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Next-Generation Dynamic Event Model for Perforated Completions

IPS -16-36

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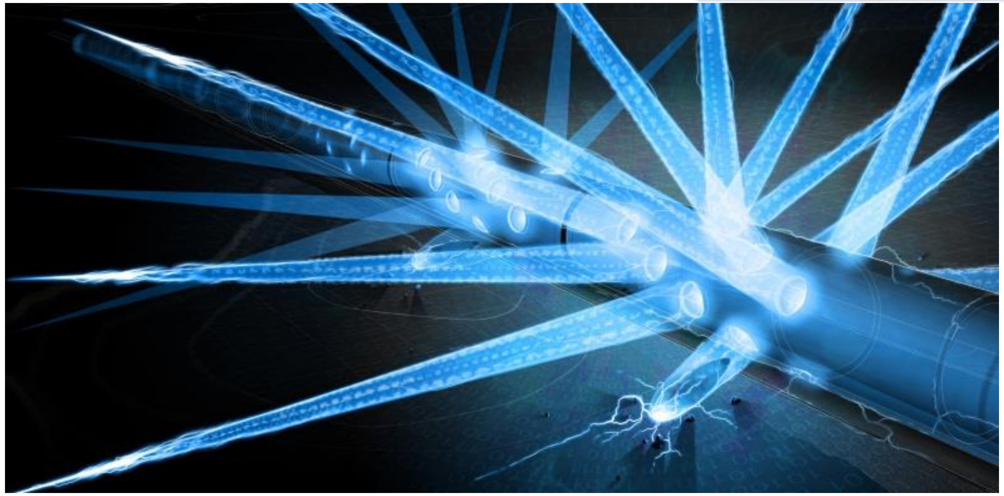
AGENDA

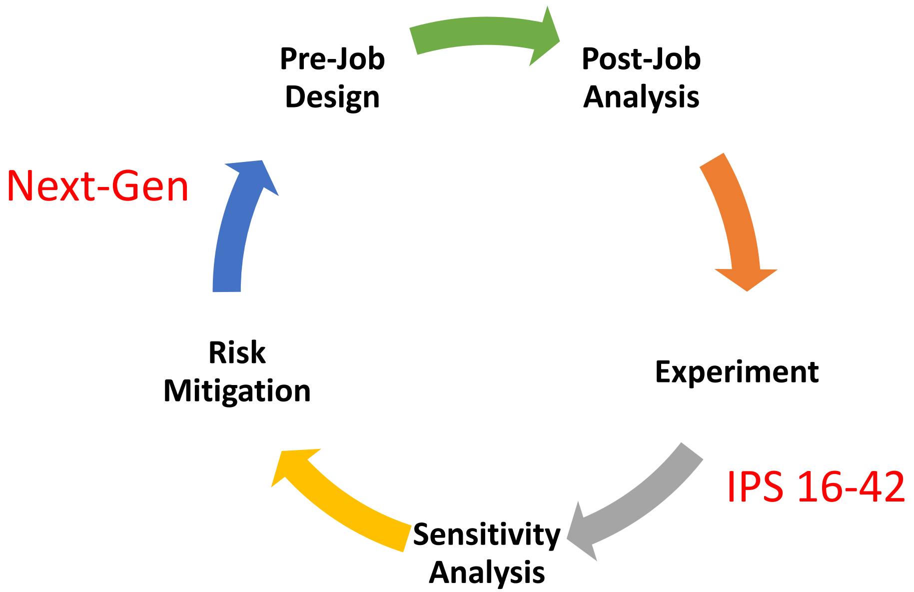
SUBTITLE

- Introduction – what is driving our efforts?
- Challenges, Legacy Software, & New Progress
- Numerical Results
- New User Interface
- Field Study
- Summary & Future Work



Introduction

What is driving our efforts?



Modeling and **simulation** of dynamic downhole events during perforation operations are important for:

Pre-job design work flows that

- Quantitatively evaluate options that optimize well completions
- Mitigate risk of damage to completion/production equipment due to shock loading

