# New Shock Sensing Sub Permits Greater Understanding of the Dynamic Response of Perforating Gun Strings

**Jim Wight**
**Technical Advisor  Perforating Systems Technology**

**Halliburton - Jet Research Center**

**IPS-14-03**



HALLIBURTON

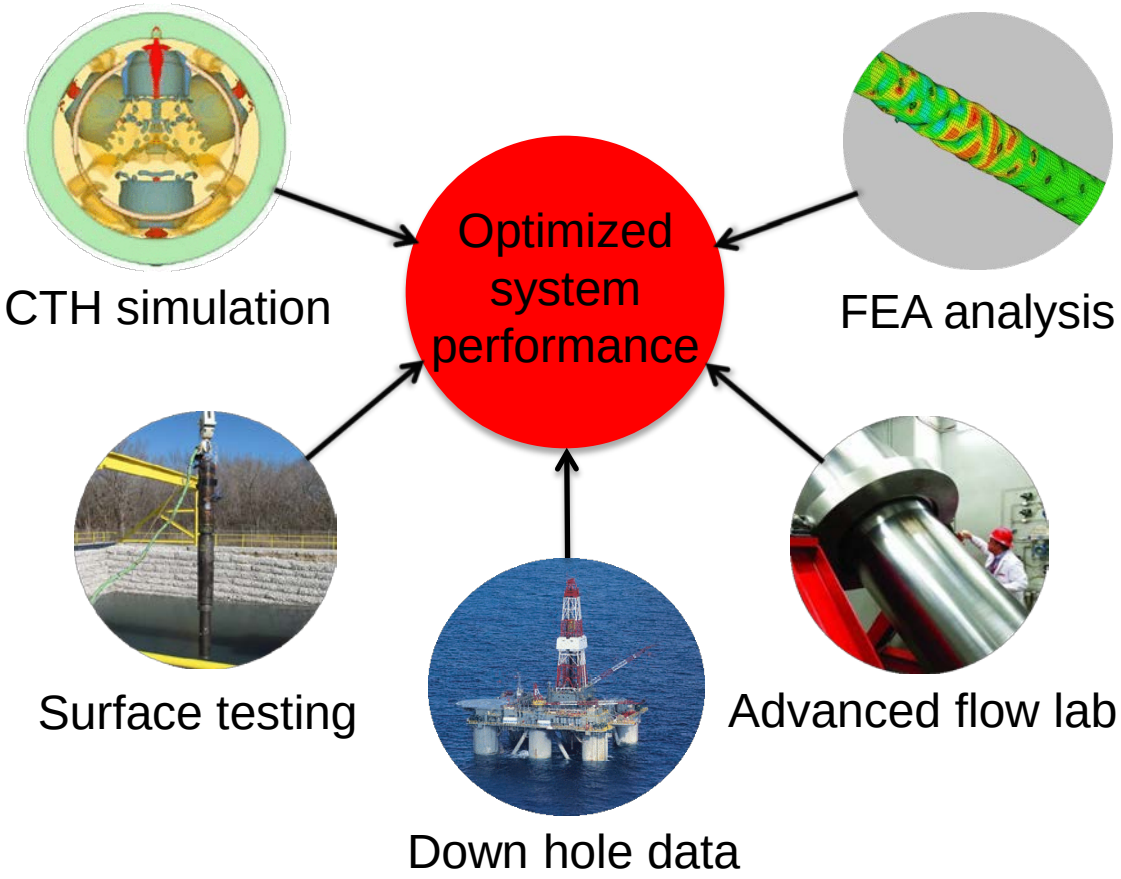
# Agenda

- Introduction
- Perforating System Optimization Methodology
- Shock Sensing Sub
- Field Trial 1 Job Description
- Field Trial Data
- Field Trial 2 Job Description
- Field Trial Data
- SSS for FEA Model-Data Validation
- Summary and Conclusion

# Introduction

- Current well designs are pushing the limit of perforating gun design
- Traditional gun design approaches need improvement
- Loads imposed during the perforating event should be better understood to maximize charge performance and ultimate productivity
- Dynamic events in longer perforating strings need to be better understood

