IPS 2024

IPS 24-8.2

Maximizing Production Efficiency through Perforation Strategy Comparison

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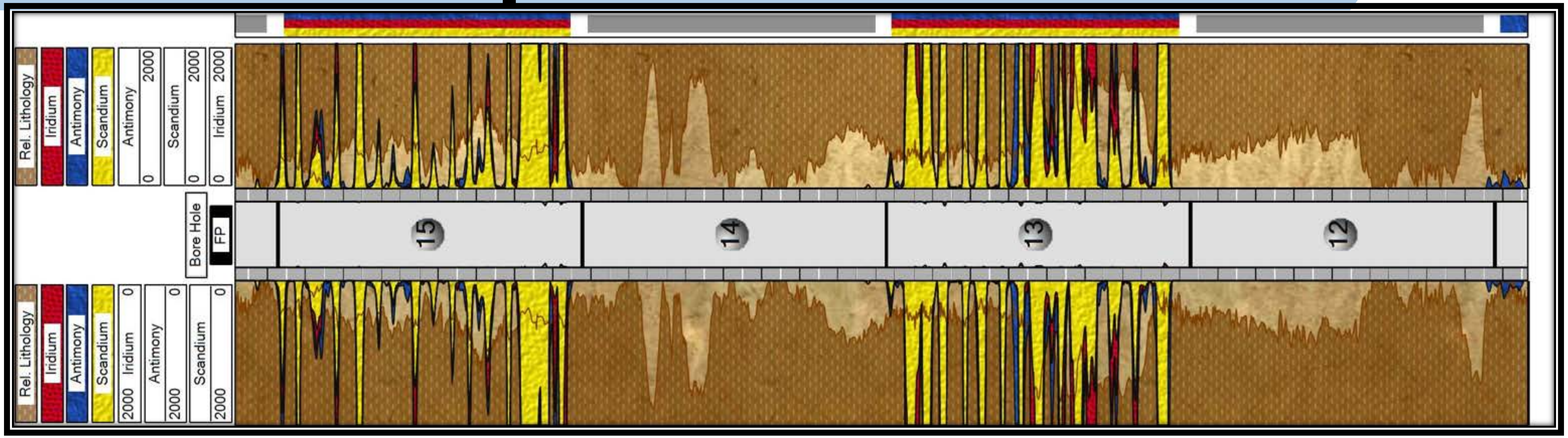
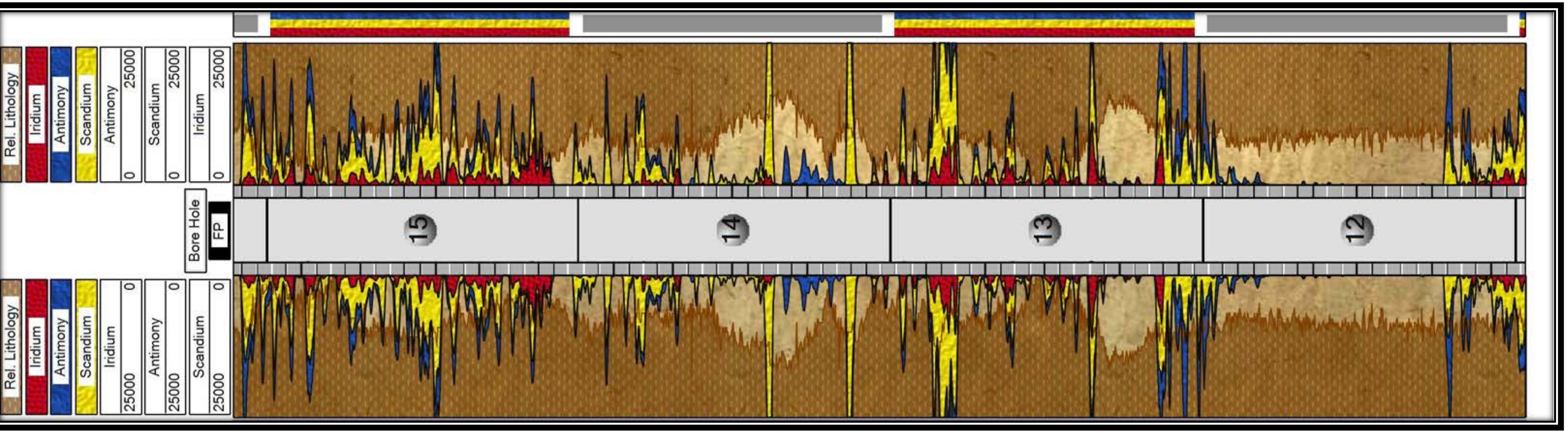
Agenda

- Project Background
- Diagnostic Overview
- Design of Experiment
- Pre/post-frac Imaging
- Oil Tracer Analysis
- Results

Expectations



Rotated & Centralized



Non-Rotated

Project Background

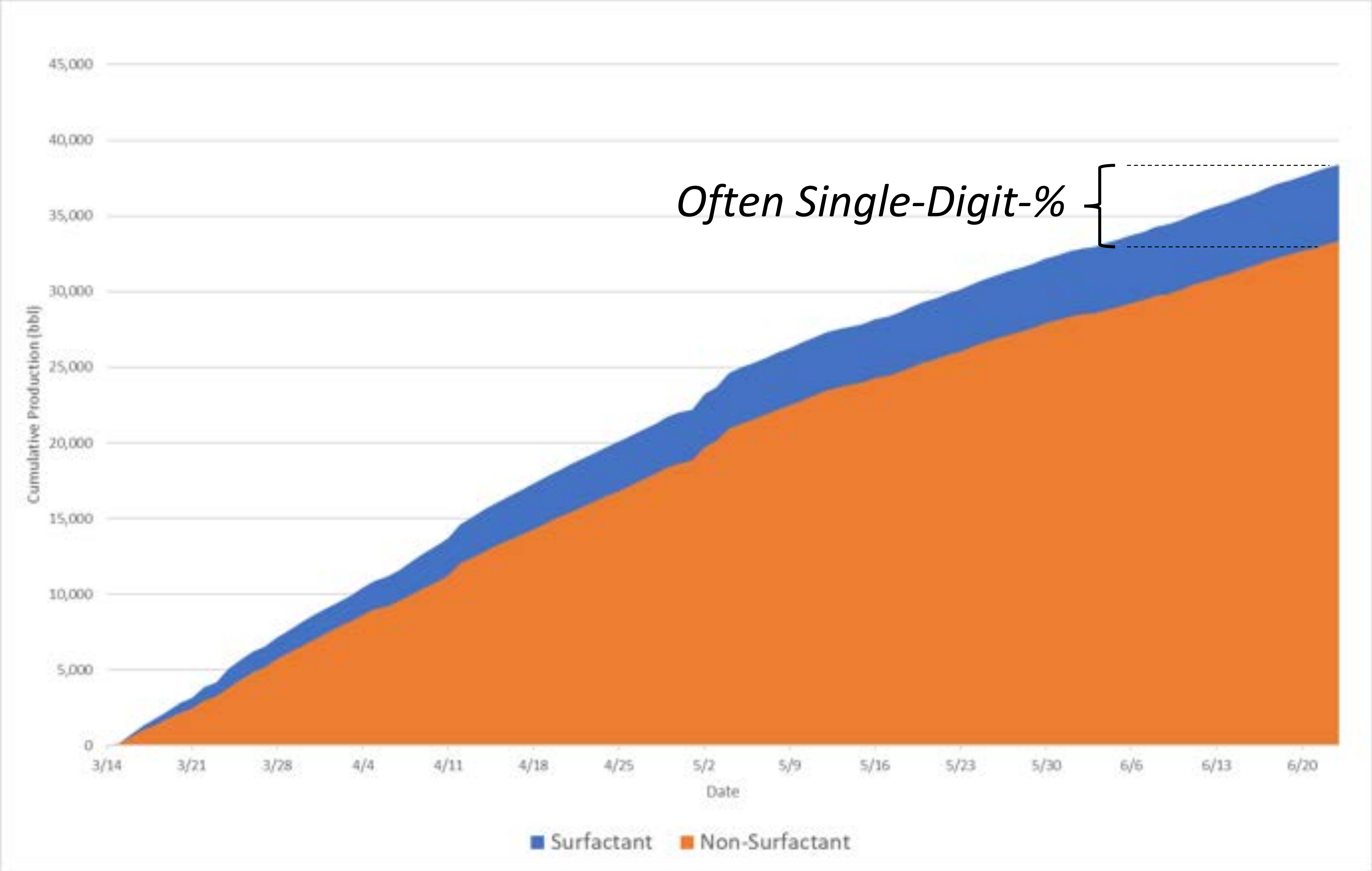
Looking for Answers to the Important Questions:

De-risk… Can we determine the %Uplift of using Strategy A vs. B, without having to experiment in too many wellbores/pads?

Full Cycle Perspective… We expect that any %Uplift from using Strategy A vs. B, will be single digits… Is there a way to measure such small differences for IP90 and IP180?

D&C/Reservoir Interactions… Is there a way to eliminate all the biases when testing Strategy A vs. B?

Project Background



More Specifically (example of AB Tests):

- Frac fluid chemistry (i.e. Surfactants)
- Perforation strategy (i.e. Oriented, #clusters)
- Frac Intensity (i.e. pounds of prop/ft)
- Use of the same strategy Bench A vs. Bench B.
- Etc.

***Attainable** following a Worldclass Methodology for Oil Tracer Selection to be Used for Diagnostics.*

Diagnostic Overview

Chemical Tracers

- Hydrocarbon soluble tracers are injected throughout the proppant-laden portion of the fracturing treatment.
- These hydrocarbon tracers are adsorbed into a solid 40/70 mesh medium which ensures that the tracers stay within the proppant pack.
- After fracture operations are completed, oil samples from the flowback stream are then caught and analyzed with gas chromatography/mass spectrometry to determine which tracers are present and at what concentrations.

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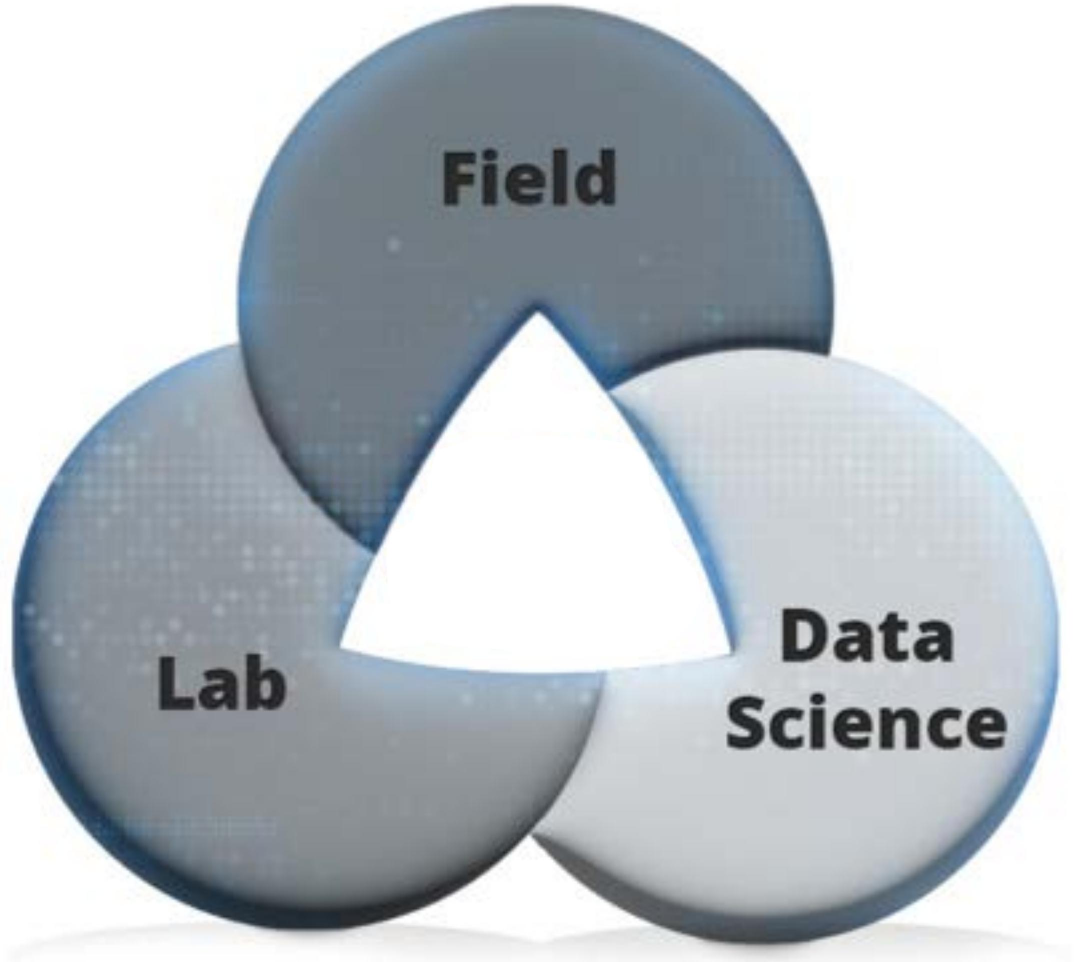
Diagnostic Overview

High Resolution Chemical Tracers



3-Tier Approach to the Selection of Tracers for A/B Testing:

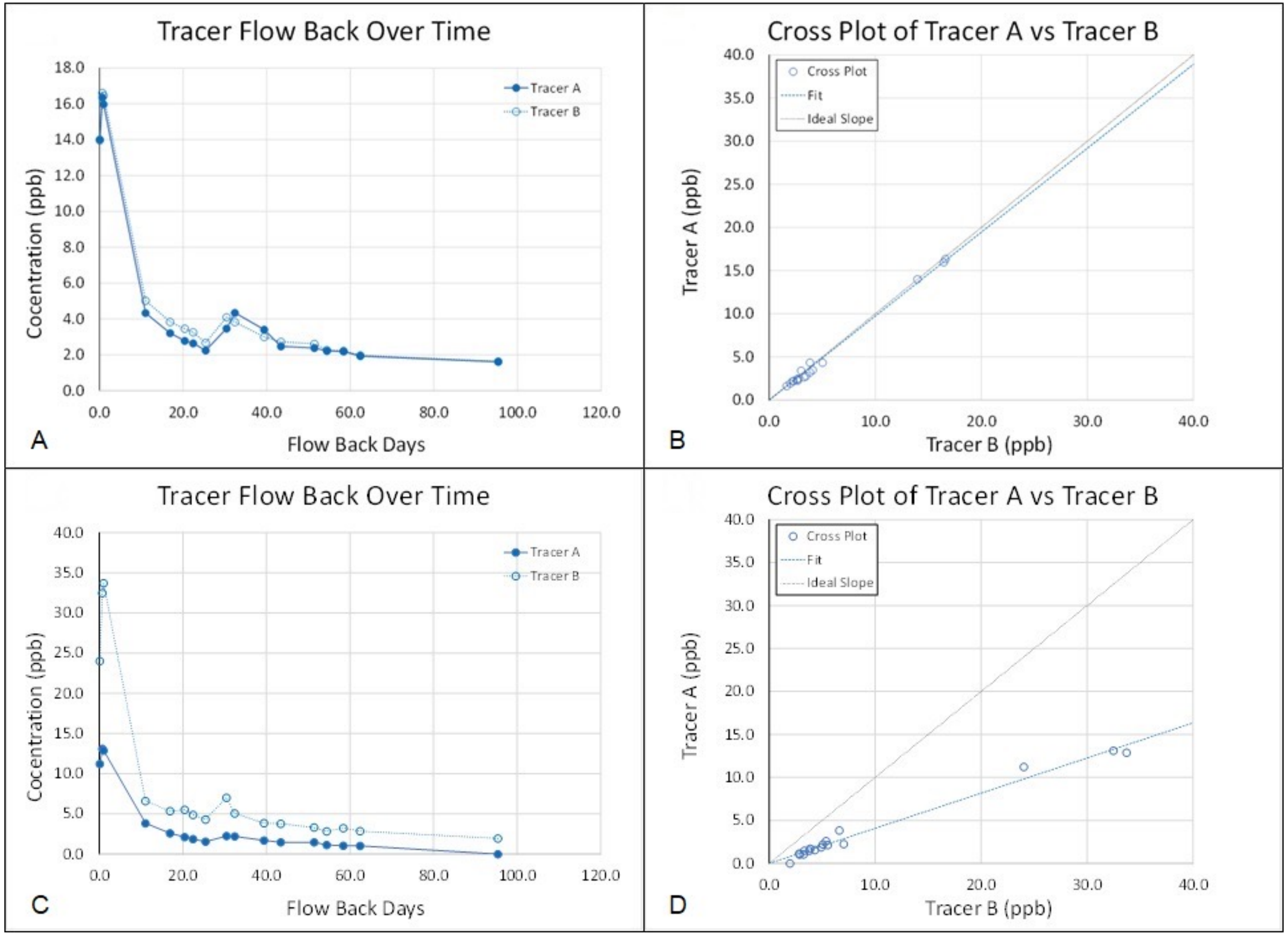
Data Science - We posses the biggest by far, dataset in the industry, we intend to use it for the benefit of our partners.

Field - Take the learnings from the computational modelling to the regional assets of our partners.

Duplication in the Lab - Are these results consistent, repeatable, is there an opportunity to fine-tune the enhancement in an extremely controlled setting?

Diagnostic Overview

- Chart displays both ideal tracer pairs (A/B) and non-ideal tracer pairs (C/D) to be utilized for high resolution AB testing.



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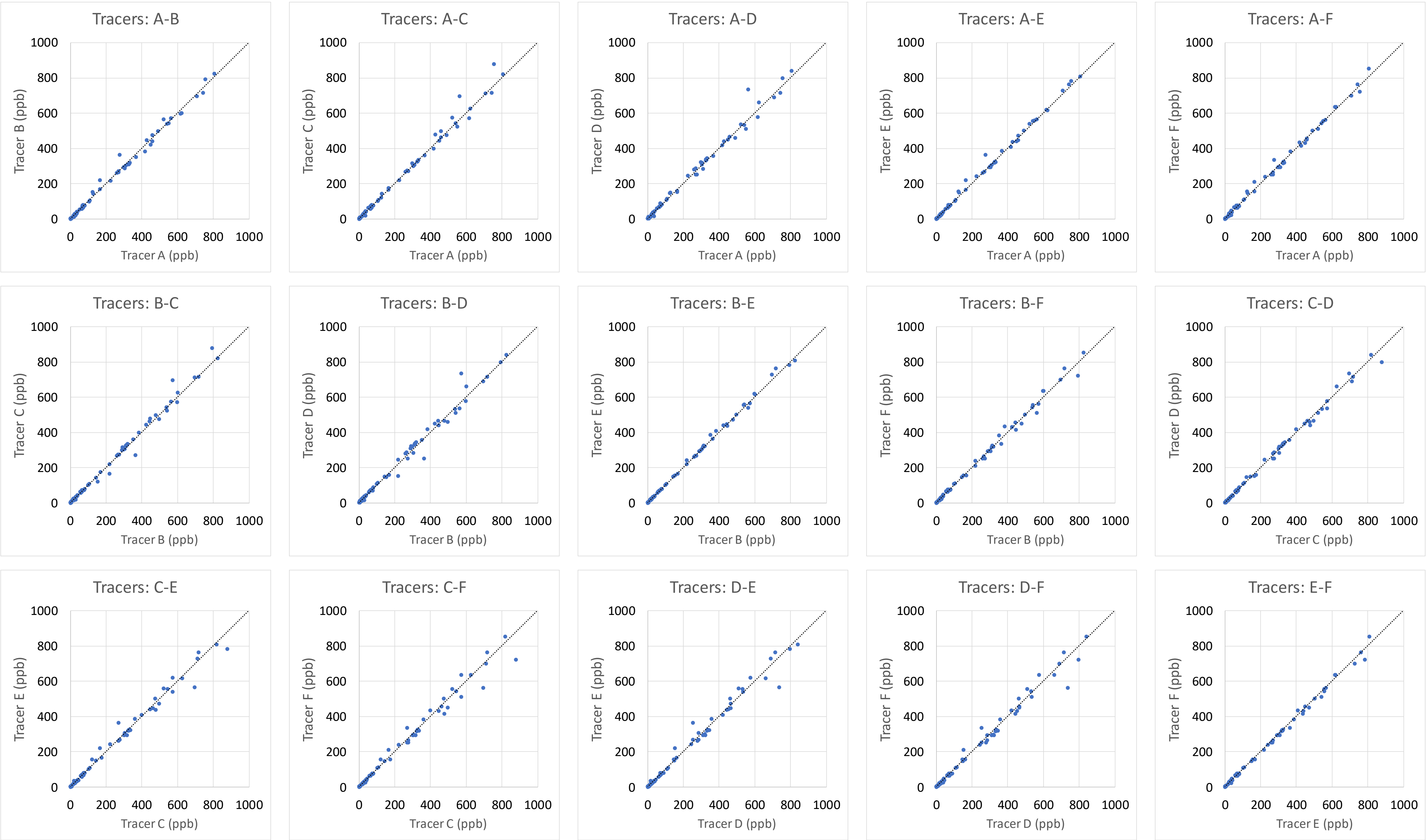
Diagnostic Overview

Field Calibration Test



1. Objective:

- Identify the optimal tracers for a specific Formation/Region.
- Upgrading of tracers for A/B Testing Methodology.