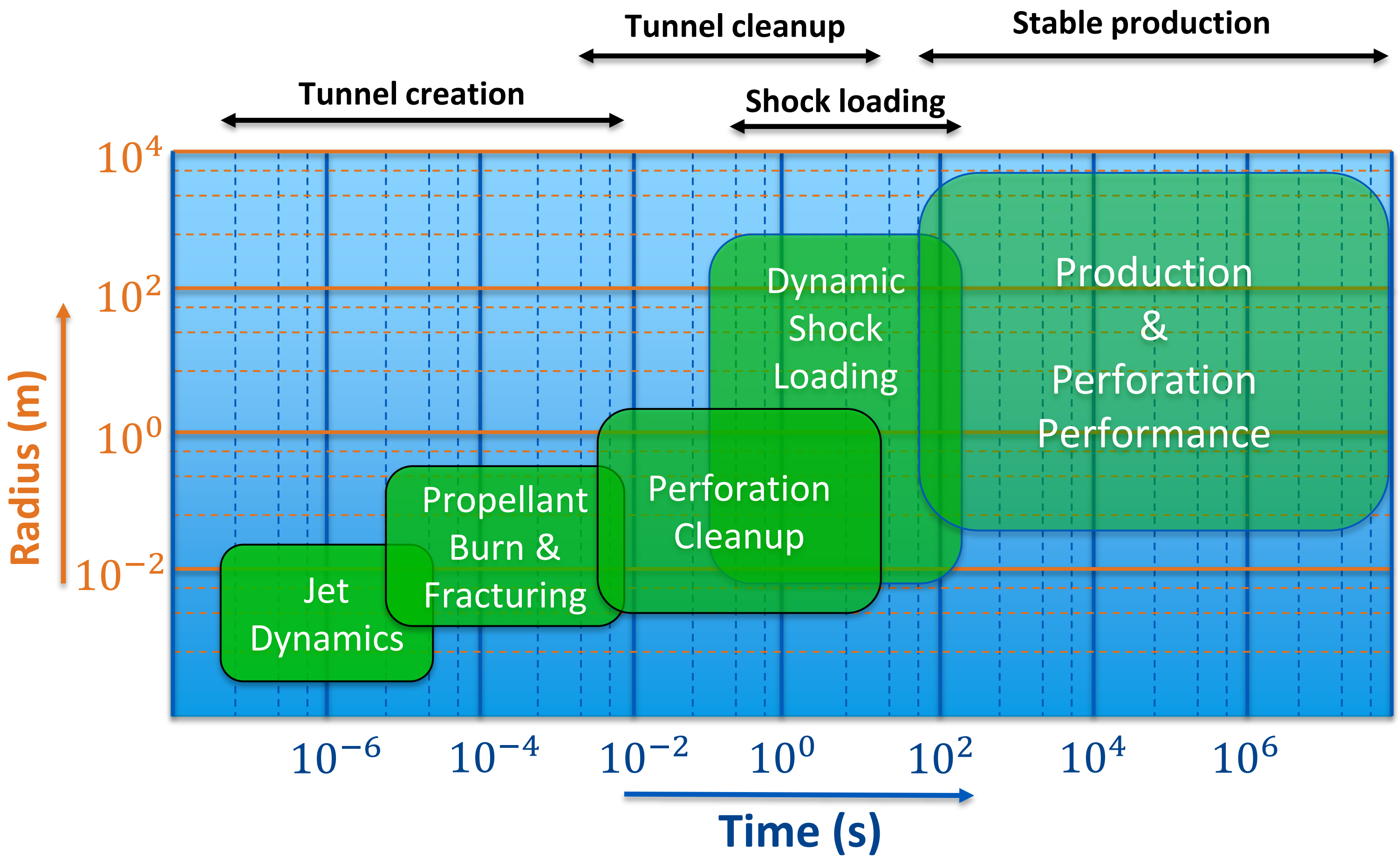
Post-job analysis that

- effectively integrates knowledge gained from field data back into the design work flow

Sensitivity analysis that

- helps identify and understand dominant variables in flow laboratory experiments used to simulate components of the well-scale system

Challenges in Modeling Perforating Events



- Physics of perforating depends on a large range of space & time scales:
  - ✓ Good perf tunnels --> connectivity with ***high production efficiency***
  - ✓ Good cleanup --> properly flushed and ***clean perforation tunnels***
  - ✓ Low risk of ***shock damage*** to downhole equipment
  - ✓ Minimal tunnel wall damage --> stable production environment

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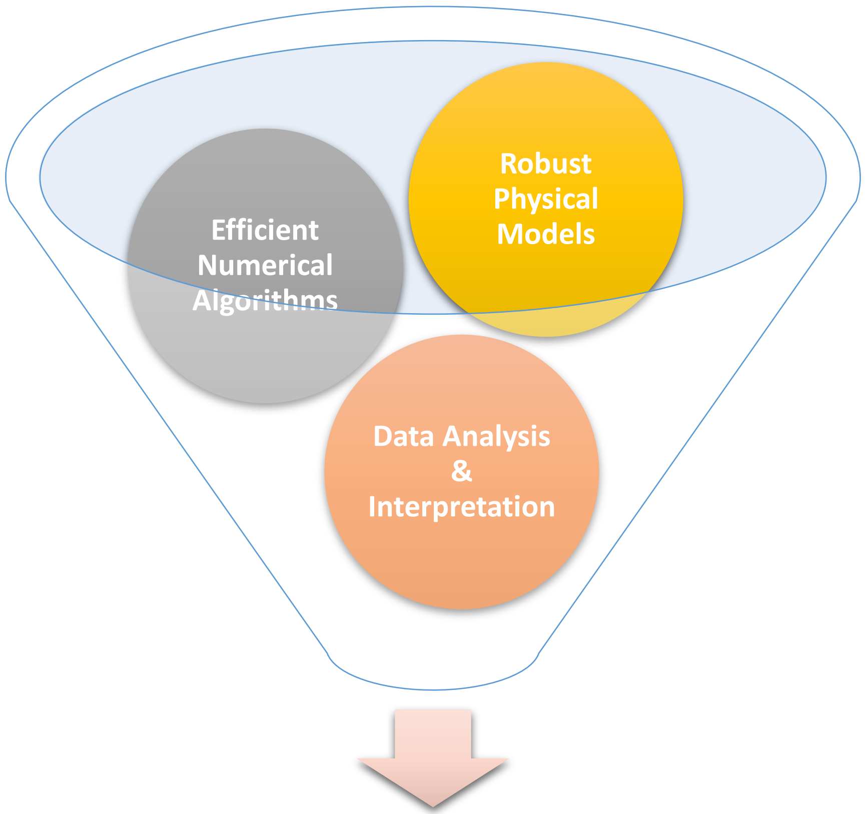
Challenges in Modeling Perforating Events



Predictive Modeling with Practical Runtimes

- Full system encompasses a non-linearly coupled wellbore – perf – reservoir with inherently different time- and space-scales
- Flow equations governing evolution are multi-phase & multi-dimensional
- HPHT thermo, shock, and gas burn physics

- Solutions with strong gradients (e.g., pressure, velocity, density, etc.)
- Small time scales with long working zones
- Detonation/Deflagration waves
- Complex tooling & perforation geometry

- Must build cautious and constrained conclusions
- Answer the right questions for risk analysis & mitigation
- Field-scale interpretation through lab-scale modeling & experimentation