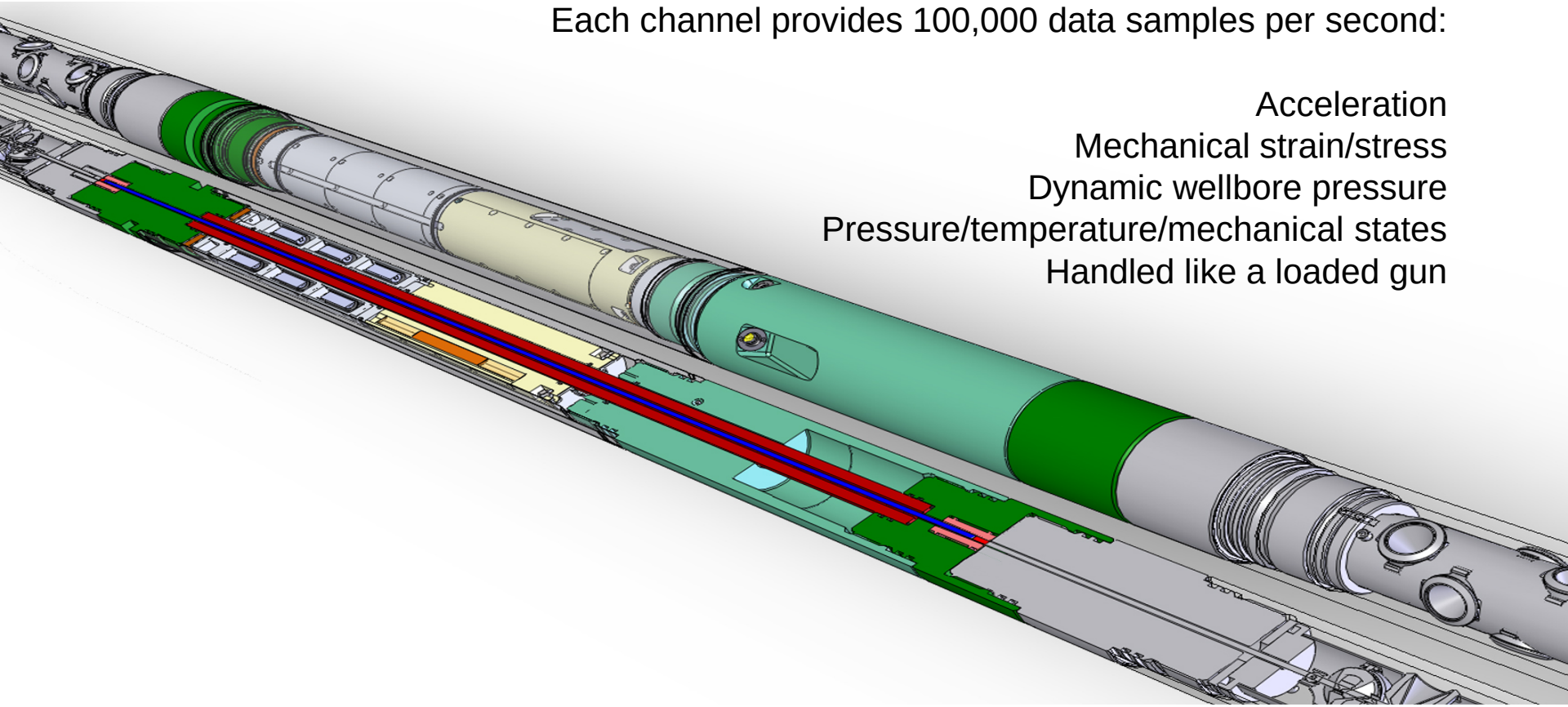
# Methodology



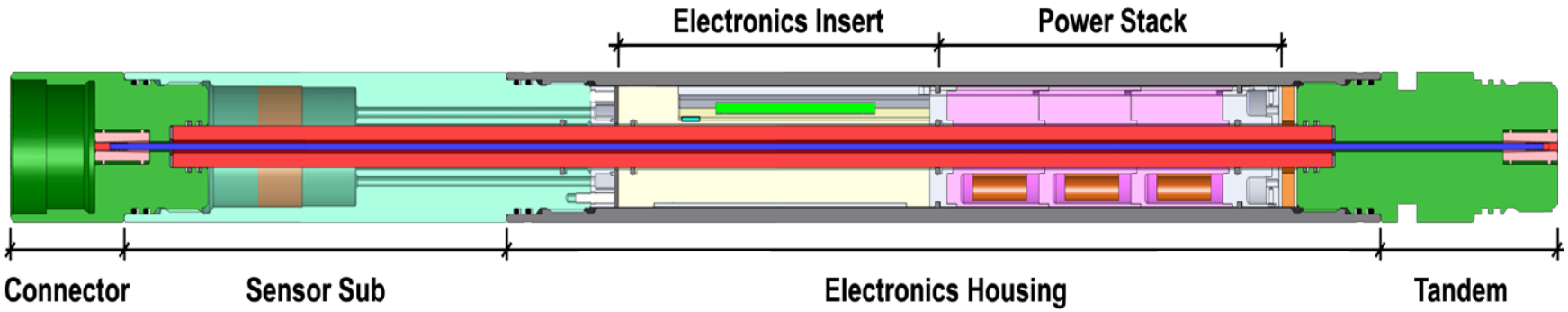
# Down Hole Data - Shock Sensing Sub

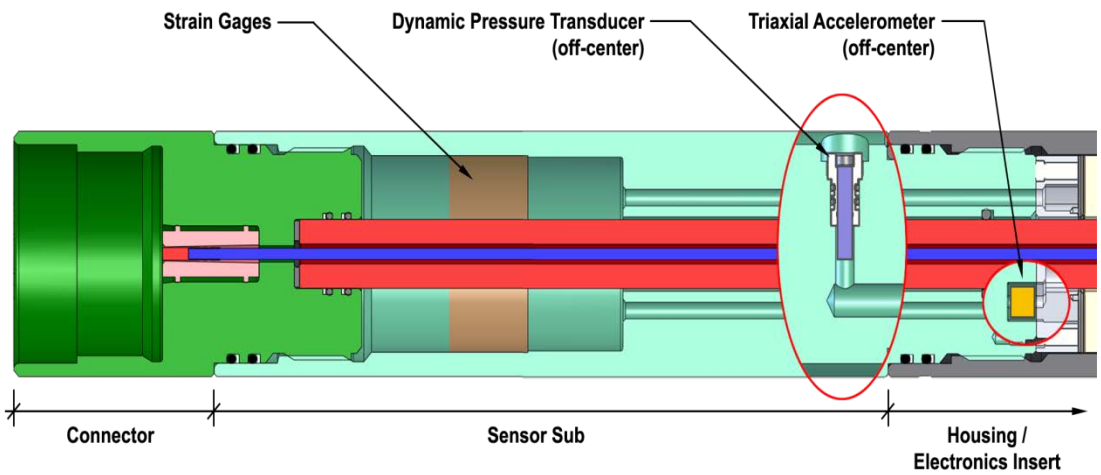
Developed a sub to collect data anywhere in the string
Each channel provides 100,000 data samples per second:

Acceleration
Mechanical strain/stress
Dynamic wellbore pressure
Pressure/temperature/mechanical states
Handled like a loaded gun