2. Process:

- At least in one wellbore (more is better).
- All available eOFT are blended.
- The blend of eOFT is injected in the same stage.
- Flowback samples are analyzed in a typical 10-to-25 samples in a 3-month period.

3. Results:

- Tracer-to-Tracer comparison. (Well and Database)
- Ranking/ Upgrading takes place. (Statistical Significance is assessed)
- Results are discussed with Company for the selection of tracer for the application.

Design of Experiment

Test Design	Cluster Spacing	Flow Area / 300'	Stages	Footage	OFT Pumped
300' Top Shots	X	X	14	4,200'	3200 g
300' 90/270	X	X	14	4,200'	3200 g
150' Top Shots	0.5X	2X	28	4,200'	3200 g

Figure 1—Simple design summary alternating stage architecture every 300'.

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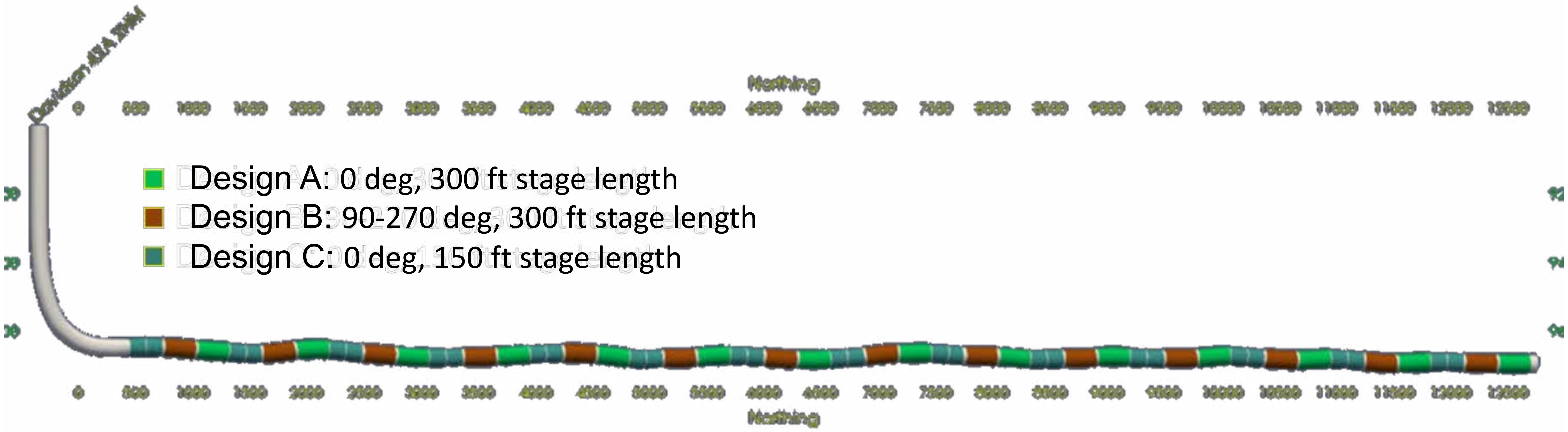
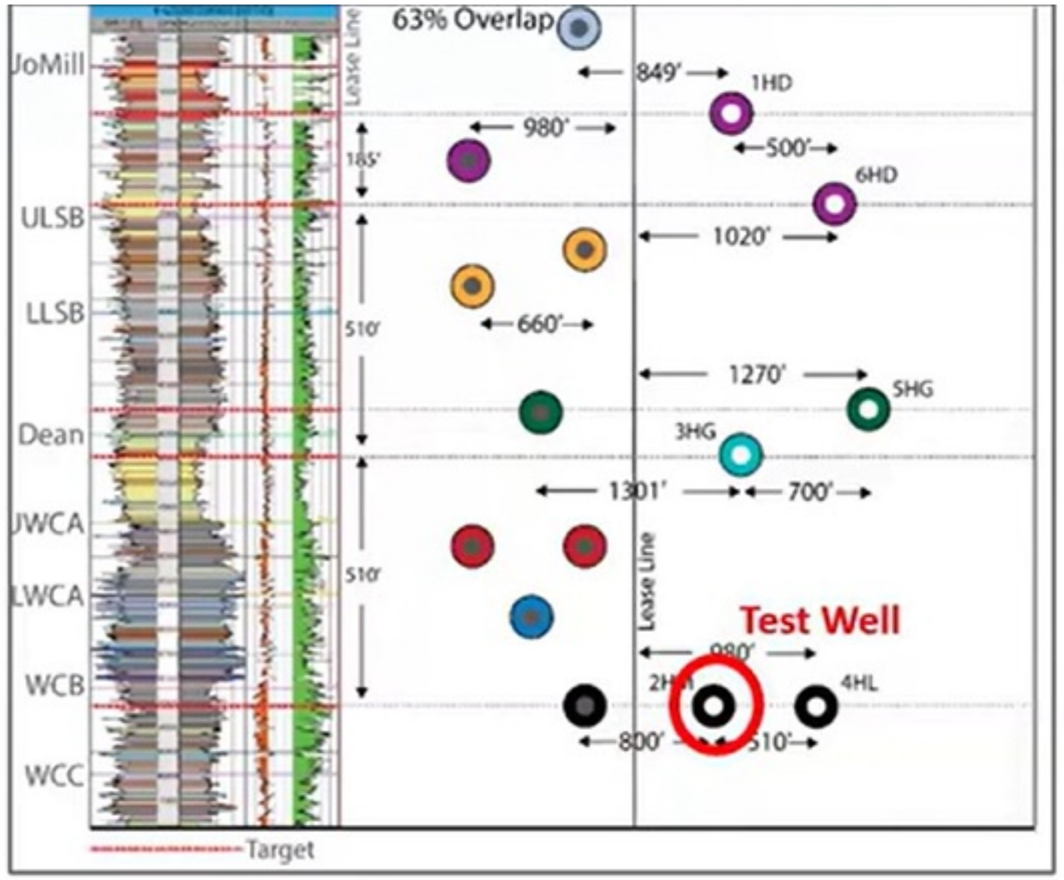


- In addition to oil soluble tracers the operator also deployed a down-hole imaging tool as well as a carbon fiber rod.