Legacy Modeling Platform

Software platform for

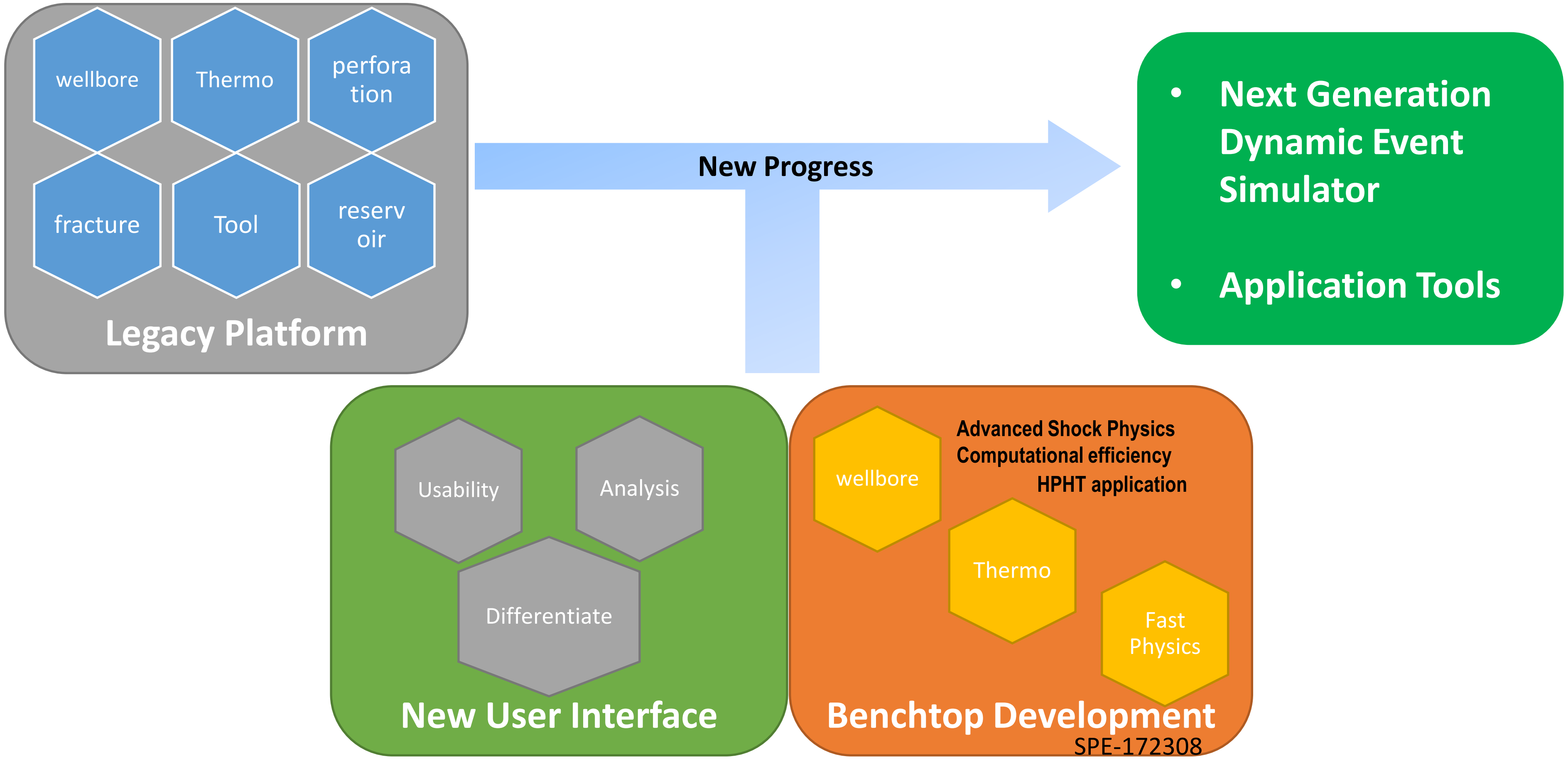
computational modeling of transient, downhole perforating events.

- Scientific platform capable of simulating short-time (0.5-tens of seconds) dynamic events in the coupled *wellbore-perforation-fracture-reservoir* system.
  - Application space of perforation / stimulation jobs
  - Power lies in the fact that each component (i.e., physical sub-model) is self-consistently coupled → no need for a priori assumptions on their relative importance
  - Embodies our current physical knowledge of dynamical wellbore/reservoir system
  - Flexible input for tooling and conveyance

- Powerful Simulation Platform for Job Design and Analysis
  - ✓ Power lies in entire down-hole system pre-job modelling
  - ✓ Risk assessment and strategic mitigation,
  - ✓ completion design and optimization,
  - ✓ Performance prediction and Post-job analysis.

Recent Progress

Integration with legacy platform



Recent Progress

Main focus of this work

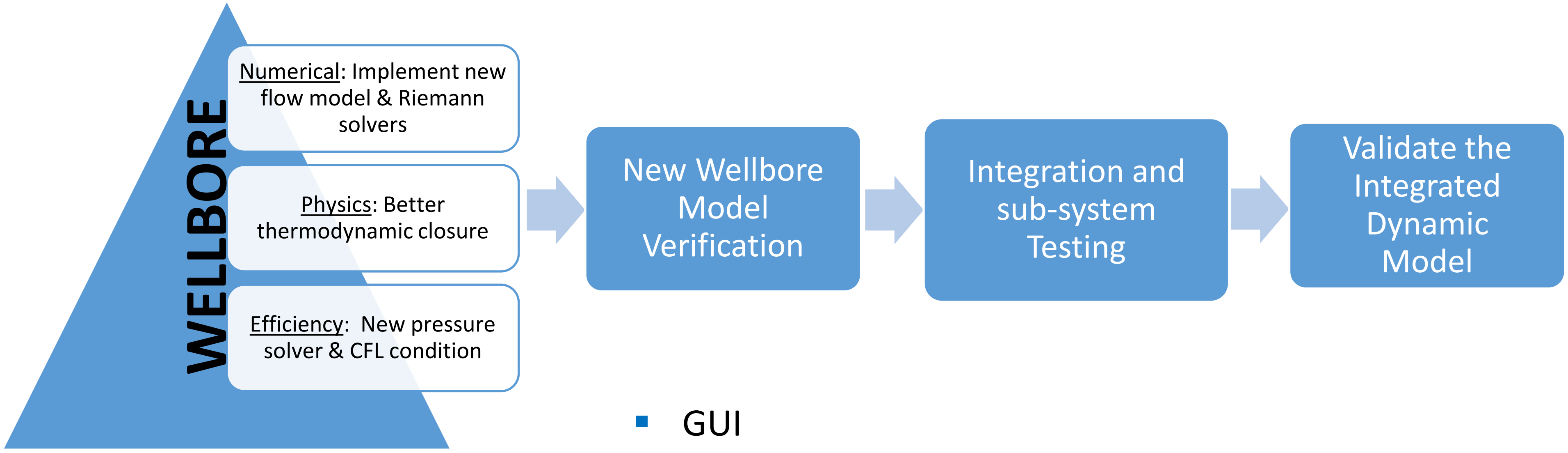
- Integration of new physics & numerical algorithms into legacy software platform
  - ➢ New wellbore flow model developed in a "benchtop" computing environment
  - ➢ Implementation of Wave Propagation Hydrodynamic solvers*
  - ➢ Improved thermodynamic closure – Riemann-based scheme – SPE-172308