# Shock Sensing Sub

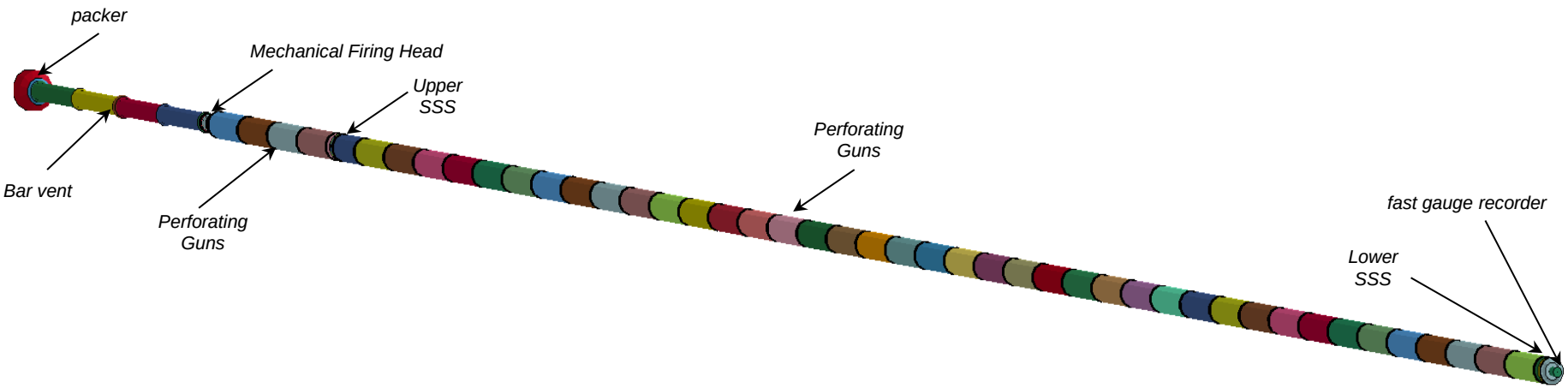


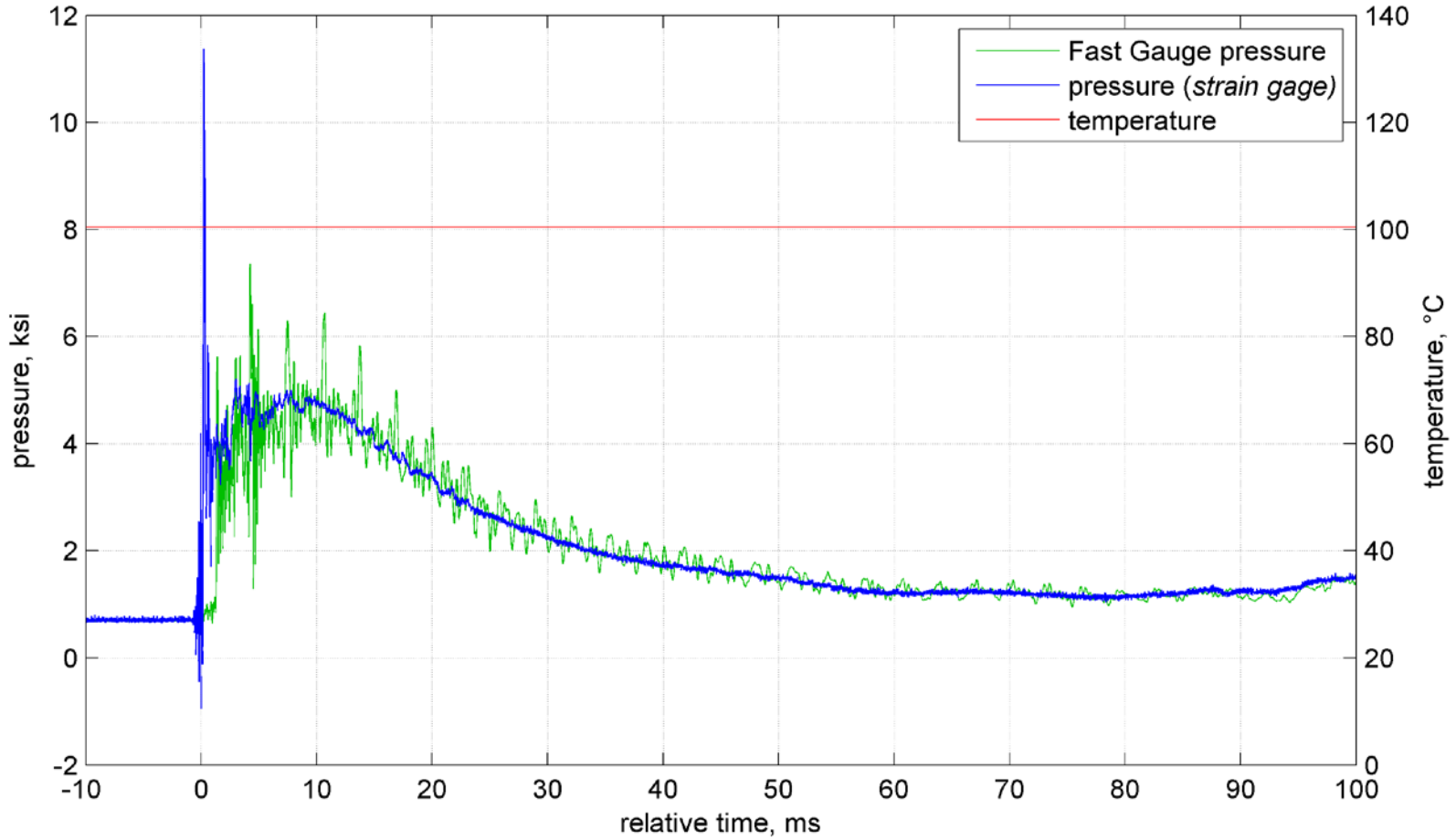

| | |
|---|---|
| **Mechanical** | |
| Diameter | 4 5/8 in. |
| Pressure rating | 20,000 psi |
| Tensile rating | 377,000 lbm |
| Connections | Standard gun threads (pin x box) |
| **Sensors** | |
| Strain gages | 3 axial, 3 hoop, 1 torsion |
| Pressure | Dynamic pressure, 100 ksi |
| Accelerometers | Triaxial, 60 kg |
| Temperature | RTD |
| **Environmental** | |
| Temperature rating | 302ºF |
| **Logging** | |
| Event sampling rate | 100 kHz |
| Event duration | 1 sec |
| Event records | 10 |
| Run duration | 5 days |

# Field Trial Job 1 Description

- Gun system: 4 5/8-in., 5 shots/ft using 39-g HMX charges
- Perforation depth approximately 7,500 ft
- Bottom hole temperature 215$^{o}$F
- Fast Gauge™ on the bottom of the string
- Two Shock Sensing Subs one towards the top of the string and one at the bottom of the string

