



Stimulation Simulation – Where is the Value?

Tobias Hoeink
BHGE Digital

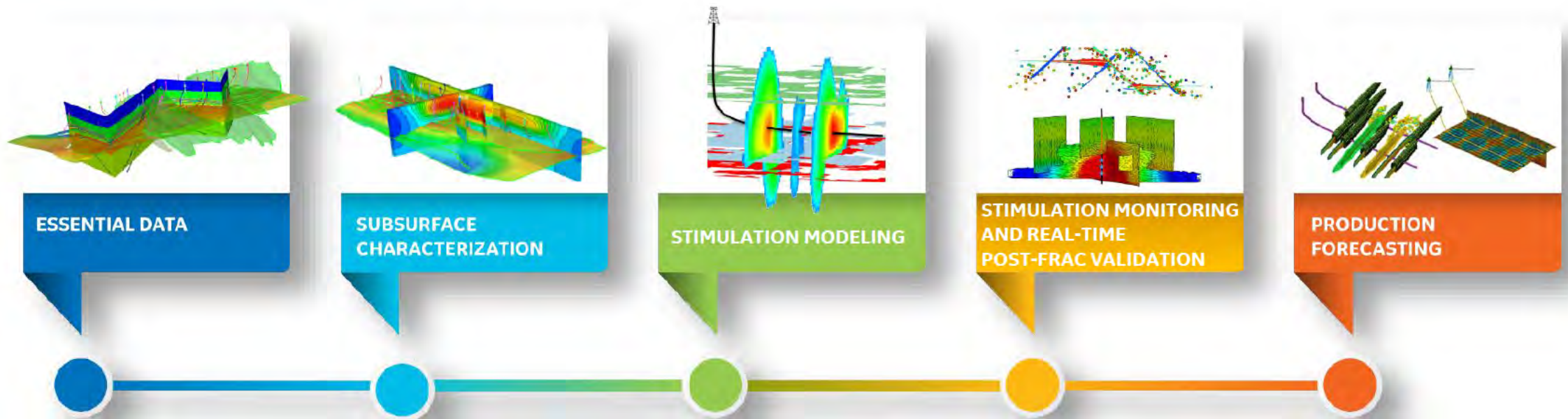
April 5, 2018

Confidential. Not to be copied, distributed, or reproduced without prior approval.

© 2018 Baker Hughes, a GE company, LLC - All rights reserved.

Stimulation Simulation

Unconventional Work Stream



Modeling & Simulation – Where is the Value?

Why model? What's in it for me?

Understand how nature works

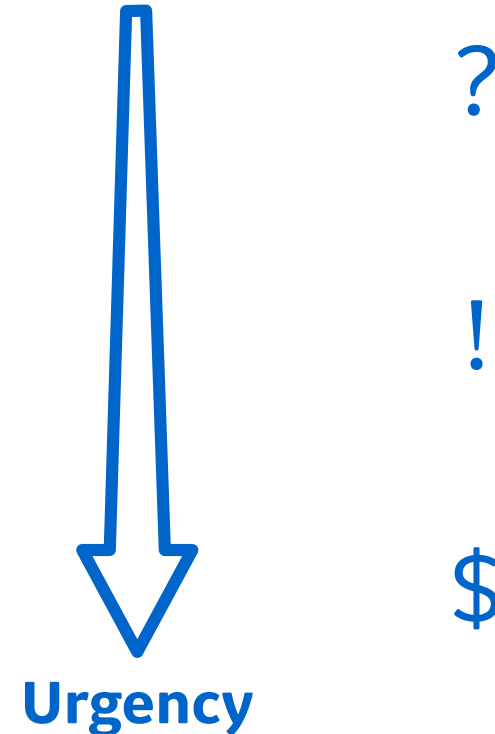
- Find something new and unexpected (then explain and understand it)
- Go beyond linearity, beyond analytical capabilities

Reputation – own/run the most sophisticated model

- Demonstrate excellence, technical advancement

Business case

- Need actionable answers to specific, well-defined questions now
- Asset optimization
- Risk mitigation



Stimulation Simulation – Where is the Value?

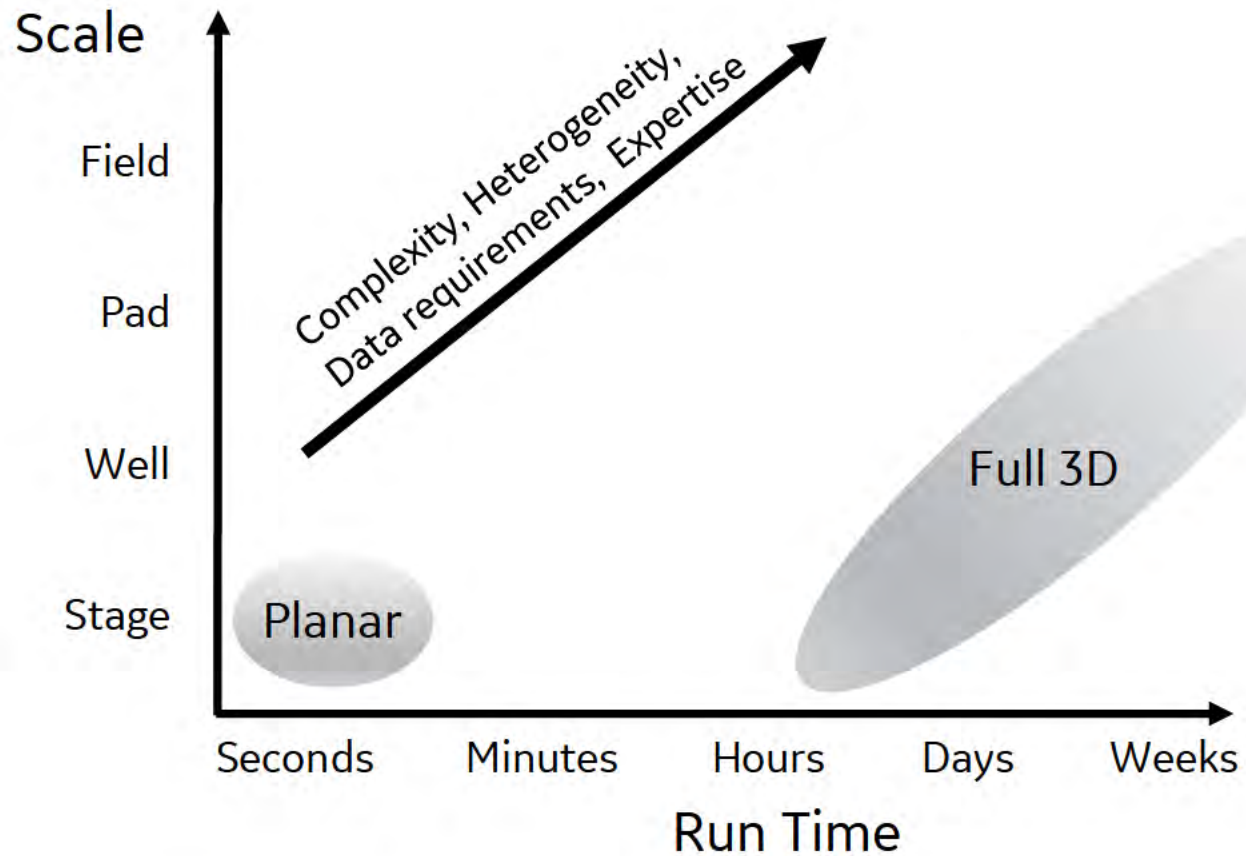
(Numerical) Modeling/Simulation of Hydraulic Stimulation

- **Optimize** landing zone, completion design, treatment
- **Maximize** connected conductivity
- **Avoid** frac hits, containment loss
- Postmortem - **Understand** complications in the field, avoid recurrence

What tool will you use?

HF Modeling Value & Complexity Spectrum

Where is the value?



Modeling

- Reduction of reality to the essential components
- Not more and not less
- If in doubt, make educated decision (aka. modelers choice)

Choice of Model

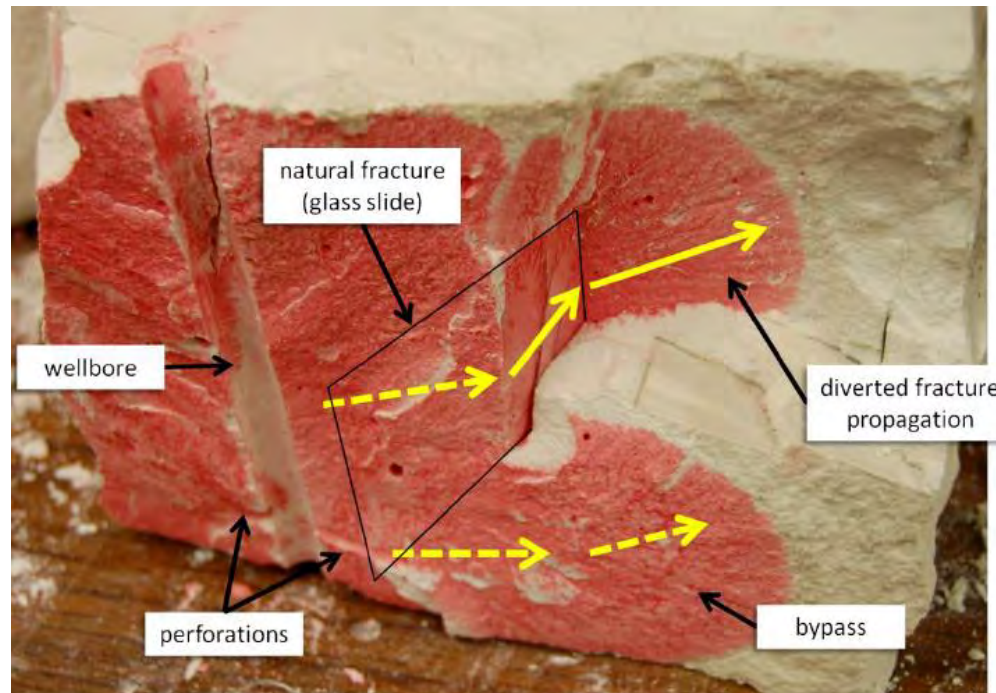
- The right tool for the job
- Which model do I need?
- What do I need to model?

Purpose of stimulation modeling?