- Release of a next-generation graphical user interface with a modern look and feel.
  - ➢ Updated input forms and software controls
  - ➢ Simplified user input

* D.S. Bale et al., SIAM J. Sci. Comput., Vol. 24, No. 3, pp. 955-978 (2002)

Integration & Testing

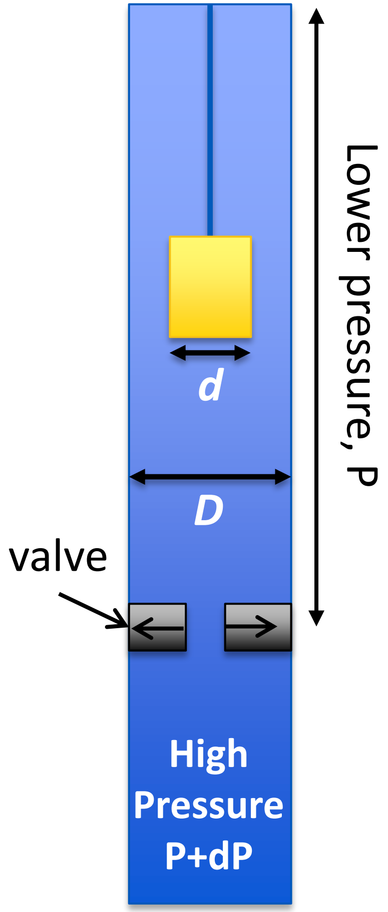
New algorithms and GUI



- GUI
  - Compatibility testing
  - Unit testing
- Calculation Engine
  - Standard Riemann Problems
  - Simplified Downhole scenarios
  - Test suite of complicated completions