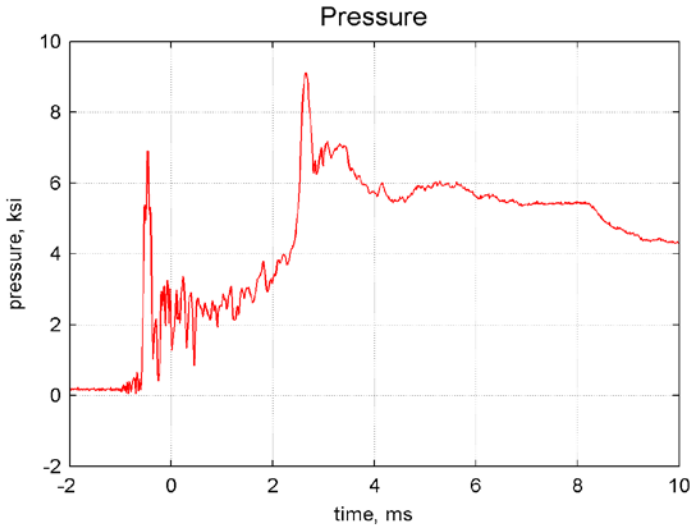


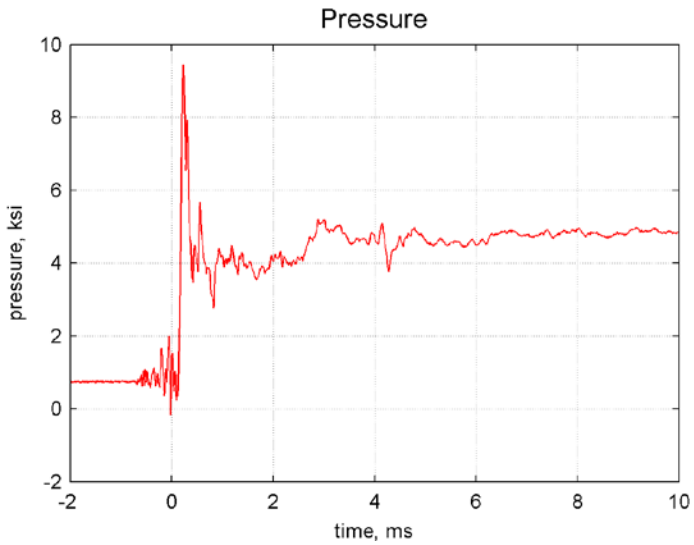
# Validation Against Fast Gauge



# Dynamic Events

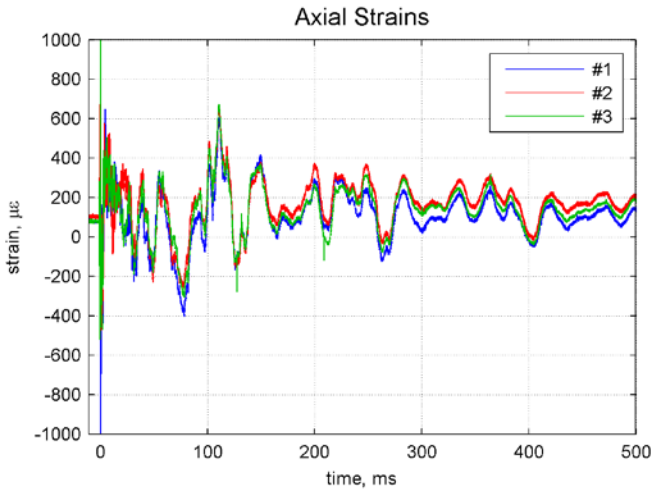
- Pressure measurement:
  - Upper Sub positioned five guns from the top of string
  - Lower SSS placed at base of string
- Pressures and loads are not the same across the string
- Multiple tools can be used to record the pressure event at different locations in the string
- Placing fast gauges at the base of the string does not give a full understanding of the dynamic pressure events at different locations in the string