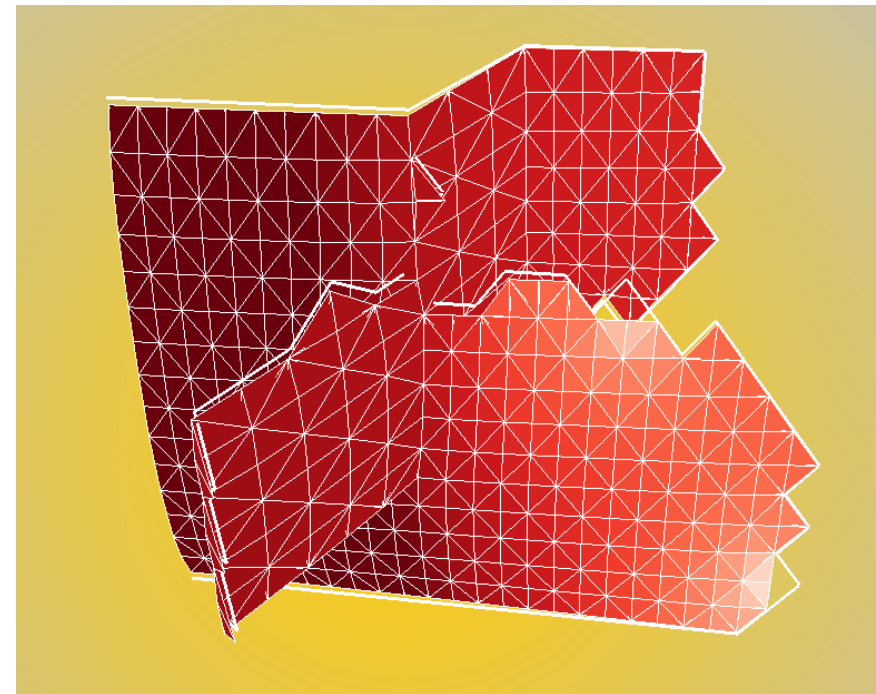
- What answer can a model provide?
- What answer do we need from a model?

Advanced 3D Modeling with Discontinuities

- Complex interaction between hydraulic fractures and discontinuities (i.e., natural fractures, heterogeneities, layer boundaries)



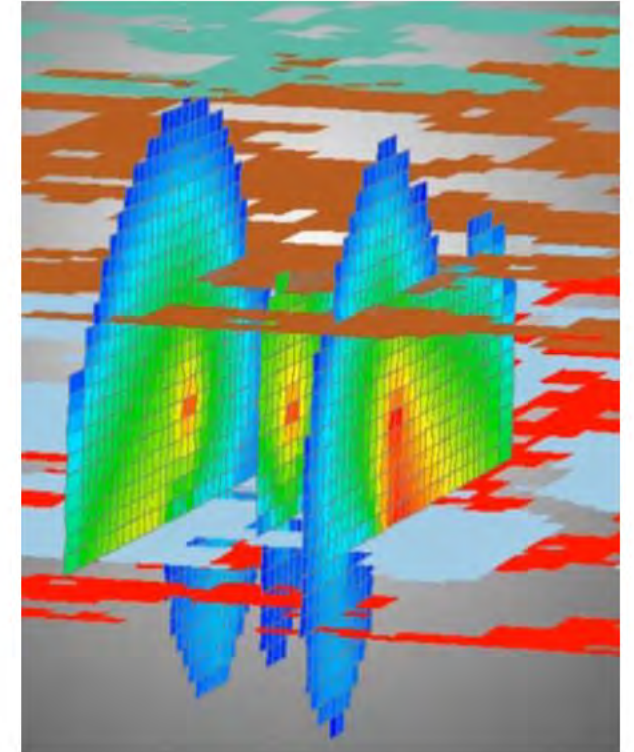
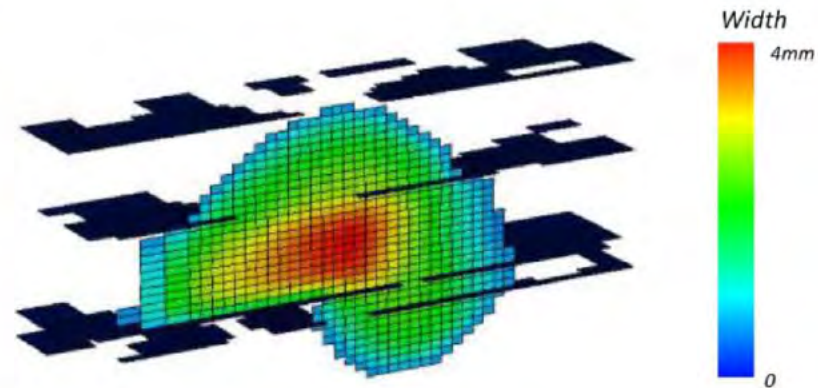
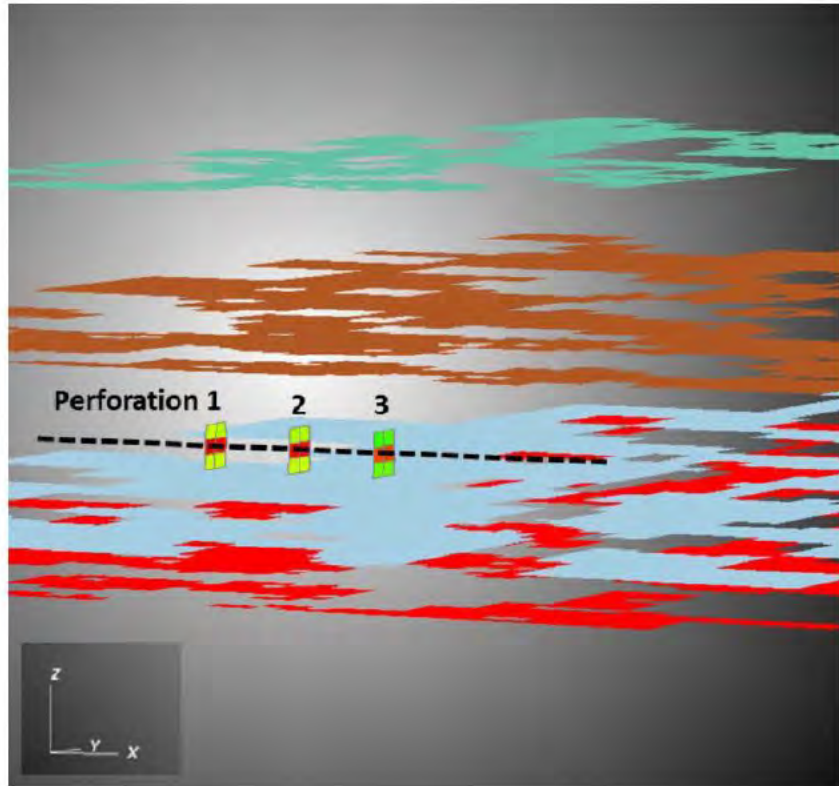
(from Bahorich and Olson, 2012)



Advanced 3D model

Stimulation with Structural Features

- Hydraulic fracturing in the presence of weak interfaces

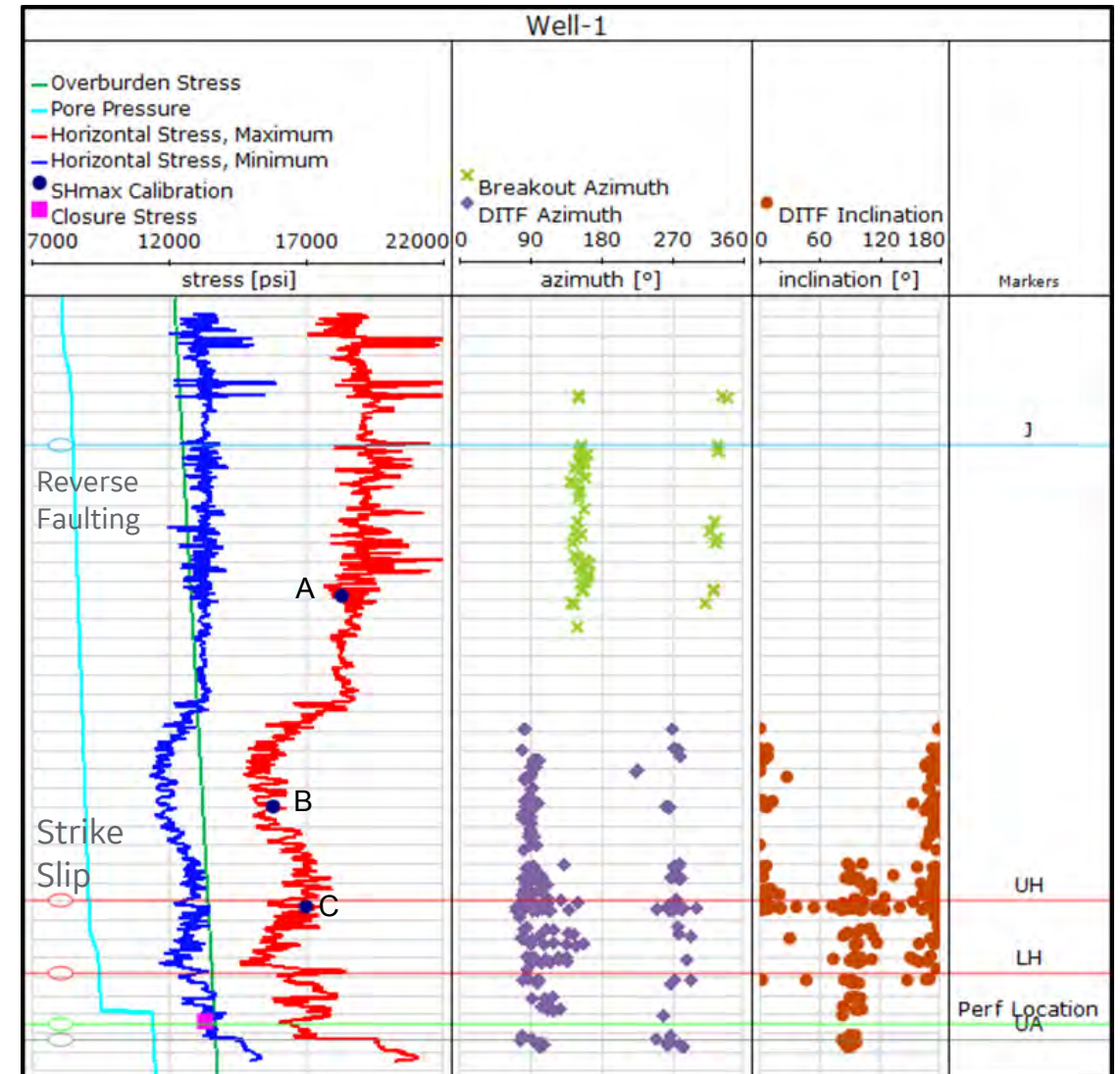


Izadi et al. (2017)

Full 3D Modeling (Offshore UAE)

Complex Carbonate Reservoir

- Log derived stress and log analysis confirm complex switch between stress regimes in landing zone (reverse faulting – strike slip)
- Q: Impact of weak bedding planes?