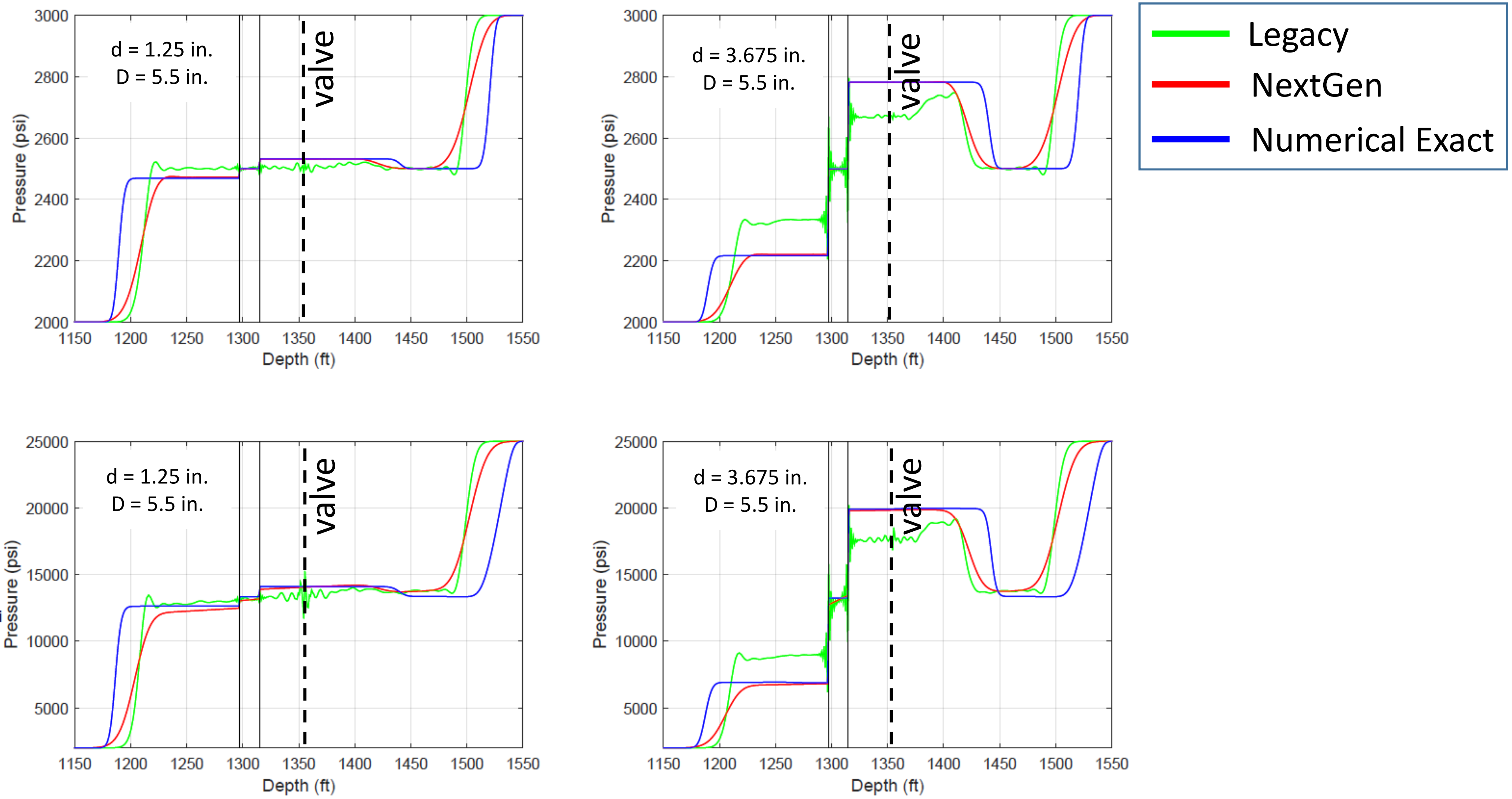
Numerical Results

Low Pressure



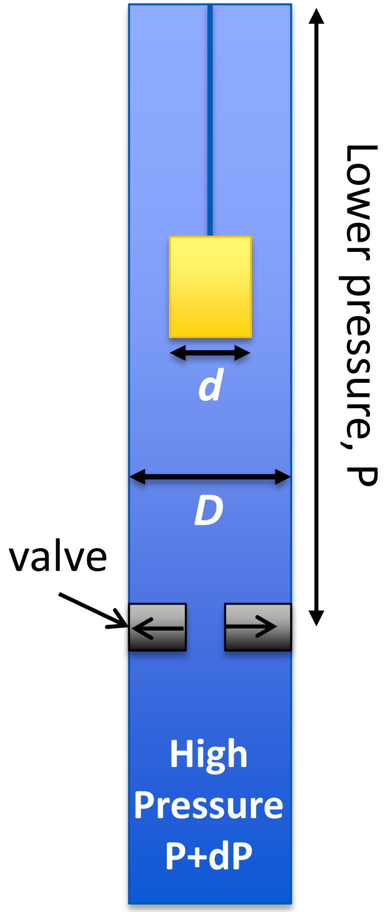
P=2000 psi
dP=1000 psi

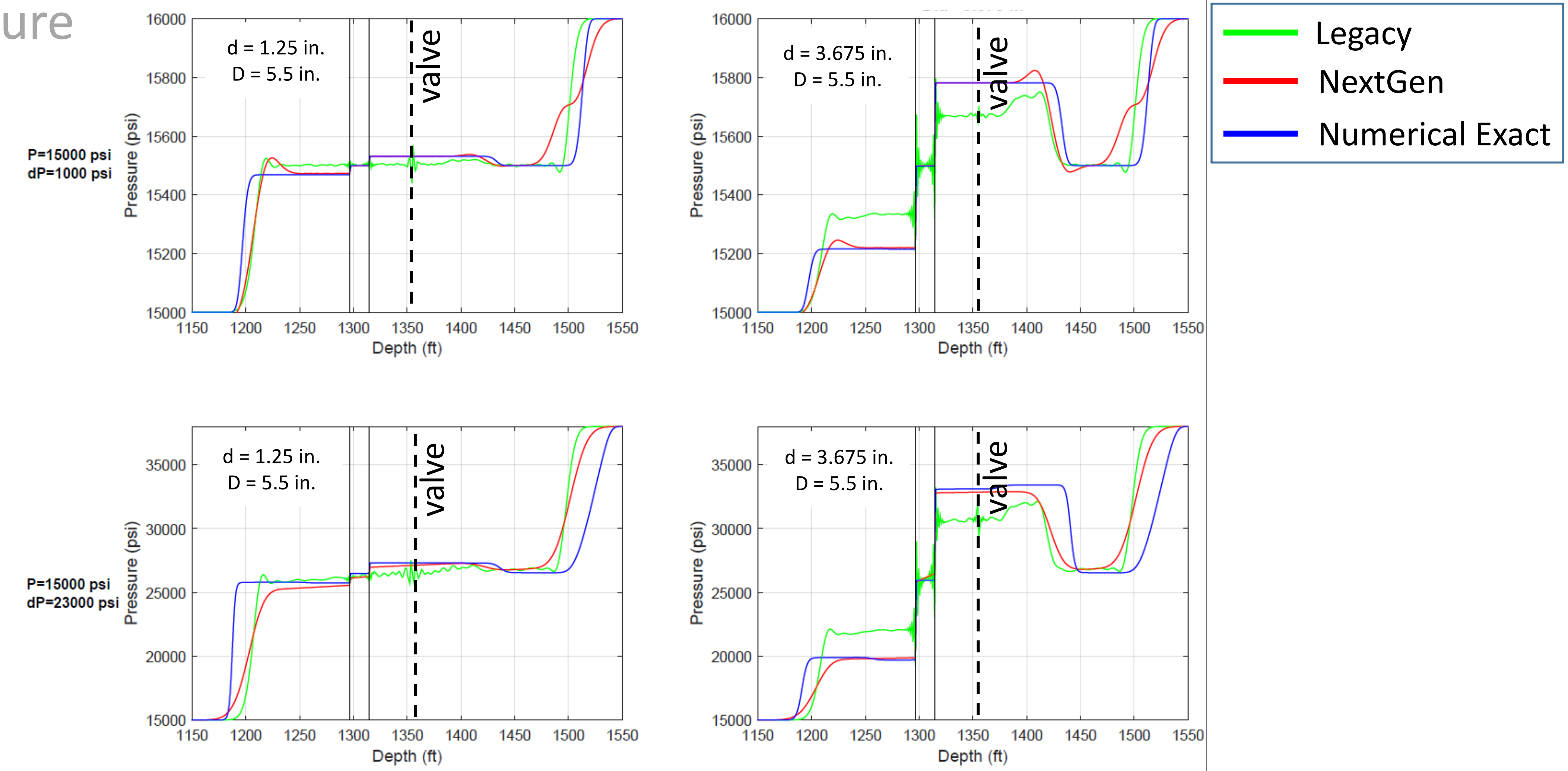
P=2000 psi
dP=23000 psi



Numerical Results