Design of Experiment

Design of Experiment

Objective: Determine how different stage architecture configurations affect long and short-term production (ppf and gpf held constant, perf friction lower with 90/270)



<u>Diagnostic Tools</u>

- High Frequency Accelerometer Geo Data
- Camera/Ultrasonic Imaging
- Oil Tracer
- Fiber Rod

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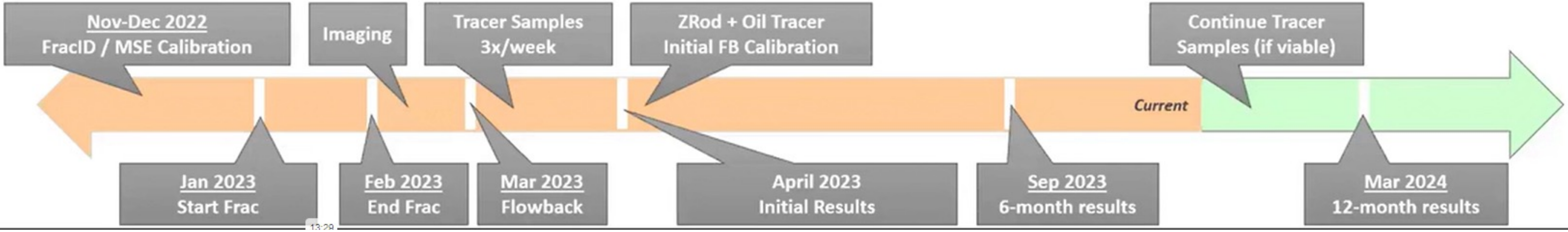

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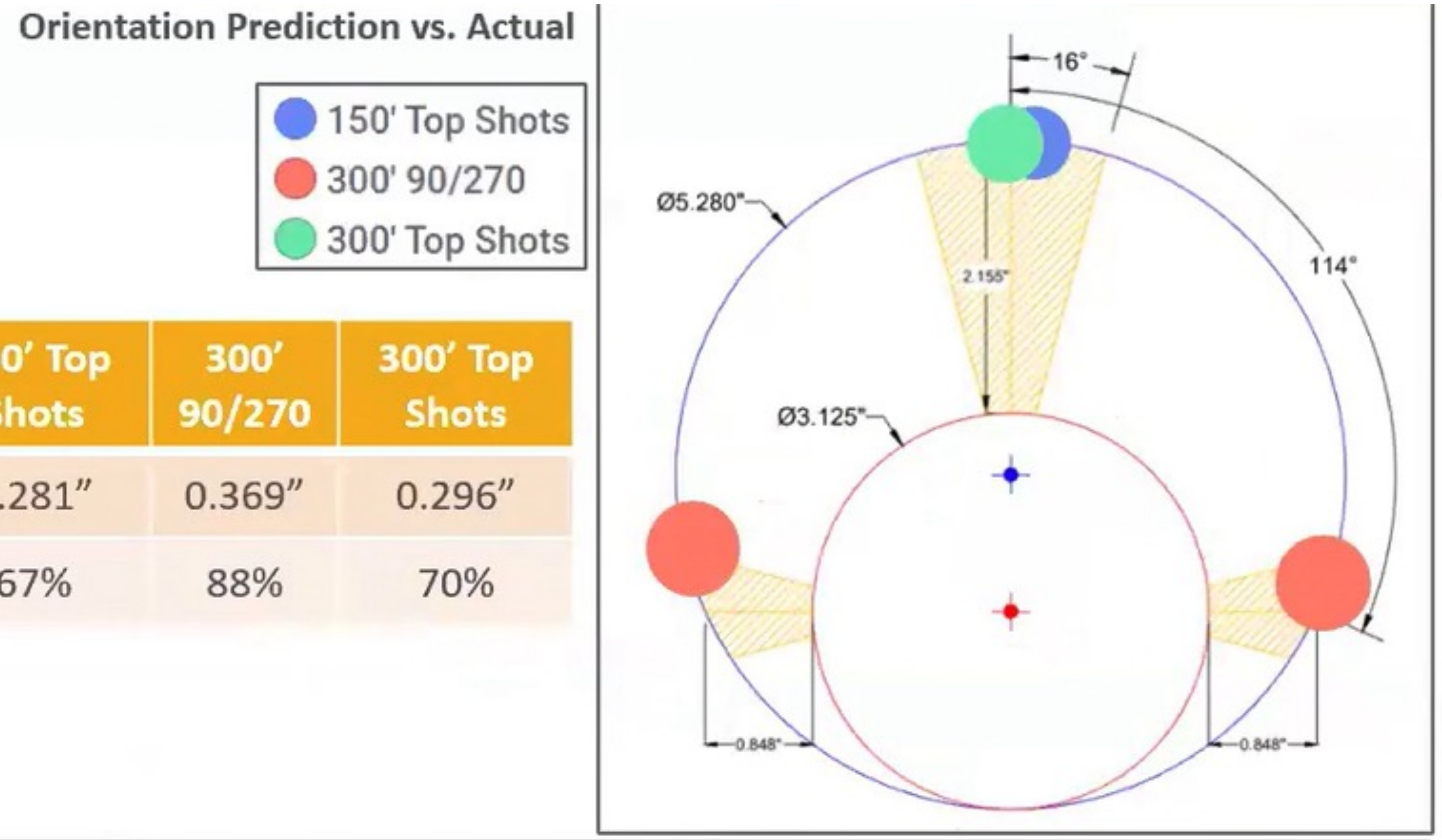
Pre/Post Frac Imaging