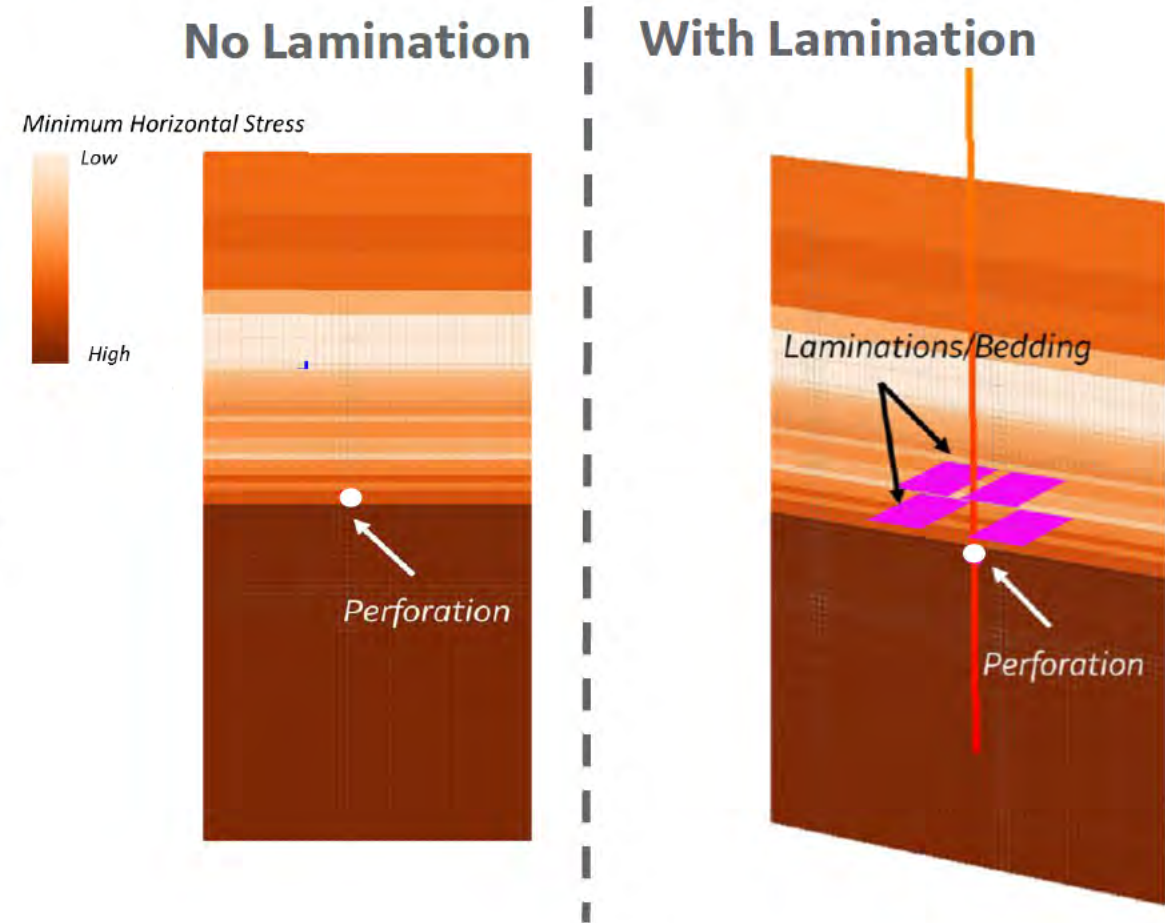


Izadi et al. (2018)

Full 3D Modeling (Offshore UAE)

Complex Carbonate Reservoir

- Log derived stress and log analysis confirm complex switch between stress regimes in landing zone (reverse faulting – strike slip)
- Q: Impact of weak bedding planes?

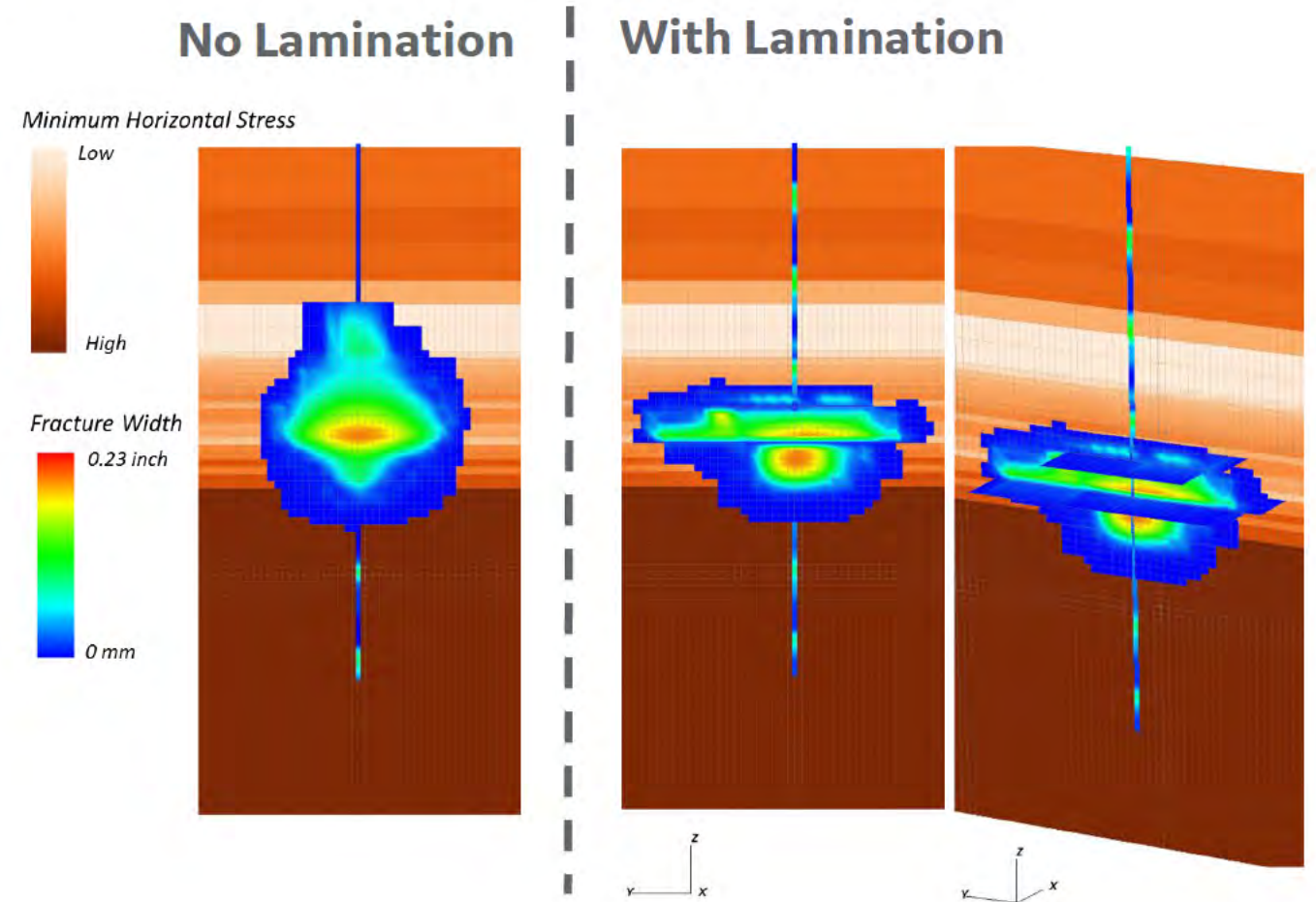


Izadi et al. (2018)

Full 3D Modeling (Offshore UAE)

Impact Of Weak Bedding Planes

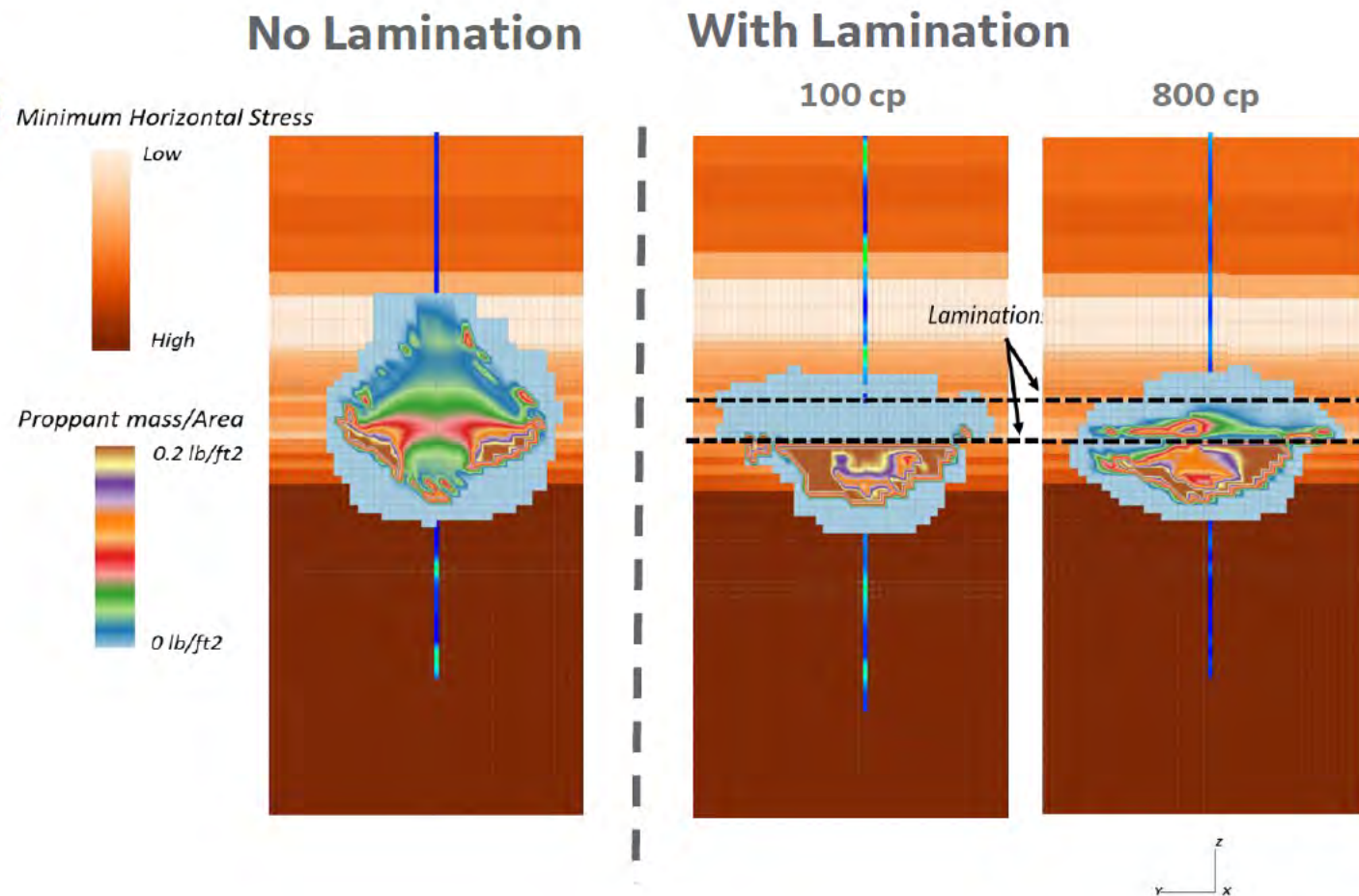
- Height growth is contained where fractures intersect weak portions of bedding surfaces.



