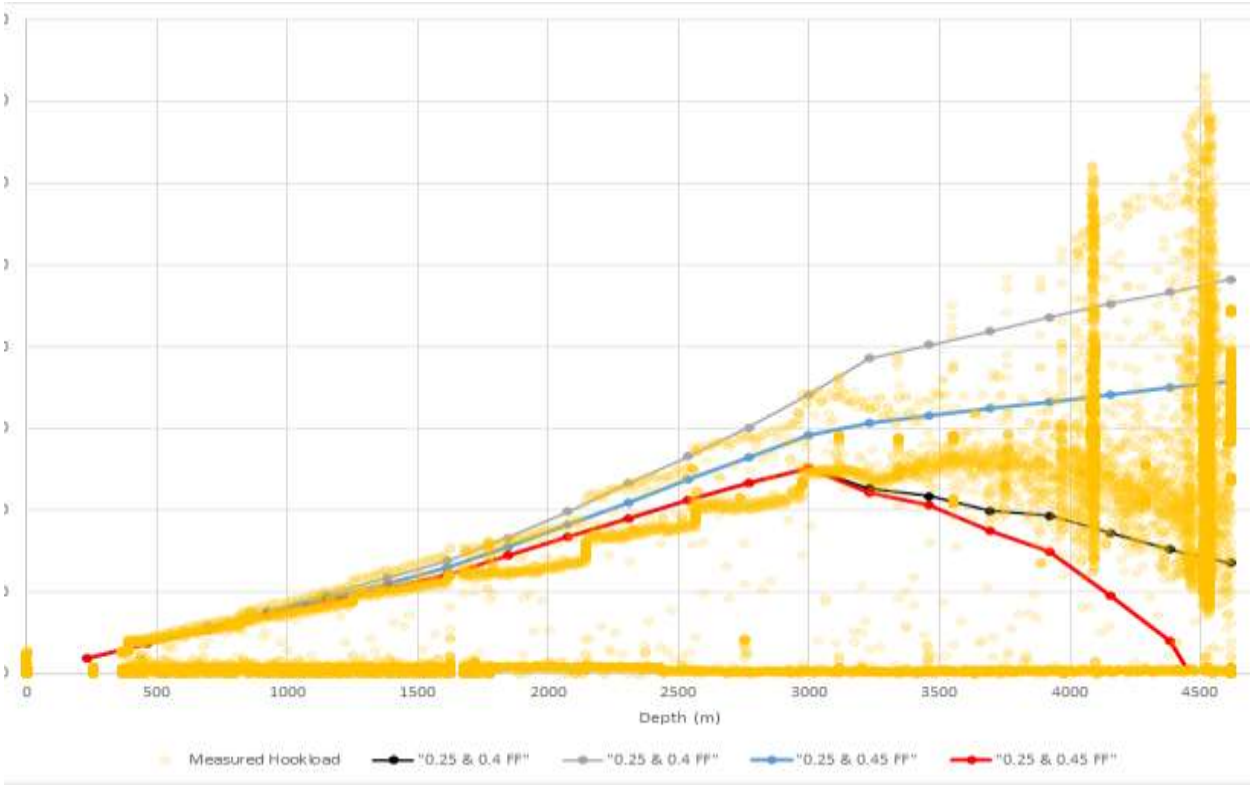
Do centralizers reduce friction?

- That's what we've all assumed
  - Because they reduce contact area
- But the evidence clearly shows centralizers increase drag under most circumstances
  - The centralizer type is critical to the drag impact
- Is "reducing contact area" ever helpful?
  - Yes when differential drag / sticking is present…
    - Under these circumstances, it is a "stuck pipe prevention" tool (and the best one available)

Information courtesy of K&M Technology Group

A barrier to placing a primary barrier

- 3D Modeling
  - Torque & drag can now be modelled more effectively



A barrier to placing a primary barrier

Rotating centralizer configurations

- Pipe rotates within centralizer
  - Reduces torque required to rotate
- Pipe rotates with centralizer
  - Used when reaming-in is necessary to overcome sliding drag
  - Integral or mold on centralizers required