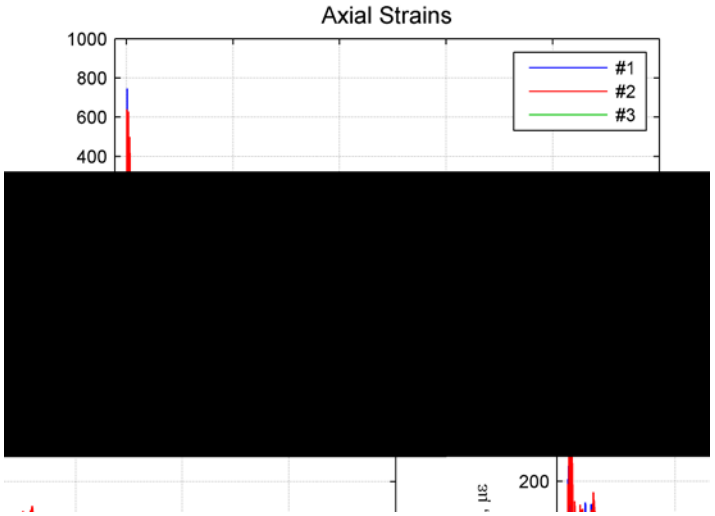


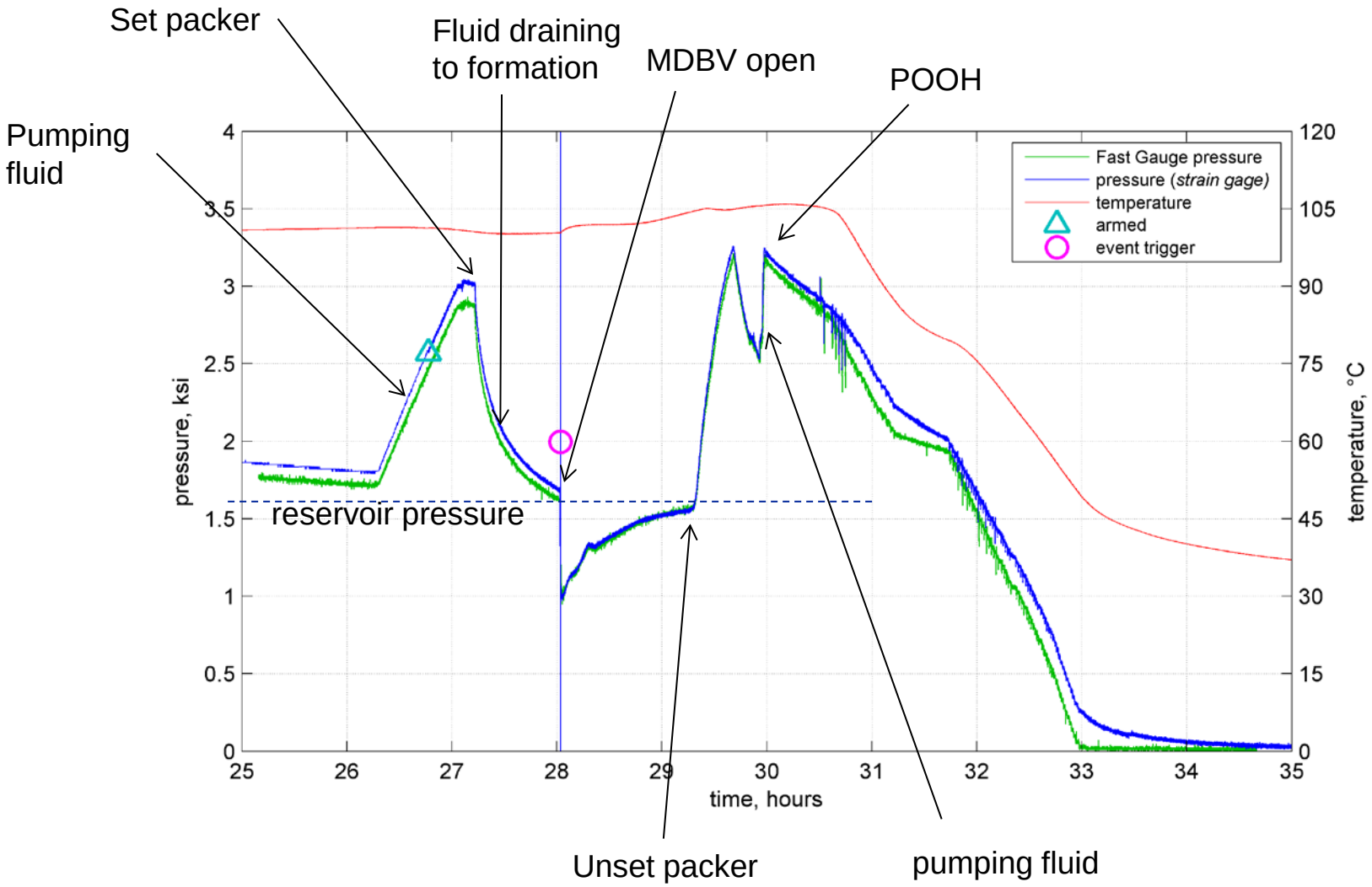
# Dynamic Events

- Strain measurement:
  - Upper Sub positioned five guns from the top of string
  - Lower SSS placed at base of string
- The tool at the base of the string captures the initial event
- By placing tools at the base / top of the string you do not capture the loads within the gun string