Full 3D Modeling (Offshore UAE)

Impact Of Weak Bedding Planes

- Height growth is contained where fractures intersect weak portions of bedding surfaces.
- Most of the proppant settles below the laminated interval, substantially reducing propped height coverage.
- With increased viscosity, proppant can bypass laminations; some proppant placed in laminations.

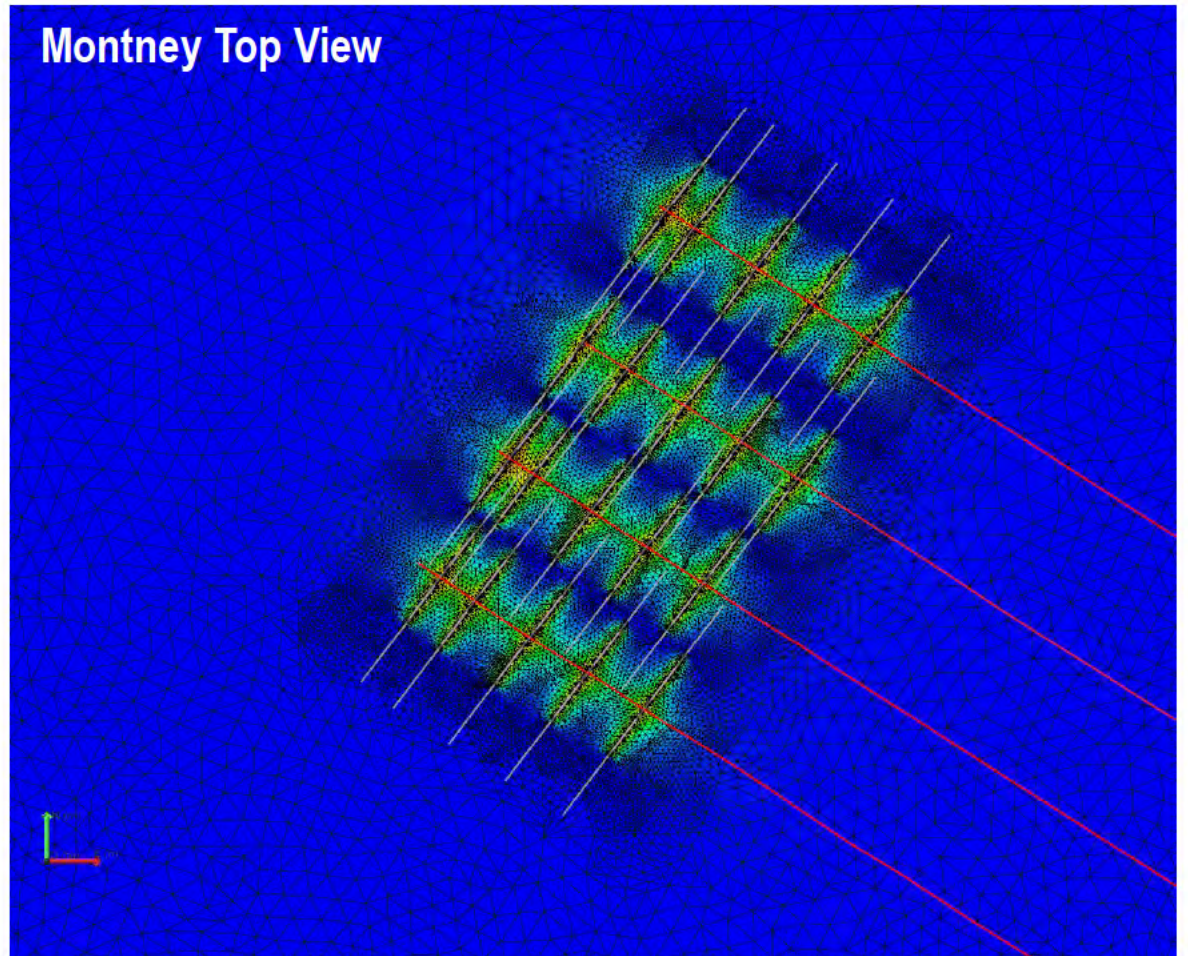
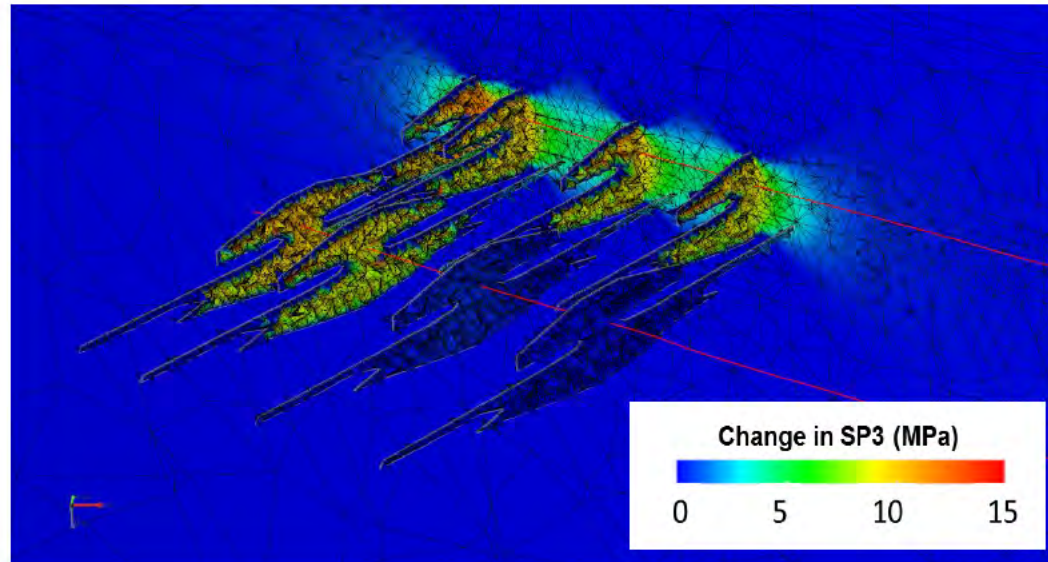


Izadi et al. (2018)

Full 3D & Analytical Modeling (Montney, CA)

Stress Perturbation

- 4 parallel, horizontal wells with 300m spacing
- 5 irregular fractures along each well in staggered configuration

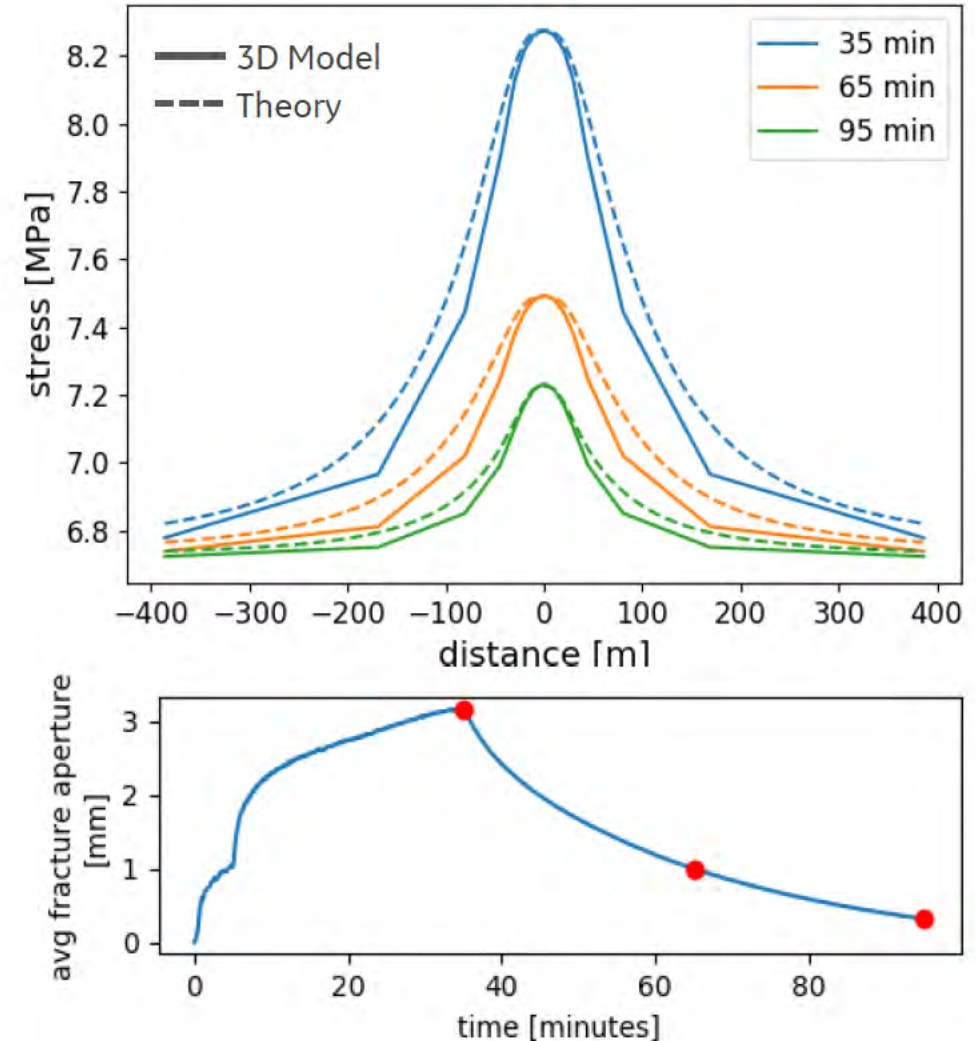


Hoeink et al. (2018)