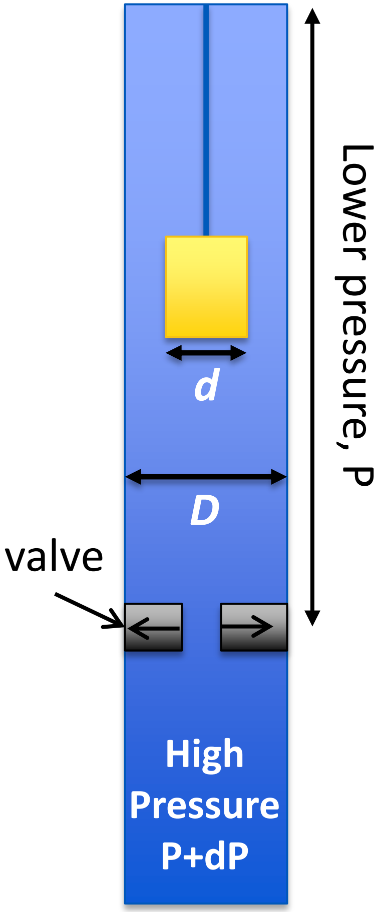
High Pressure

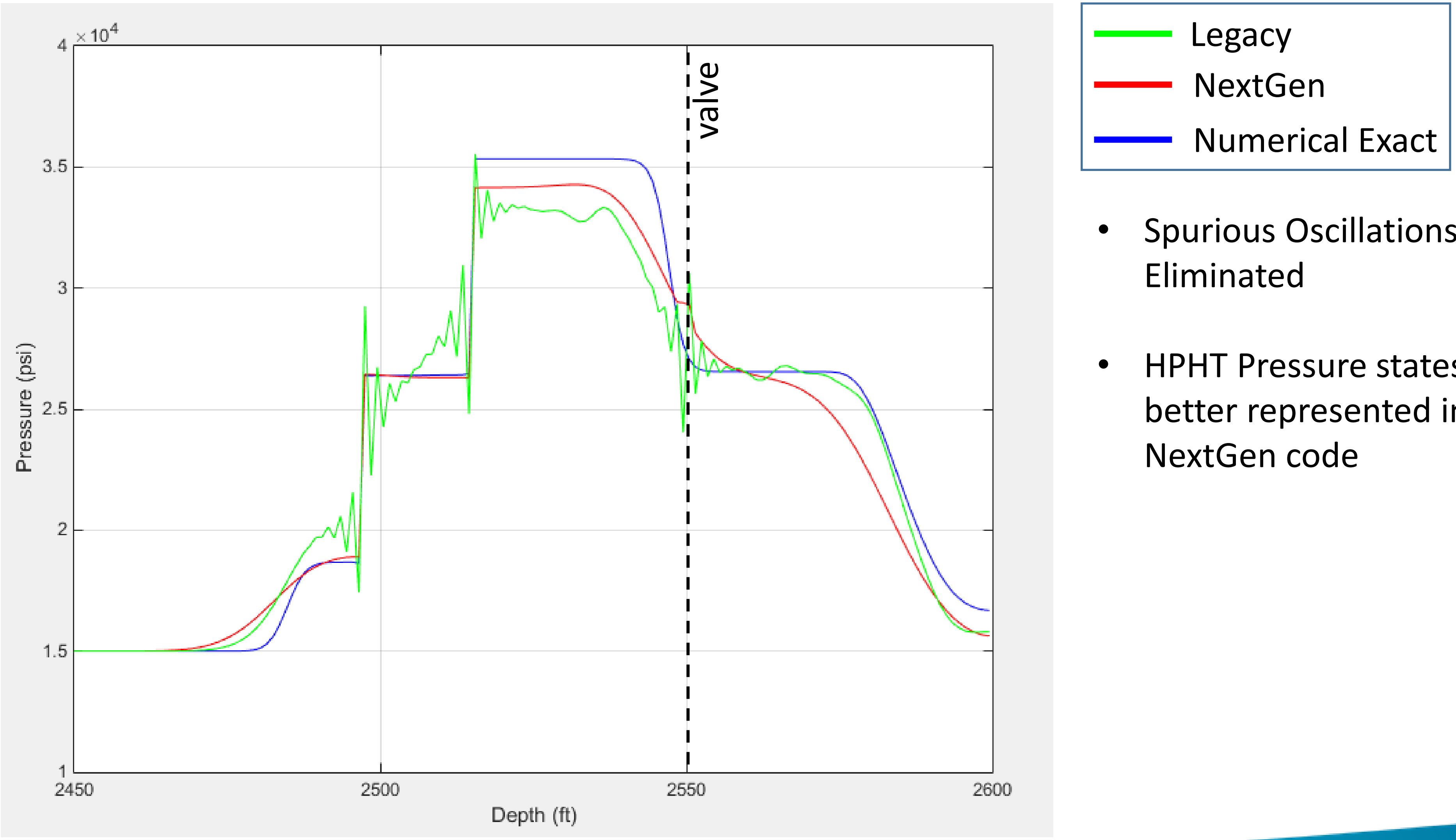




Numerical Results

HPHT



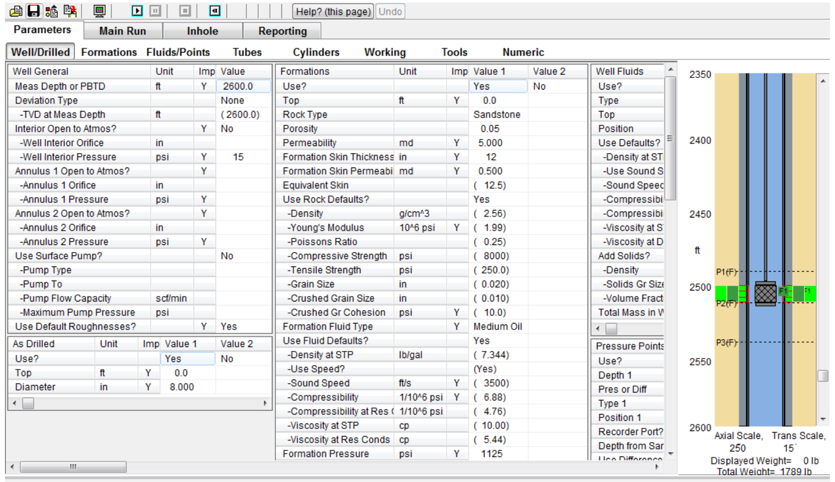


- Spurious Oscillations Eliminated
- HPHT Pressure states better represented in NextGen code