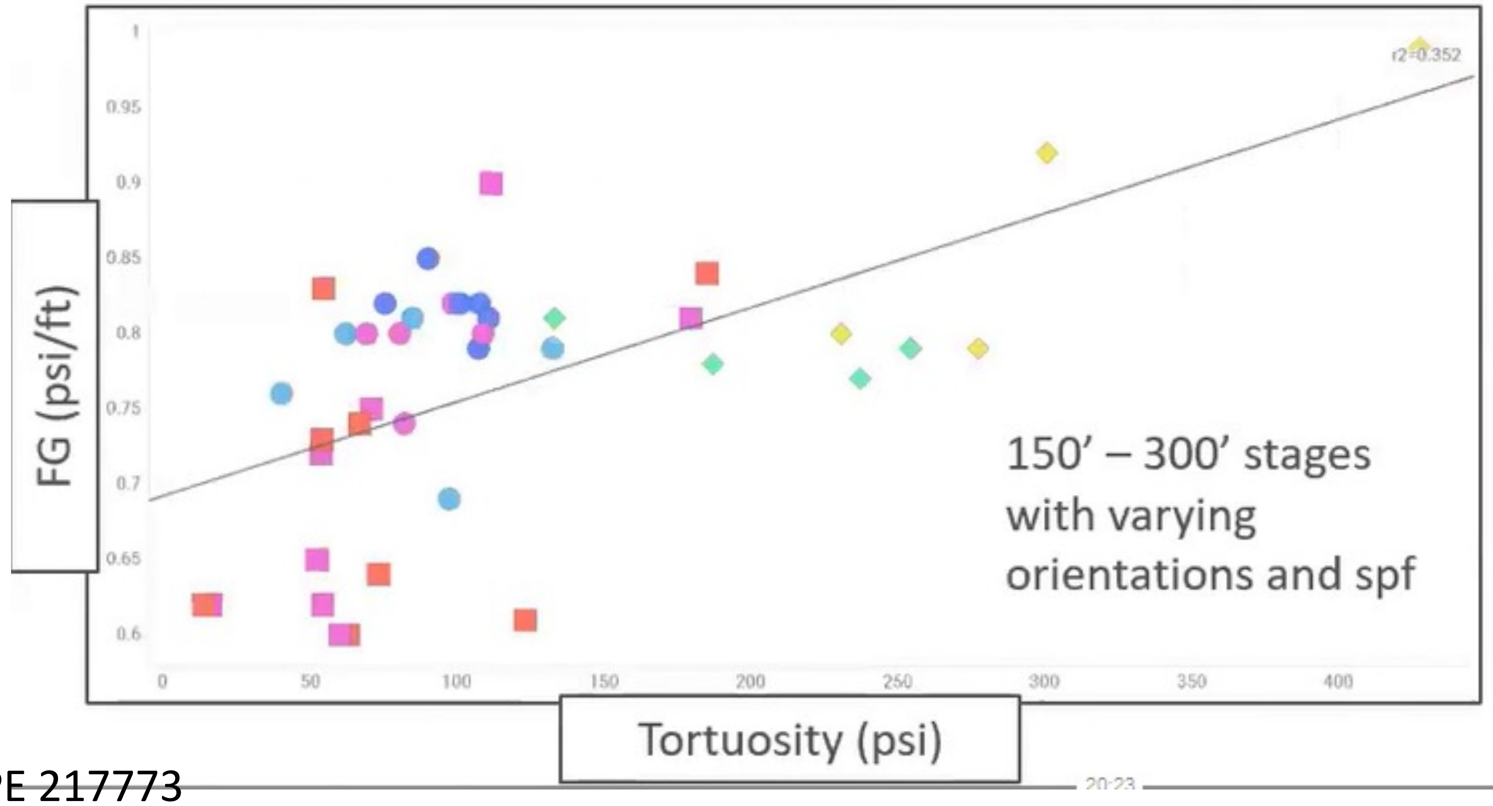
Pre-frac Imaging and Step Down

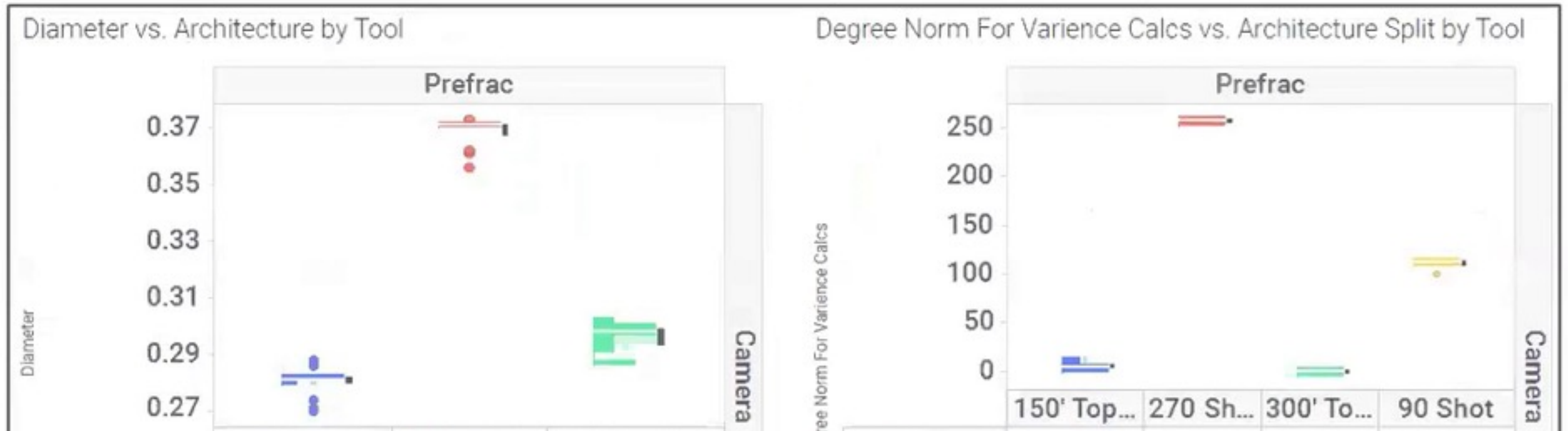
Key Observations

- Diameter
  - Solid uniformity regardless of orientation
  - Designed EHD shot 12-33% smaller (usually ~20% in 5.5" csg)
  - 90/270 shot 0.073" larger than 300' top shots
- Orientation
  - Self-orienting guns continue strong performance
  - Largest standard deviation = +/- 5.1 degrees
- Step Down Tests
  - Fracture Gradient has greatest influence on tortuosity



0.42" Charge	150' Top Shots	300' 90/270	300' Top Shots
Avg EHD	0.281"	0.369"	0.296"
% of Spec	67%	88%	70%





	150' Top Sh...	300' 90/2...	300' Top Sh...
Count	32	18	12
Avg	0.281	0.369	0.296
Outliers	5	4	0
StdDev	0.003	0.005	0.005
StdErr	0.001	0.001	0.002

	150' Top...	270 Sh...	300' To...	90 Shot
Count	32	9	12	9
Avg	4.543	256.899	-1.014	109.945
Median	3.469	257.660	-0.638	111.112
Outliers	0	0	0	1
StdDev	5.122	3.911	3.233	5.066
StdErr	0.905	1.304	0.933	1.689

Pre/Post Frac Imaging

Post-frac Perf Size & Orientation

Key Observations
- Diameter
  - Solid uniformity regardless of orientation
  - Smaller shots eroded more
  - **Uniform erosion for all designs**