Full 3D & Analytical Modeling

Stress Perturbation During Shut-in

- Compressive formation stress closes fracture
- Fluid leaks off
- Pressure drops
- Fracture shrinks
- Stress shadow reduces
- Analytical model captures effect to first-order

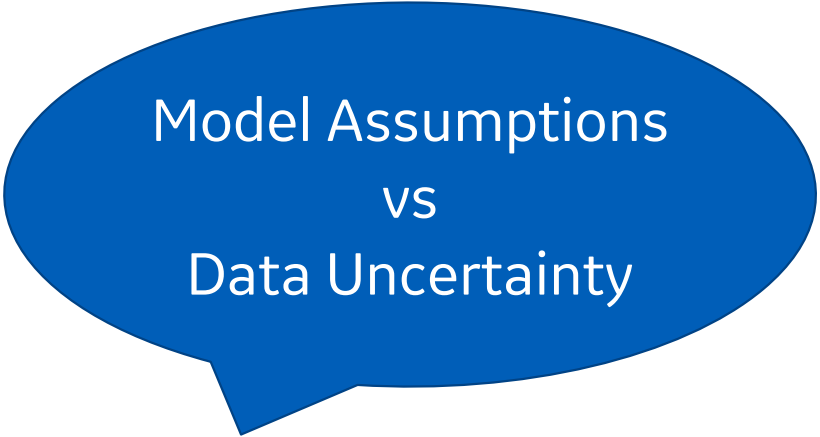


Hoeink et al. (2018)

Where is the Value?

Quotes from 2018 SPE HFTC

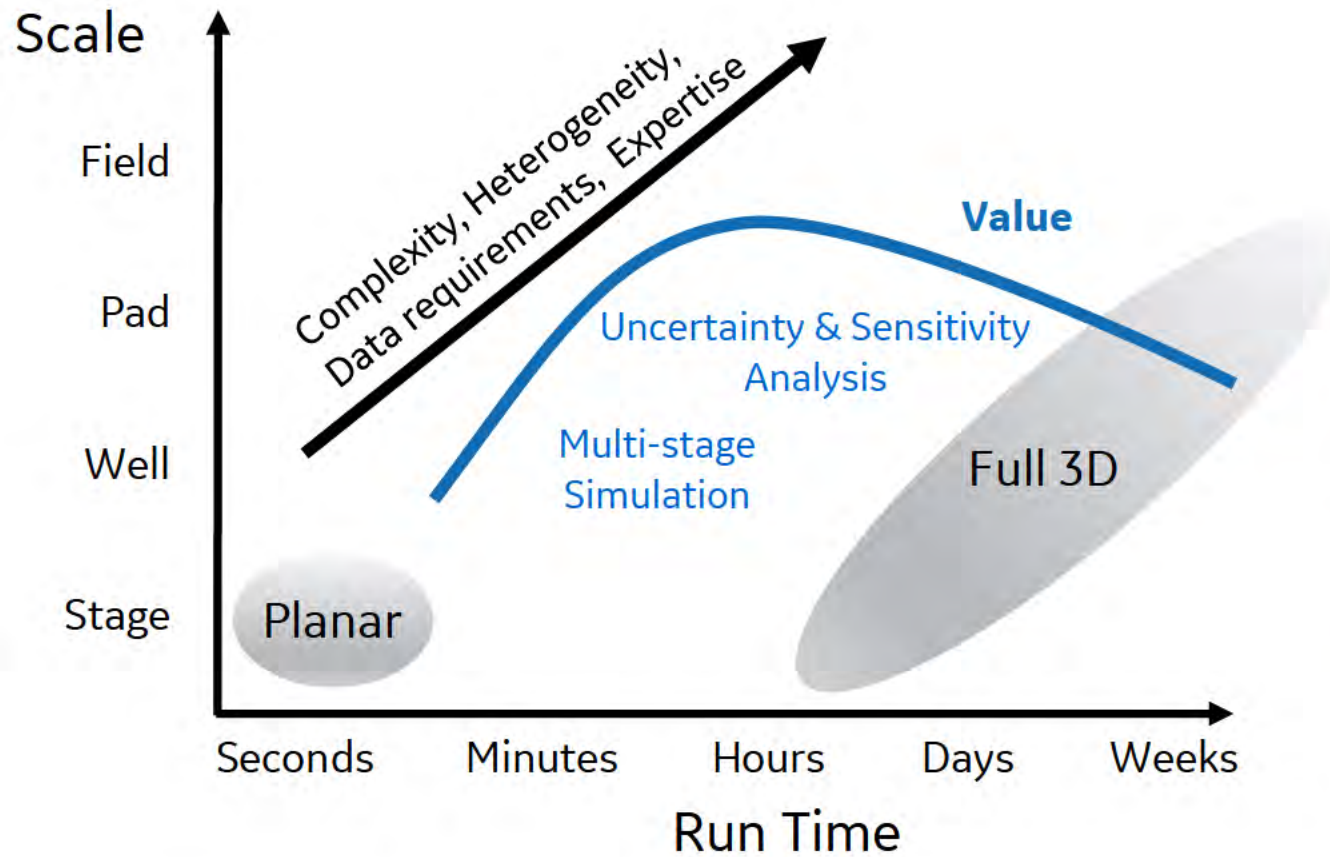
- You cannot learn anything from 3 models when you have 20 variables.
- Fancy models are “intuition enhancers”.
Need sensitivity analysis.
- Simple model has fewer knobs to turn, complex models are harder to use, results are similar.



Model Assumptions
vs
Data Uncertainty

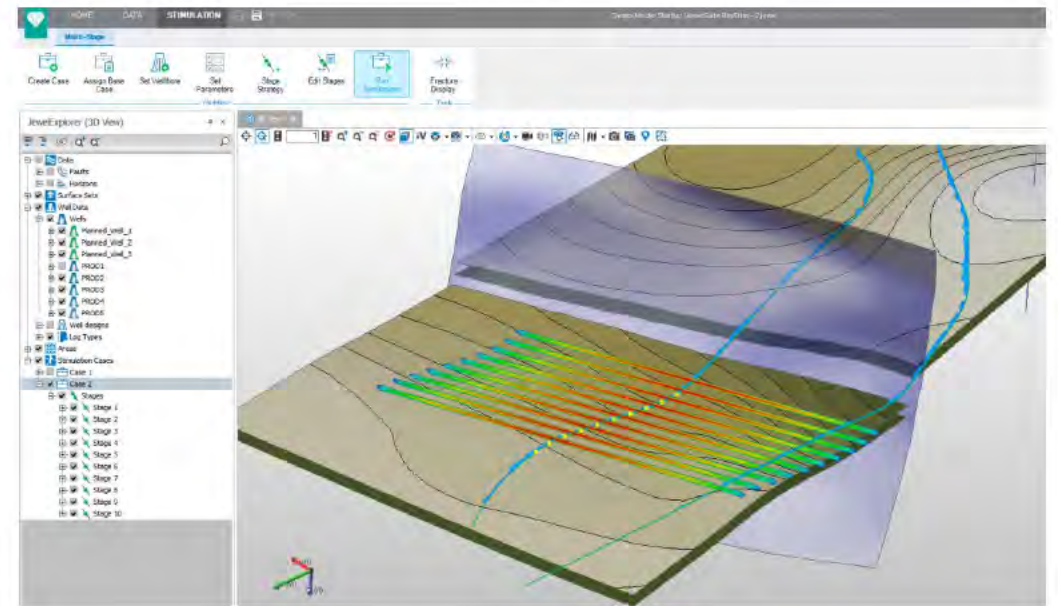
HF Modeling Value & Complexity Spectrum

Where is the value?