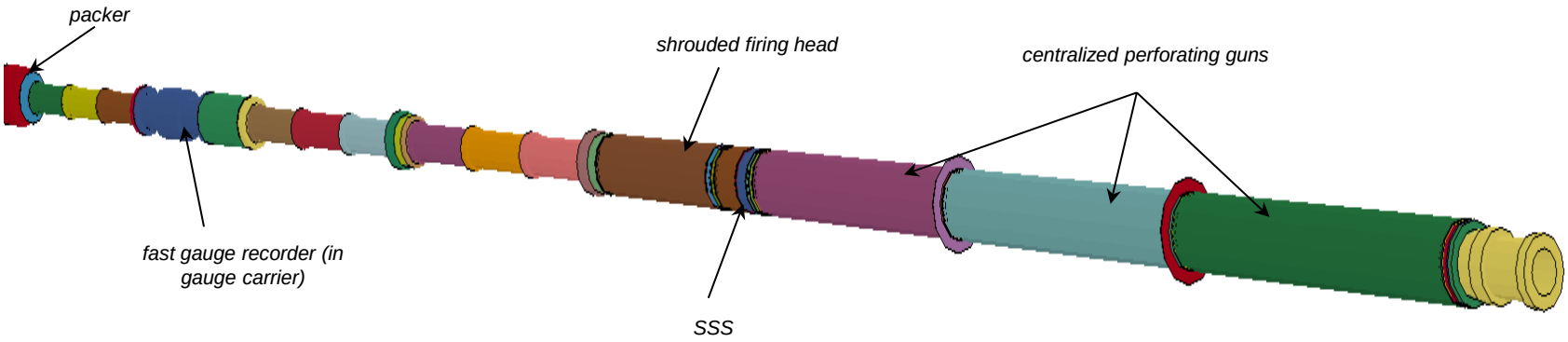
# Job History




IPS-14-03

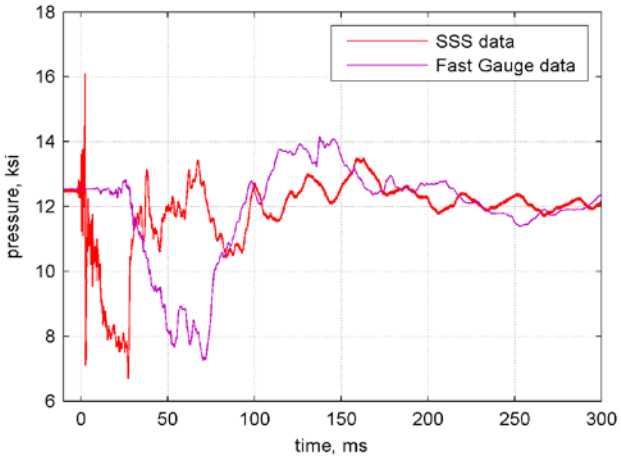
# Field Trial Job 2 Description

- Gun system: 4 5/8-in., 12 shots/ft using 28-g HMX SH LD charges
- Perforation depth approximately 16,000 ft
- Hydrostatic pressure 12,400 psi
- Bottom hole temperature 190$^{o}$F
- Fast Gauge™ recorder 40 ft below the packer
- Shock Sensing Sub placed between firing head and top gun