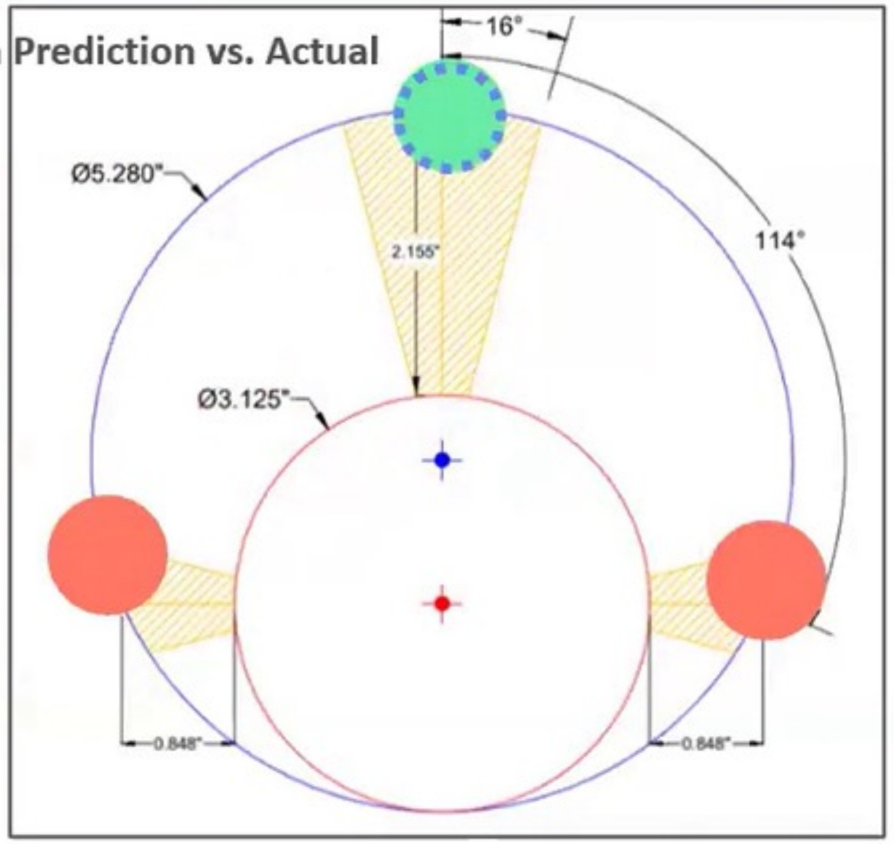
- Orientation
  - Self-orienting guns continue strong performance
  - Largest standard deviation = +/- 8.4 degrees

Key Takeaways
- High cluster efficiency for all designs
- Larger hole size in 6” casing led to FR savings while maintaining CE
- **Possible to reduce treating pressure by ~1,000 psi and reduce FR consumption if we can identify a charge that shoots ~0.37” at 0 degrees in 6” csg**
  - Dugan Hughes presented on this spinoff a few months ago…go watch it if you didn’t catch it live!

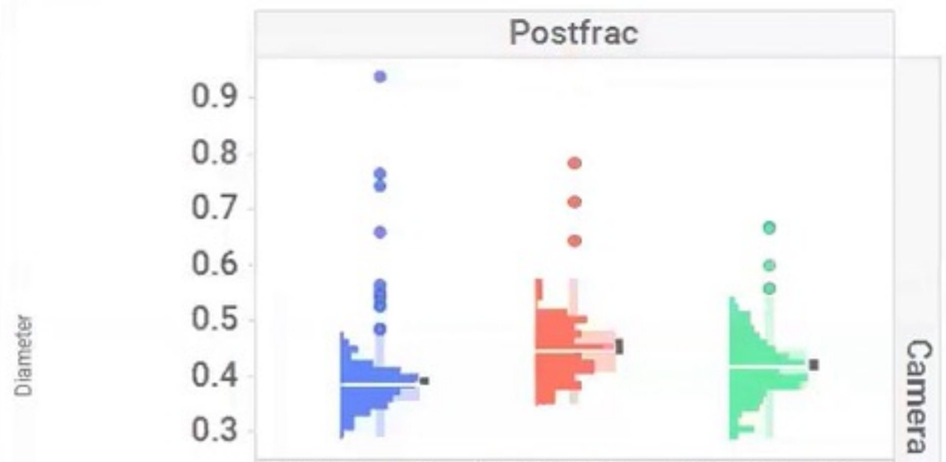
150' Top Shots
300' 90/270
300' Top Shots

0.42” Charge	150’ Top Shots	300’ 90/270	300’ Top Shots
Initial EHD	0.281”	0.369”	0.296”
Final EHD	0.390”	0.453”	0.417”
Growth	+0.109”	+0.084”	+0.121”
% Growth	+39%	+23%	+41%
% of Spec	93%	108%	99%

Orientation Prediction vs. Actual



Diameter vs. Architecture by Tool



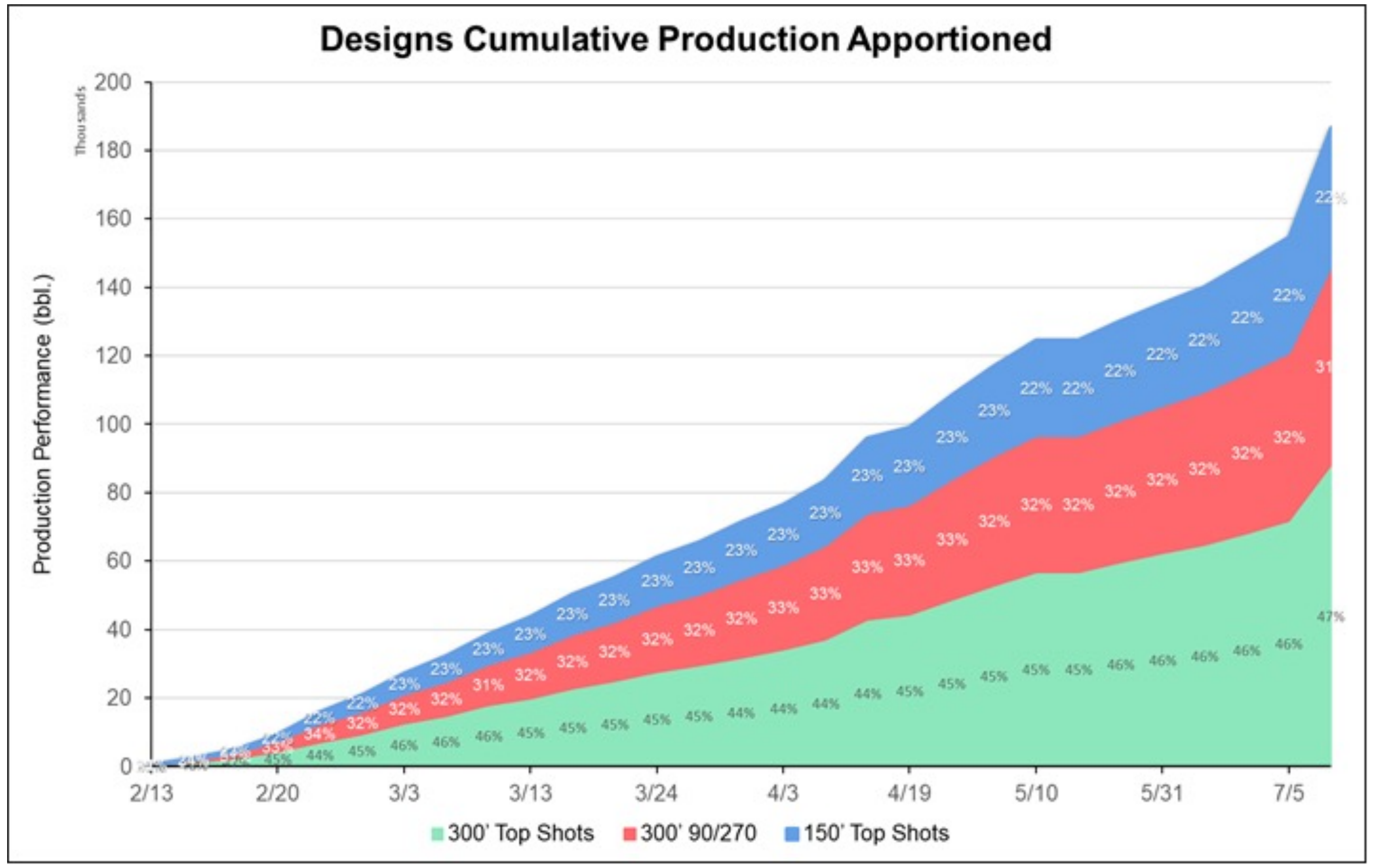
	150' Top Sh...	300' 90/2...	300' Top Sh...
Count	309	94	168
Avg	0.390	0.453	0.417
Outliers	14	3	5
StdDev	0.063	0.068	0.063
StdErr	0.004	0.007	0.005