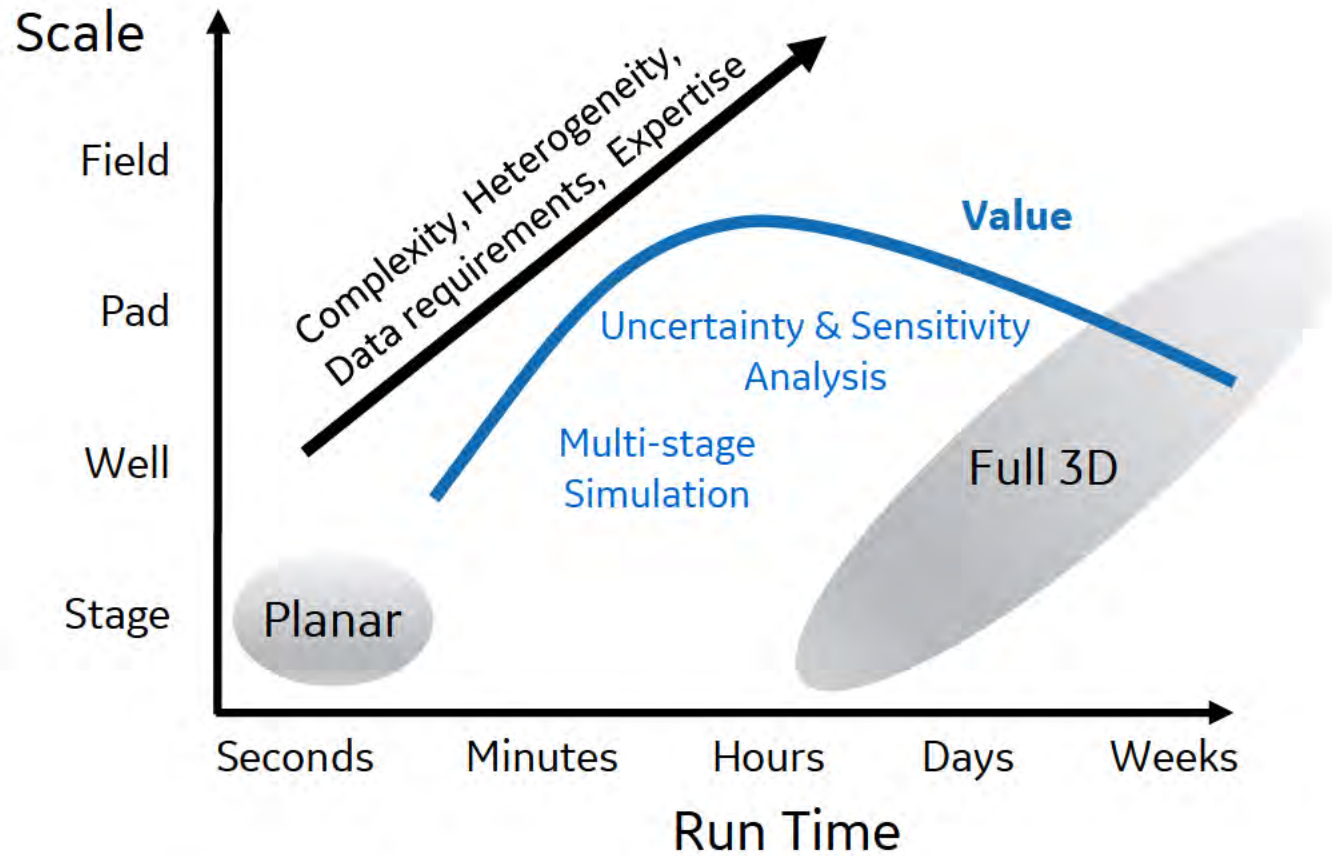
Multi-stage Modeling

- All stages along a well (incl. interaction)
- Seamless integration with upstream workflow
- Quick iterations
- Data-driven advisors



HF Modeling Value & Complexity Spectrum

Where is the value?

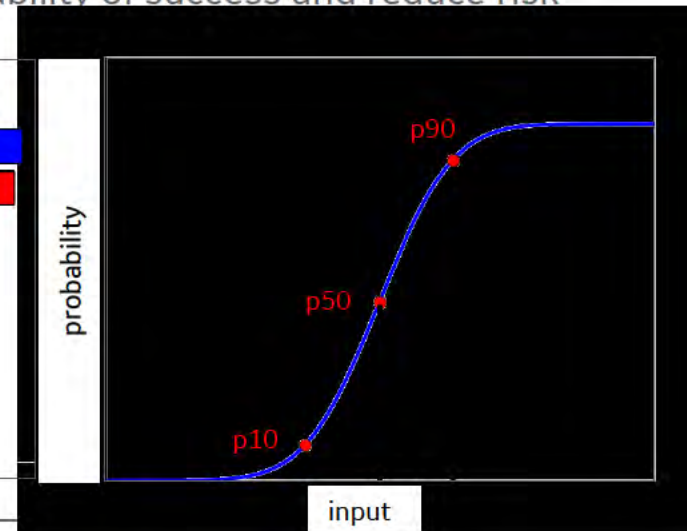
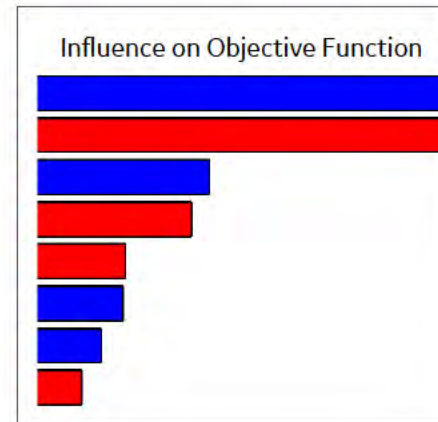


Sensitivity

- Understand stimulation as a system
- What is most important changeable parameter?
- Limit spending to where it matters

Uncertainty

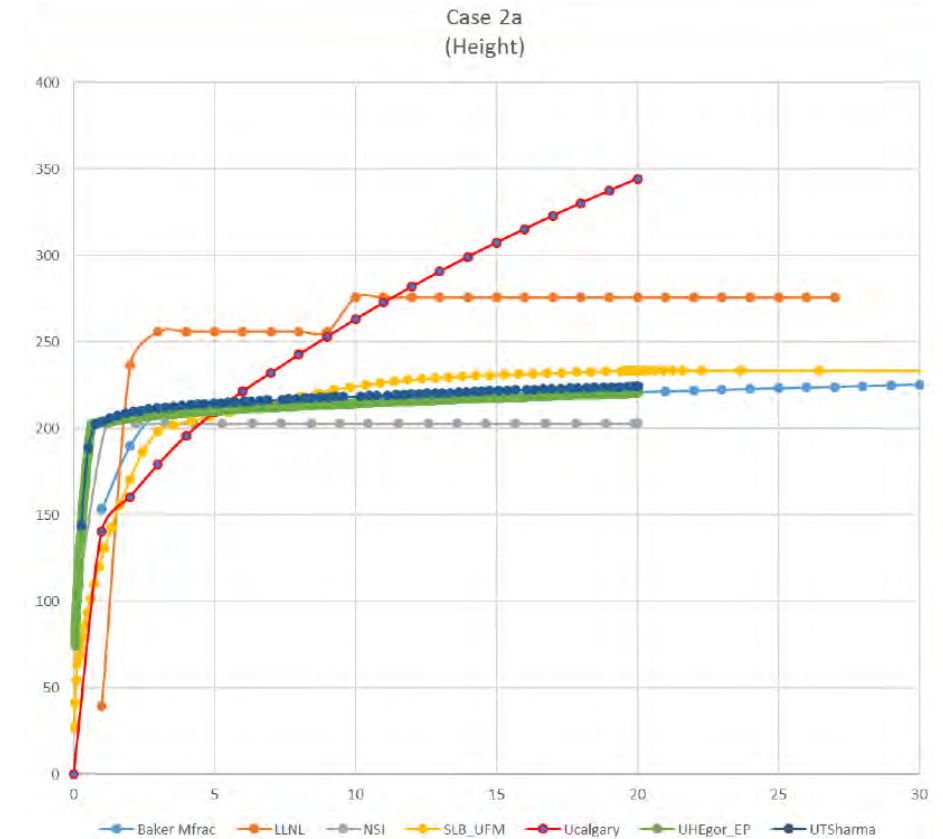
- Quantify probability of success and reduce risk



Industry-wide Hydraulic Fracturing Benchmark

ARMA Technical Committee on Hydraulic Fracturing

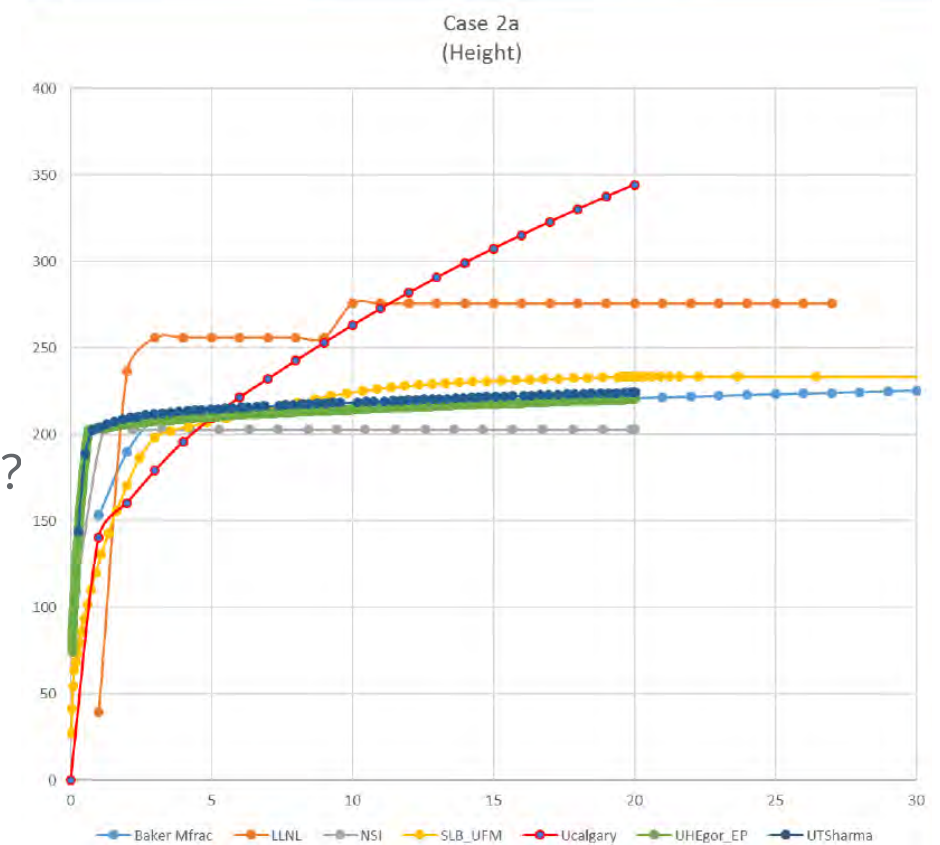
- 20 models comparing 7 cases
- Standardized input and output requirements
- Legacy 2D, pseudo 3D, planar 3D, fully coupled 3D
- Variety of methods: Analytical solutions, Finite Element (FEM), Finite Difference (FDM), Boundary Element (BEM), Finite Volume (FVM), Discrete Element (DEM), Finite-Discrete Element (FDEM)
- Majority agreement



Industry-wide Hydraulic Fracturing Benchmark

What does that mean for the modeler?