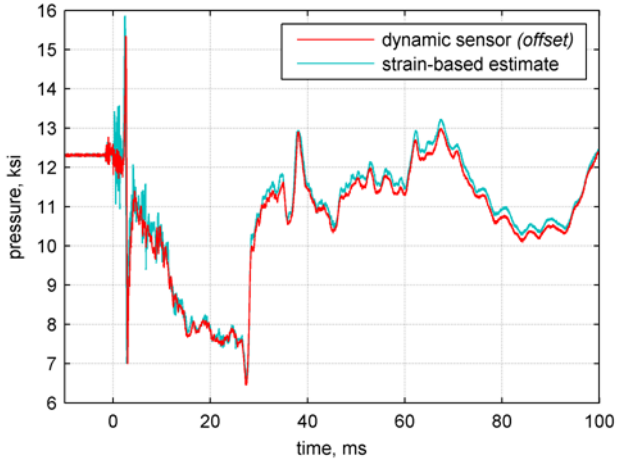


# Down hole Data

- Selected pressure results:
  - Shock Sensing Sub
  - Fast Gauge recorder
- Shock Sensing Sub pressure measurement against accepted tool

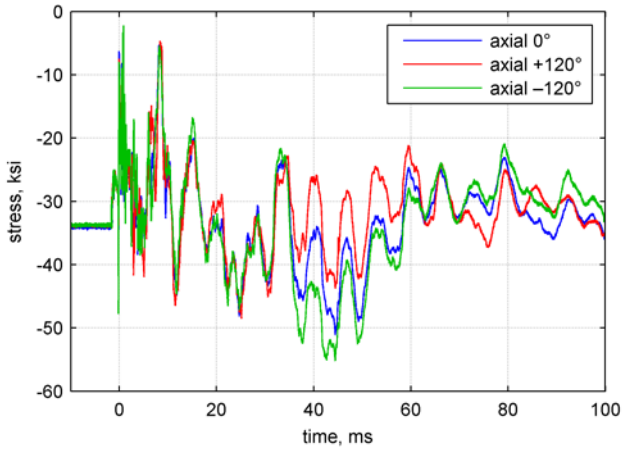


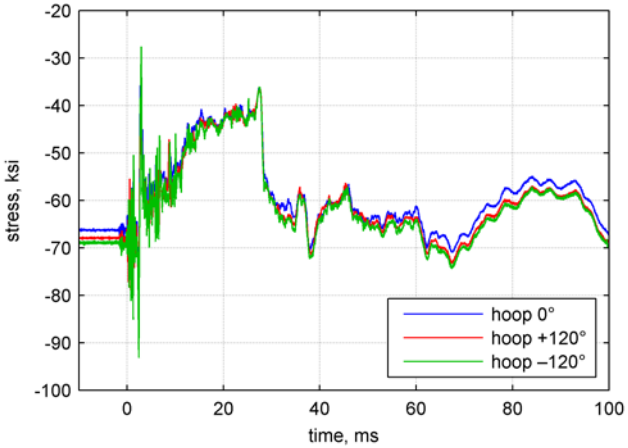

- Internal validation of pressure results:
  - Dynamic pressure sensor
  - Strain-based estimate
- Excellent correlation between two independent measurement sources on the Shock Sensing Sub