Information courtesy of K&M Technology Group

A barrier to placing a primary barrier

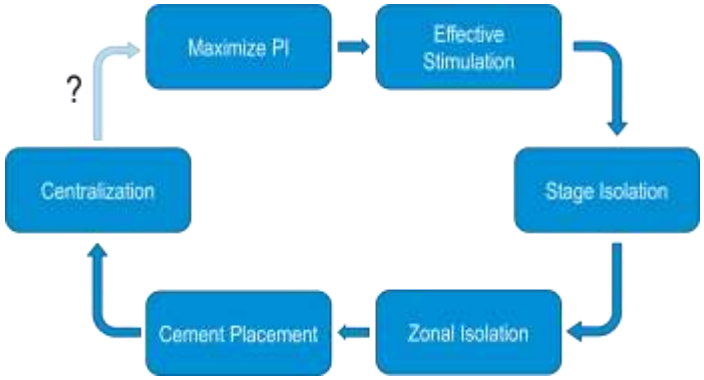
- Hardware choices

Installation	✓
Starting Force	✗
Running Force	✓
Pipe Movement	✗
Standoff	✓
Cost	✓

Installation	✗
Starting Force	✓
Running Force	✓
Pipe Movement	✓
Standoff	✗
Cost	✗

Installation	✗
Starting Force	✓
Running Force	✓
Pipe Movement	✓
Standoff	✗
Cost	✓

Discussion



- Effective stimulation
  - Stage isolation is important
- Zonal isolation
  - 3D Modeling – a leap forward
    - High resolution flow characterization
    - Stiff string centralization modeling
    - Pipe rotation now simulated!
    - Azimuthal flow now simulated!
- Validation through effective cement evaluation
- Centralization knowledge & best practices established
- Have we connected the dots?

References

Tehrani, A., Ferguson, J., and Bittleston, S.H., **"Laminar Displacement in Annuli: A Combined Experimental and Theoretical Study"**, SPE 2456, presented at the Annual Technical Conference of the Society of Petroleum Engineers (Oct 1992)
Bittleston, S.H., Ferguson, J., Frigaards, I.A., **"Mud removal and cement placement during primary cementing of an oil well – Laminar non-Newtonian displacements in an eccentric annular Hele-Shaw cell"**, Journal of Engineering Mathematics, 43 (2002), p.229-253
Tardy, P.M.J., and Bittleston, S.H., **"A model for annular displacement of wellbore completion fluids involving casing movement"**, Journal of Petroleum Science and Engineering, 126(2015) 105-123
Allouche, M., Frigaard, I.A., and Sona, G., **"Static Wall layers in the displacement of two visoc- plastic fluids in a plane channel"**, Journal of Fluid Mechanics, 424 (2000), p.243-700
Moyers-Gonzalez, M., et al., **"A Semi Analytical Closure Approximation for Pipe Flows of two Herschel-Bulkley Fluids with a Stratified Interface"**, Journal of Non-Newtonian Fluid Mechanics, (2012)
Balmforth, N.J., and Liu, J.J., **"Roll Waves in Mud"**, Journal of Fluid Mechanics, 519 (2004), p.33-54
Gorokhova, L., Parry, A., Flamant, N, **"Comparing Soft-String and Stiff String Method used to Compute Casing Centralization"**, presented at SPE/IADC Drilling Conference and Exhibition, (Mar 2013)
Ward, M., et al, **"A Joint Industry Project To Assess Circulating Temperatures in Deepwater Wells"**, SPE 83725, presented at SPE Annual Technical Conference and Exhibition (Sep 2001)
Merlo, A., et al, **"Temperature Field Measurements and Computer Program Prediction under Cementing Operation Conditions", SPE 28822,** presented at European Petroleum Conference (Oct 1994)
Bittleston, S.H., **"A Two Dimensional Simulator to Predict Circulating Temperatures during Cementing Operations"**, SPE 20448, presented at SPE Annual Technical Conference and Exhibition (Sep 1990)
Bogaerts, M., et al, **"Challenges in Setting Cement Plugs in Deepwater Operations"**, SPE 155736, presented at the Society of Petroleum Engineers Deepwater Drilling and Completions Conference (Jun 2012)
Yabin Guo, et al, **"Successful Placement of Cement Plugs in HP/HT Wells Using an Innovative Computer-Aided Simulator"**, SPE 171395, presented at the Society of Petroleum Engineers Asia Pacific Oil & Gas Conference, (Oct 2014)
Zamora, M., et al, **"Study on the Volumetric Behavior of Base Oils, Brines, and Drilling Fluids under Extreme Temperatures and pressures"**, SPE 160029, presented at the SPE Annual technical Conference and Exhibition (Oct 2012)