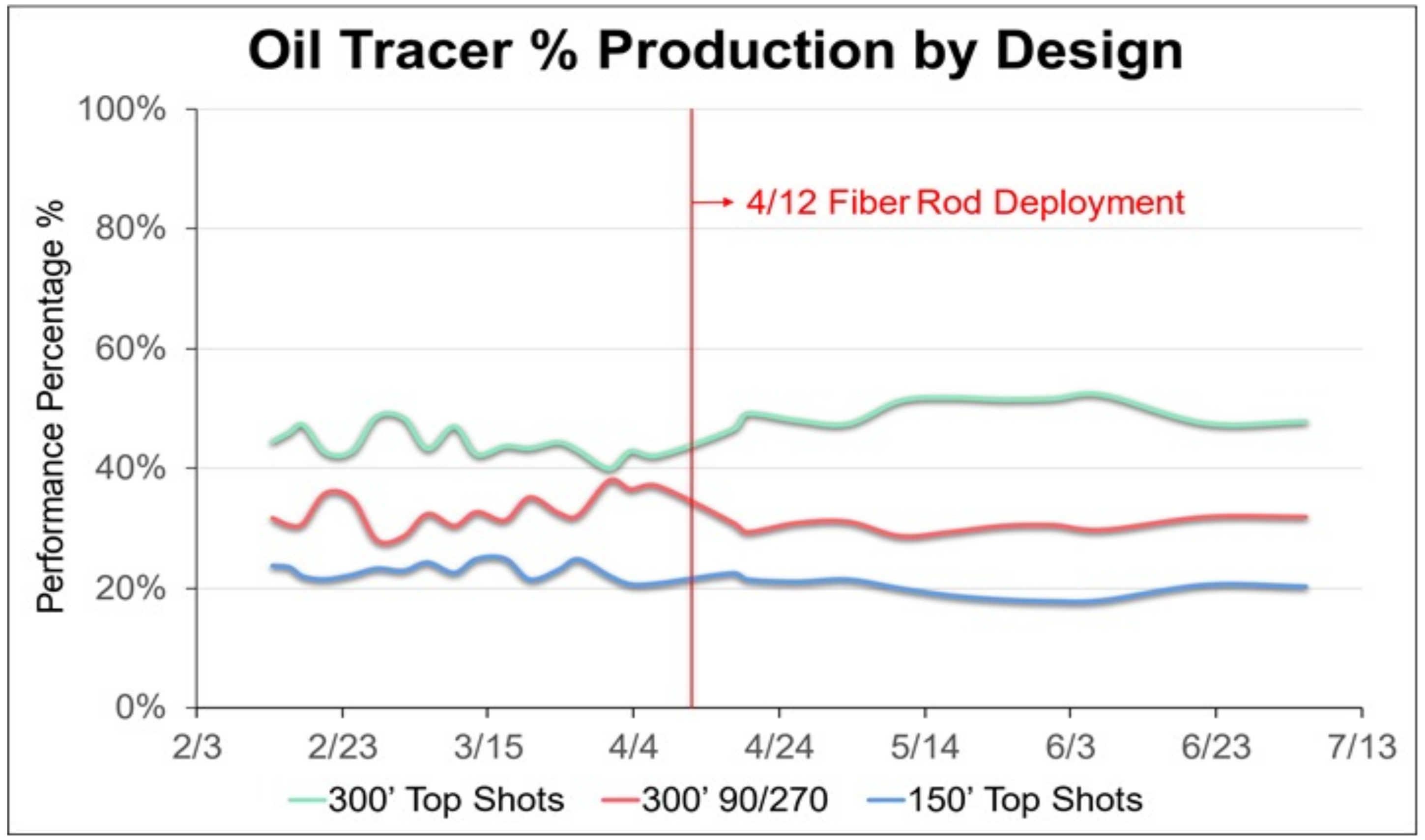
Degree Norm For Varience Calcs vs. Architecture Split by Tool

	150' Top...	270 Sh...	300' To...	90 Shot
Count	309	48	168	46
Avg	0.321	254.665	0.746	109.582
Median	0.483	254.042	0.595	107.833
Outliers	8	1	6	0
StdDev	6.585	7.134	8.391	7.903
StdErr	0.375	1.030	0.647	1.165

Oil Tracer Analysis

- Standard design is contributing about 44$ of production.
- Contribution by design has stayed relatively flat.
- Smaller stage lengths show the lowest contributions overall and on a per stage basis





Results

- Camera/ultrasonic data showed uniformity across all designs
- No clear trend with perf erosion and cluster performance
  - 150′ top shots did have a handful of more eroded perfs
    - In previous data sets these perfs were some of the worst producers.
- 300′ top shots showed the highest production based on the high resolution oil tracer data.

Conclusion

- Checkerboarding completion designs along a single wellbore with A/B testing can lessen variability
- Flowback of completion design oil tracers has stayed consistent over time with 300’ top shots leading the pack
- Integrated data sets show:
    - Stage performance more indicative of lateral placement than depletion
    - The handful of more eroded perfs correlate with poorer performance
- Rod and tracer data agreed on a cluster level
    - Further tracer normalization improves the correlation between tracer and fiber

Metric	300’ Top Shots	300’ 90/270	150’ Top Shots
FracID Depletion	● (light blue)	● (light blue)	● (light blue)
Surface Treating	● (yellow)	● (green)	● (yellow)
Cluster Efficiency	● (green)	● (green)	● (green)
Tracer Production	● (green)	● (yellow)	● (red)
Rod Produciton	● (light green)	● (red)	● (green)

What do you think?

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