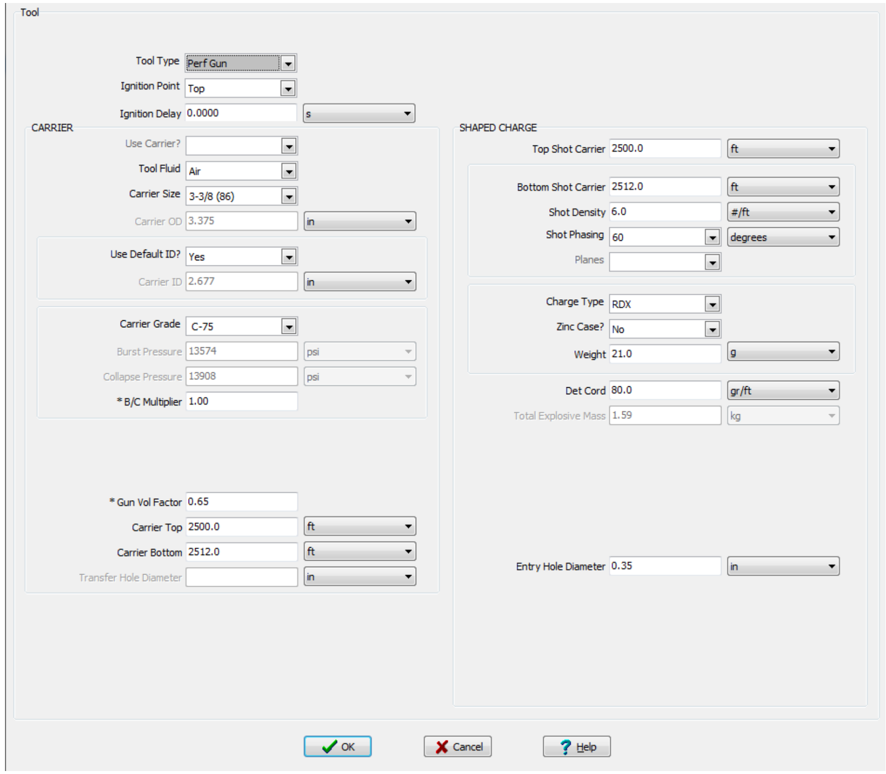
Graphical User Interface

A new look and feel

Legacy Interface



Next-Generation Interface



- Leveraged latest Delphi tool sets and capabilities.
- Design UI based on legacy workflow for consistency.
- Implemented standard oilfield terminology.
- Made improvements to plotting & data analysis modules.
- Added an easy-to-use report generator.

Field Study

Downhole conditions

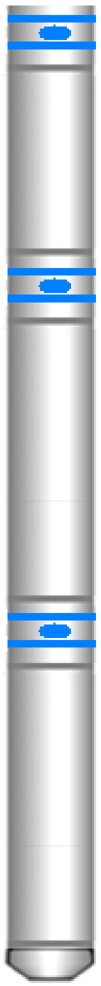
- The candidate well was a well where perforations were already present.
- In this instance, there was no perforation to be modelled
- Instead, just the underbalance was generated by the opening of the pressure valves at the level of the perforations.
- The perforated interval that needed curing was 32 ft at a depth of 11,300 ft.

Formation & Fluid Properties

Reservoir Pressure, psi	3068
Permeability, mD	314
Porosity, %	14
Temperature, °F	198
Oil Density, g/cc	0.95
Oil Viscosity, cP	13.21

Field Study

Pre-job modeling



1 IGPV 3 3/8”

1 Blank Gun 3 3/8” 7 ft

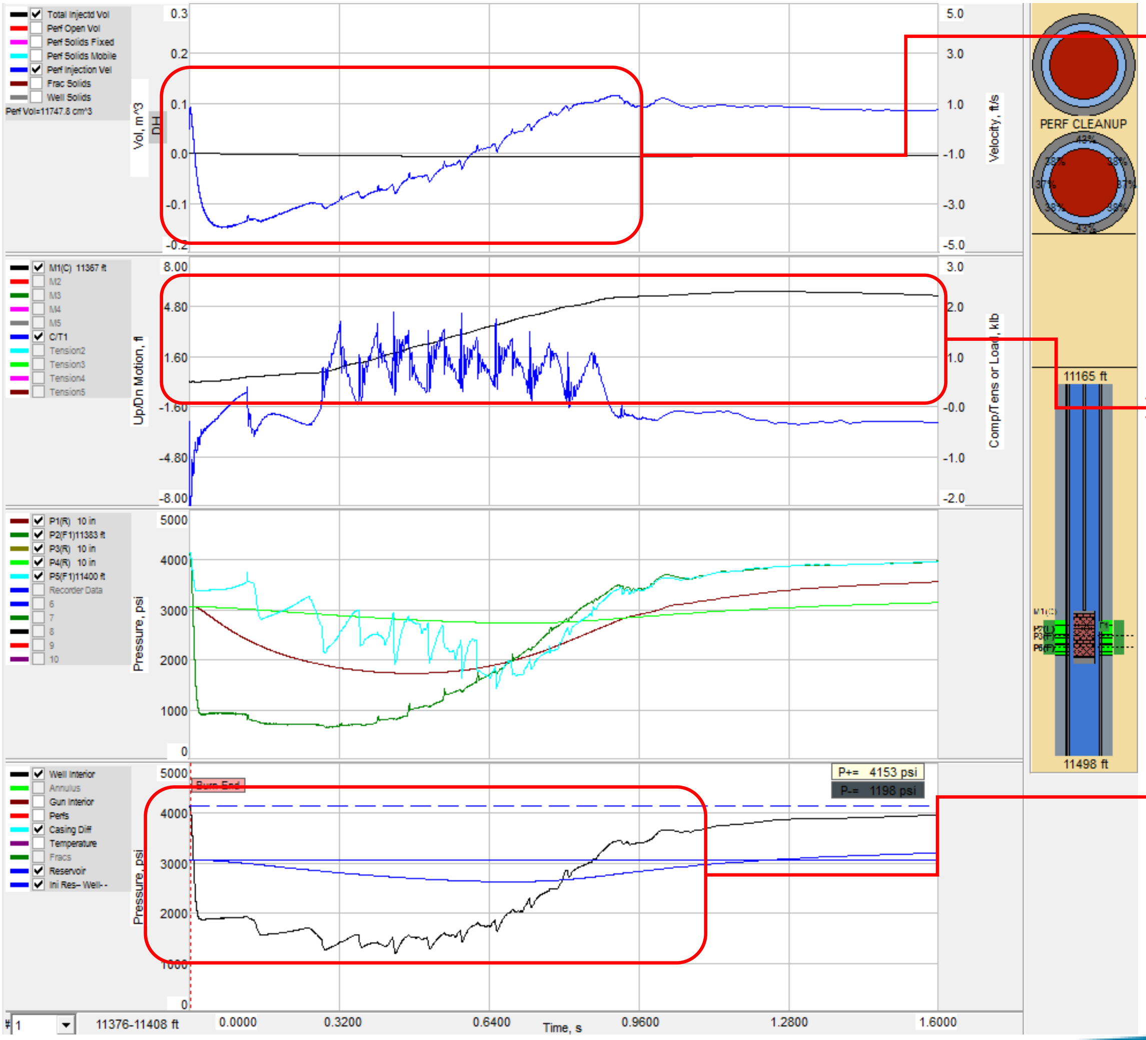
1 IGPV 3 3/8”