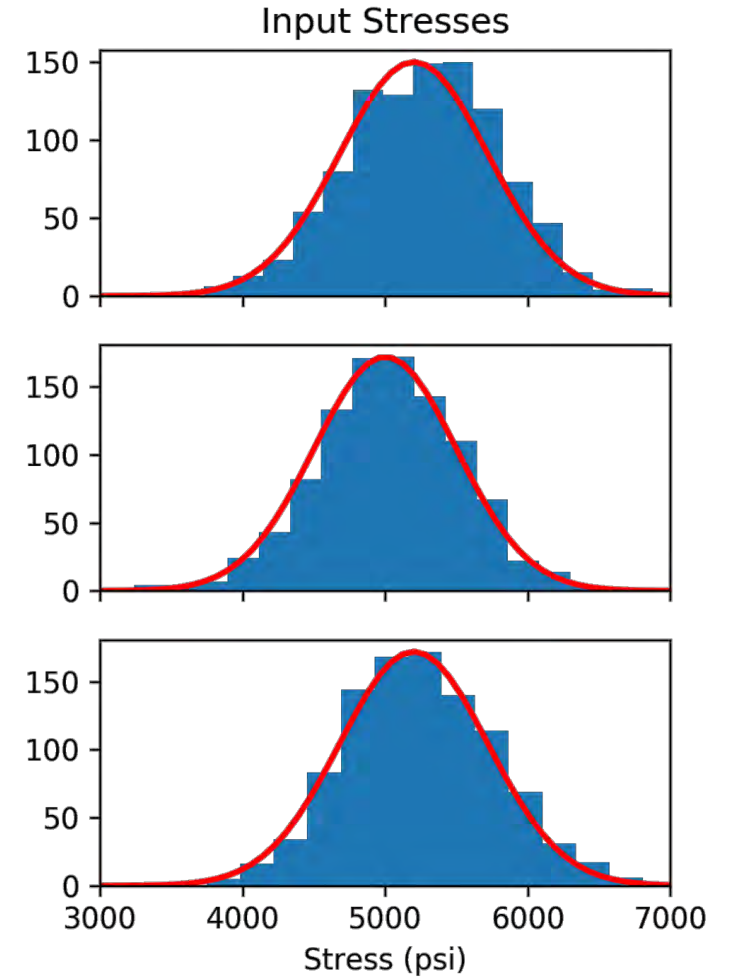
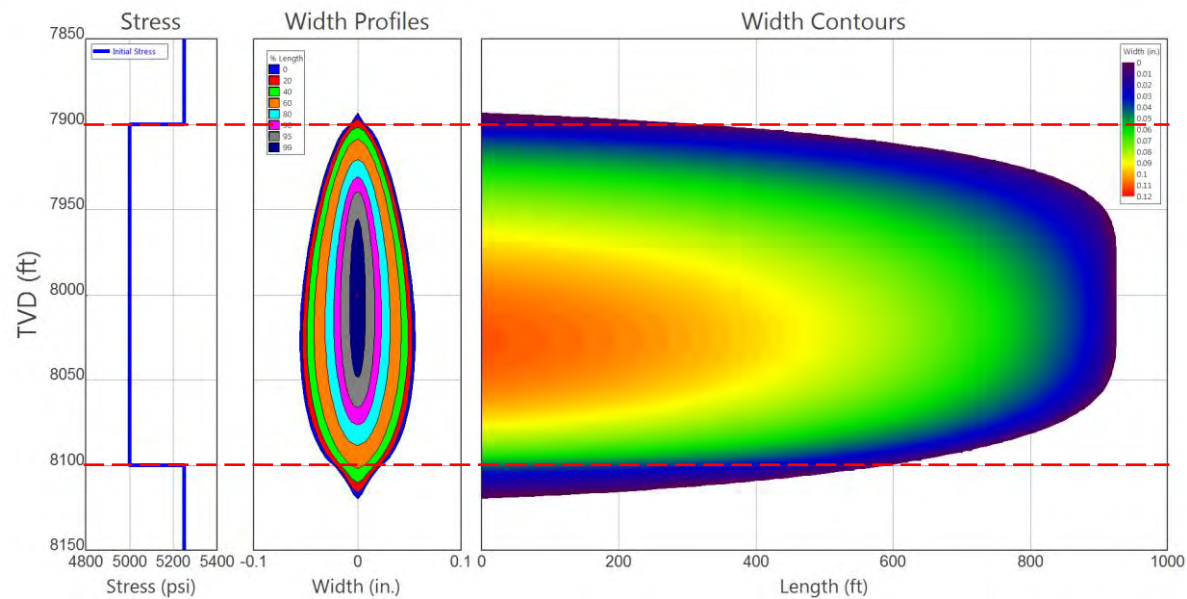
- Most models give effectively the same answer
 - On cases for which the models were designed
 - Might as well use a fast tool and iterate
- Complex scenarios require unreasonably accurate input data
 - Without that input, how do you know your answer is good?
 - What about the other >95% of free parameters you cannot systematically investigate?
 - Might be best to go with stochastic approach, embrace uncertainty and quantify probability of success



Stimulation Simulation – Where is the Value?

Benchmark Case 2a

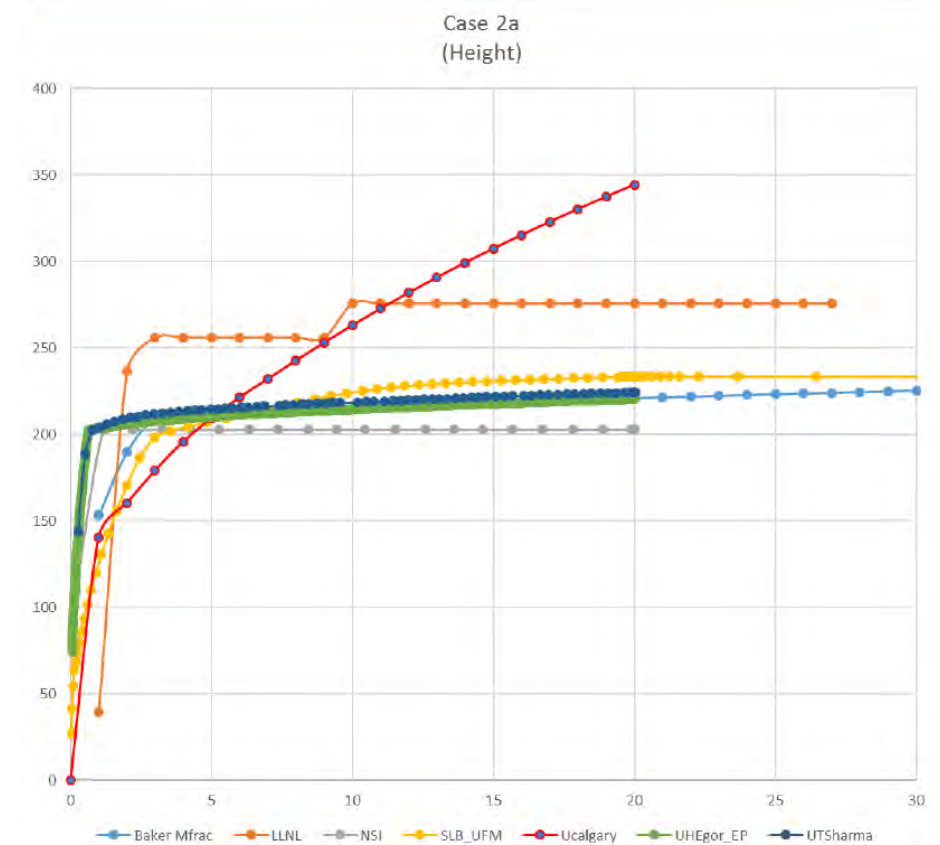
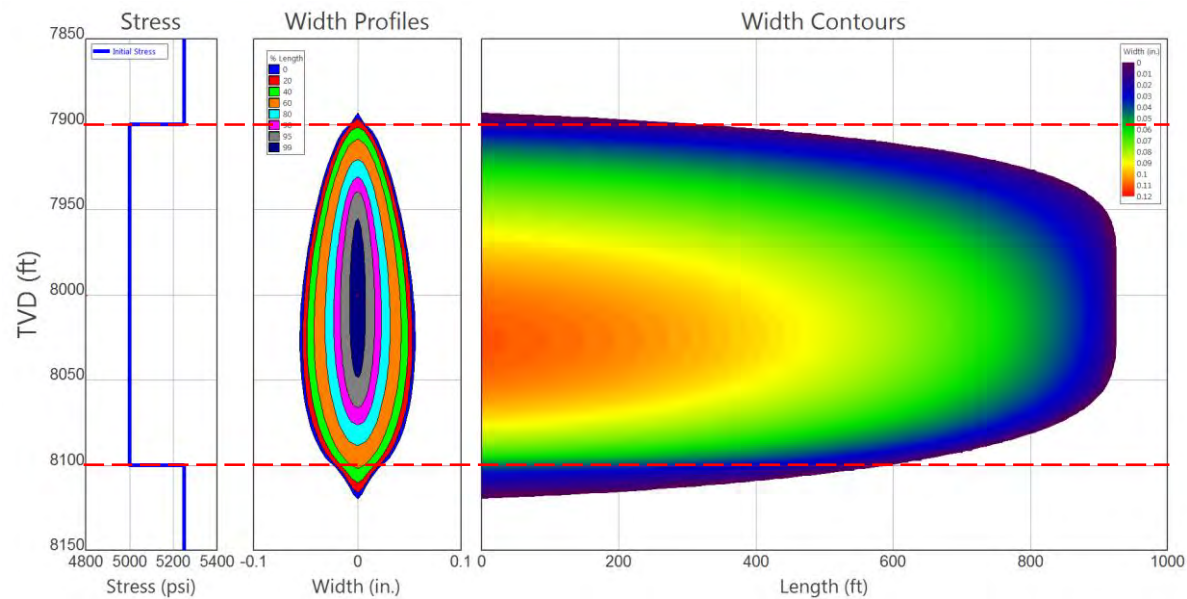
- Stress-confined fracture (200 ft)
- What if stress magnitudes vary $\pm 10\%$?
- Executed 1000 realizations, on a laptop, in < 30 minutes!



Stimulation Simulation – Where is the Value?