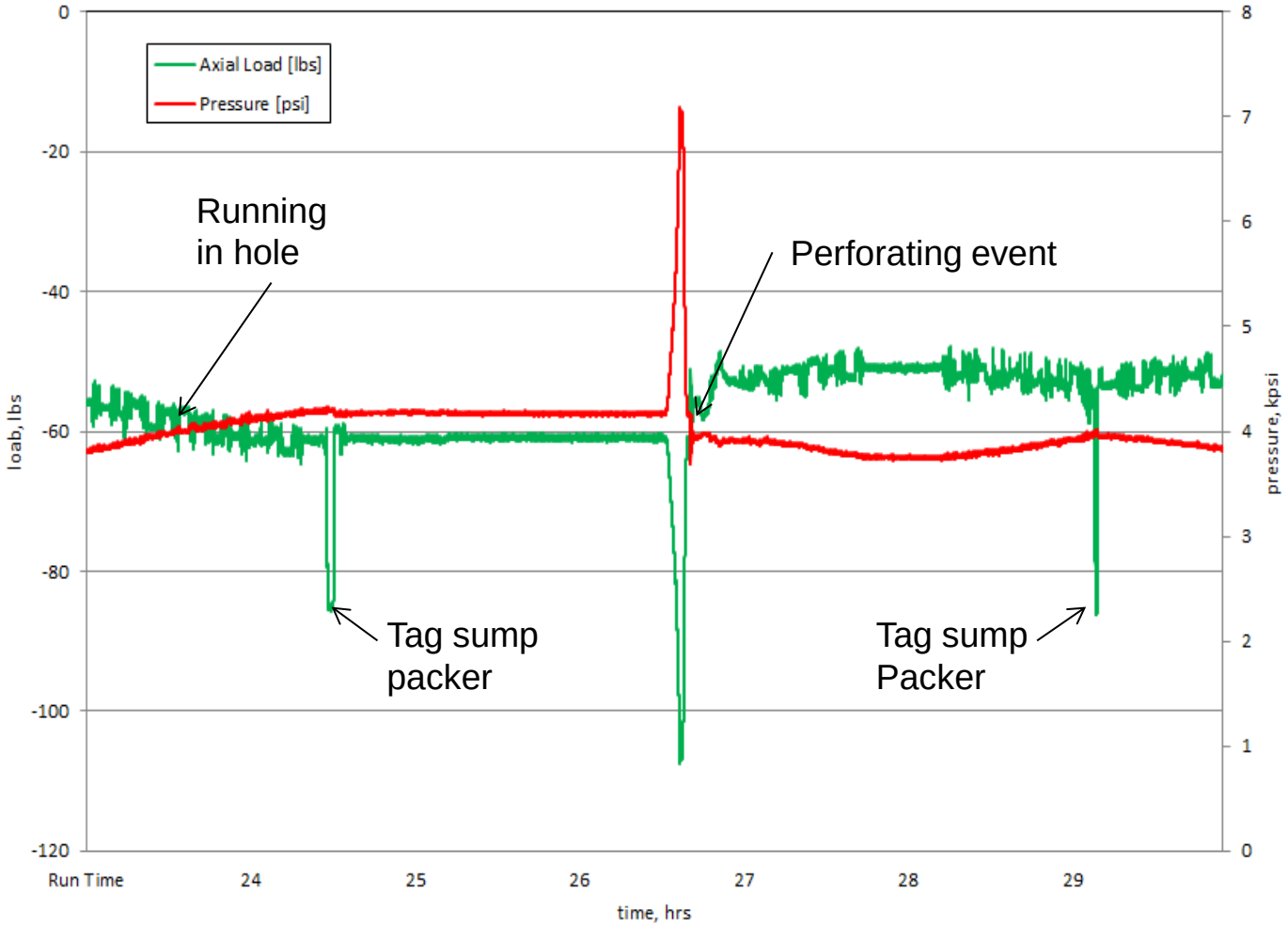
# Down hole Data

- Strain measurements:
  - Axial strain (0°, +120°, -120°)
  - Hoop strain (0°, +120°, -120°)
- Divergence of axial stresses indicates bending response
- Delayed onset of bending caused by difference in speed between dilatational and bending waves
- Hoop stress mirrors pressure
- Results can be processed to calculate average stress and ultimately, loads



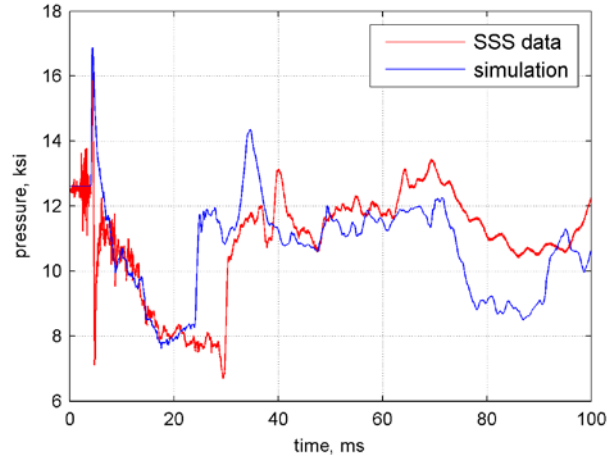
# Job History

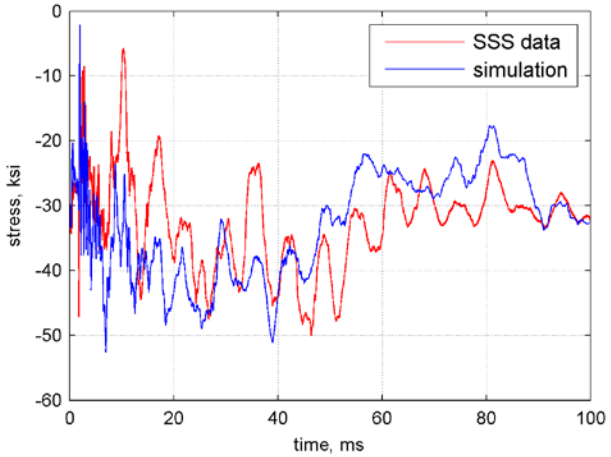



IPS-14-03

# SSS for FEA Model-Data Validation

- Used for calibration of full string model:
  - Pressure
  - Stress
- Pressure:
  - Accurate prediction of dynamic underbalance
  - Accurate capture of principal events and dynamics
- Stress:
  - Good representation of dynamic events
  - Good representation of overall stress levels



## Summary and Conclusions

- The new Shock Sensing Sub is designed to record and better understand the load and pressure events during perforating jobs:
  - Direct measurement of loads within the string
  - Direct measurement of dynamic pressure at any point in the gun string
  - The ability to have a complete record of the job history including pressure, temperature, acceleration, stresses and loads

- Improved understanding of the dynamics during perforating through acquired down hole data will ultimately lead to better gun design

- Utilizing the SSS in longer string gives the opportunity to confirm dynamic underbalance models and allow optimization for future wells

- Down hole data revealed interesting gun string dynamics and reasonable match between down hole data and simulations