1 Blank Gun 3 3/8” 11 ft

1 IGPV 3 3/8”

1 Blank Gun 3 3/8” 11 ft

Bull Plug



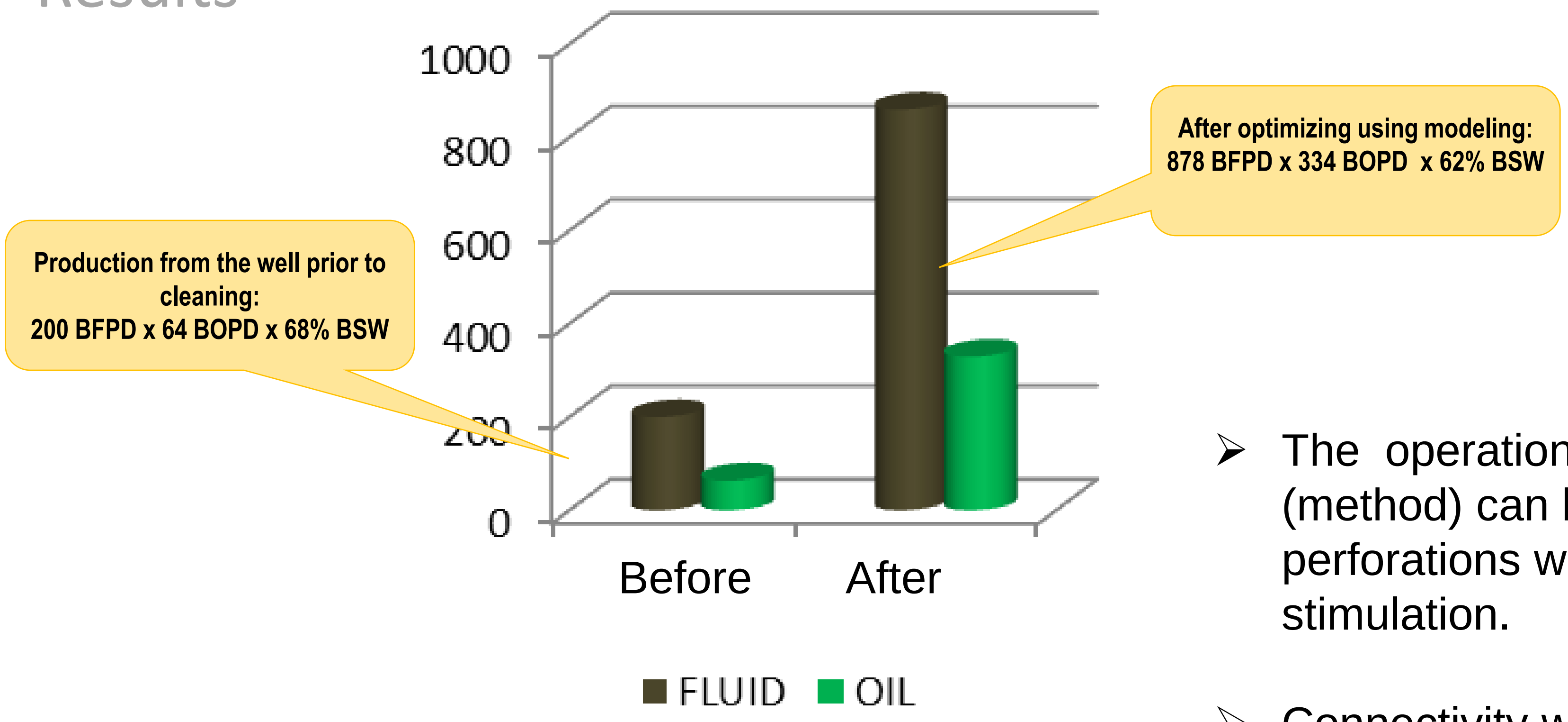
Flow rate of all the material that comes from the formation to the wellbore. The maximum speed reached during the surge is 4 ft / s in approximately 0.9 s.

Movement the guns due to the fluids rushing in (dynamic event). A movement of 5.7 ft down is observed. The cable tension and compression are within the ranges for proper operation.

ΔP pressure is observed. In this case, the dynamic underbalance generated is 1870 psi. The use of valves and vacuum chambers help keep ΔP for a prolonged time 0.9s.

Field Study

Results



increase:

- **330 % more bfpd**
- **415% more bopd**

- The operation demonstrates that the modeling (method) can be employed to cure pre-existing perforations with no re-perforation or chemical stimulation.
- Connectivity was successfully restored with limited cost and time.

Summary

- A new calculation engine has been integrated into our existing simulation platform.
  - It is robust to spurious oscillations in fluid properties that can occur near shockwaves emanating from a perforating event.
  - The post-shock fluid state is more accurately resolved.

- A next-generation graphical user interface has been implemented.
  - Modern Delphi controls have updated the software's look & feel.
  - Included automated report generation.
  - Simplified user input.

- The example field study demonstrates that dynamic underbalance modeling is critical to proper perforation clean-up and production restoration.

- Future work
  - Parallelization
  - Integration into Section IV test work flows – see IPS-16-42

THANK YOU!

Questions?