Benchmark Case 2a

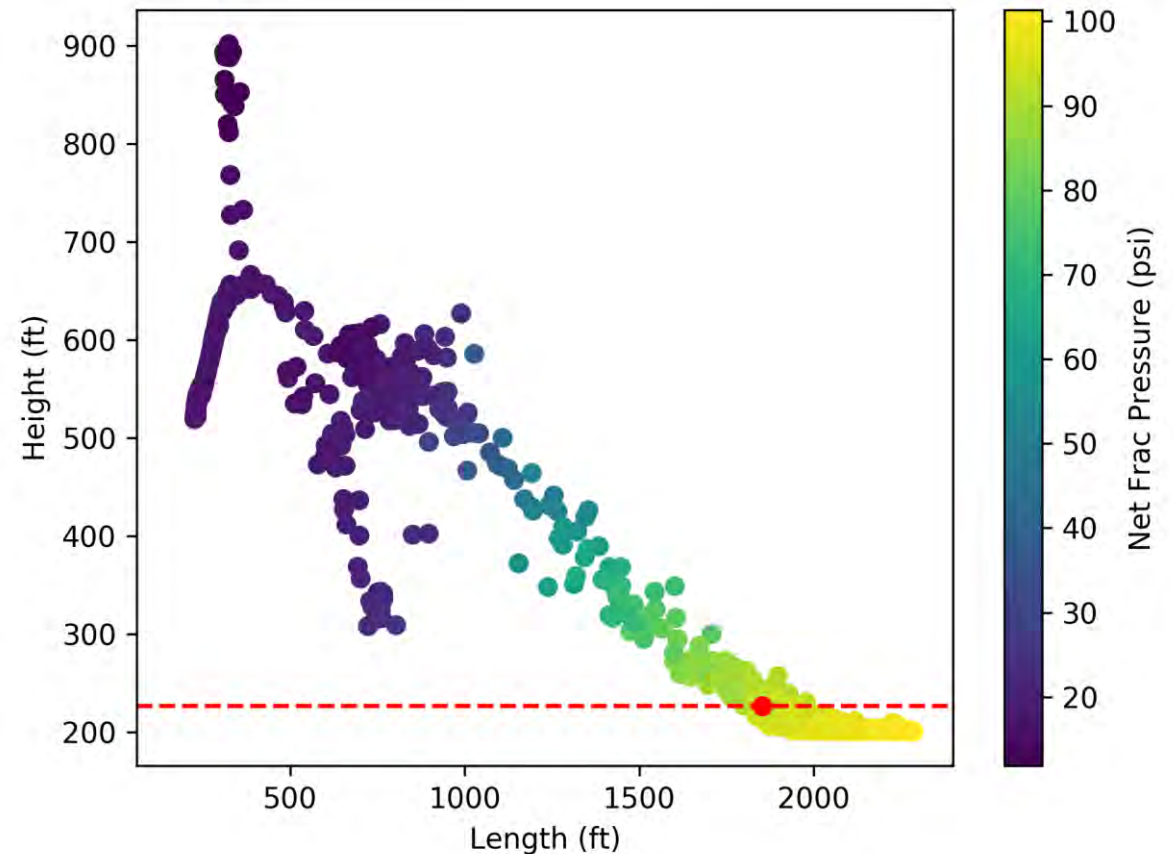
- Stress-confined fracture (200 ft)
- What if stress magnitudes vary $\pm 10\%$?
- Executed 1000 realizations, on a laptop, in < 30 minutes!



Stimulation Simulation – Where is the Value?

Uncertainty Analysis

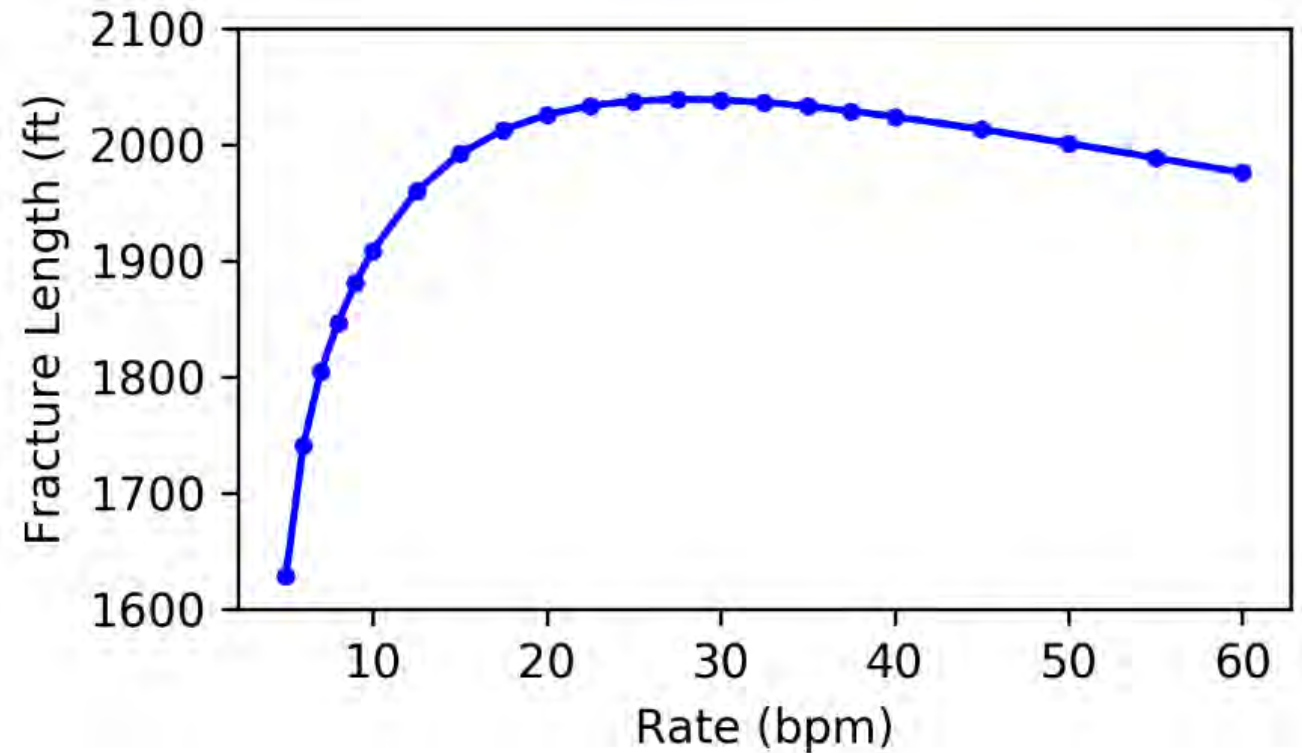
- Stress-confined fracture (200 ft)
- What if stress magnitudes vary $\pm 10\%$?
- Executed 1000 realizations, on a laptop, in < 30 minutes!
- 65% of fractures are not confined!
- Fracture net pressure lost
- Out of zone fractures are shorter



Stimulation Simulation – Where is the Value?

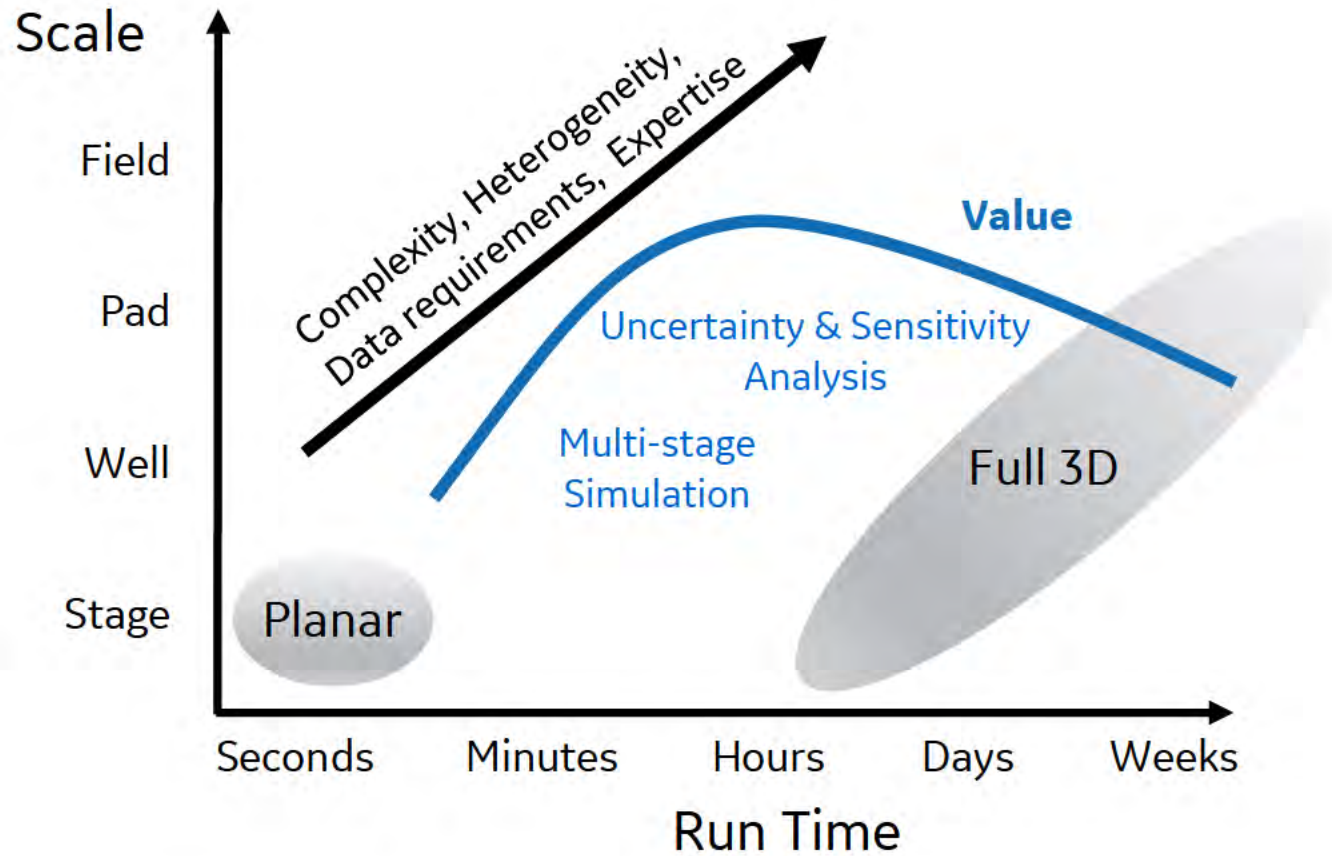
Quick Optimizations

- What is the optimum pumping rate to maximize fracture length?
- Answer in under 30 seconds!



Stimulation Simulation – Where is the Value?

Where is the value?



Multi-stage Modeling

- All stages along a well (incl. interaction)
- Seamless integration with upstream workflow
- Quick iterations
- Data-driven advisors

Sensitivity

- Understand stimulation as a system
- What is most important changeable parameter?
- Limit spending to where it matters

Uncertainty

- Quantify probability of success and reduce risk

BAKER
HUGHES
a GE company

