



An Overview of Horizontal Multi-Stage Perforating

Kenneth Stevens, Jim Hill
Halliburton

HALLIBURTON

Horizontal Multi-Stage Perforating



History of Shale Developments

1980 → 1990 → 2000 → 2010

Barnett



First Horizontal well drilled in Barnett

Woodford



Fayetteville



Haynesville

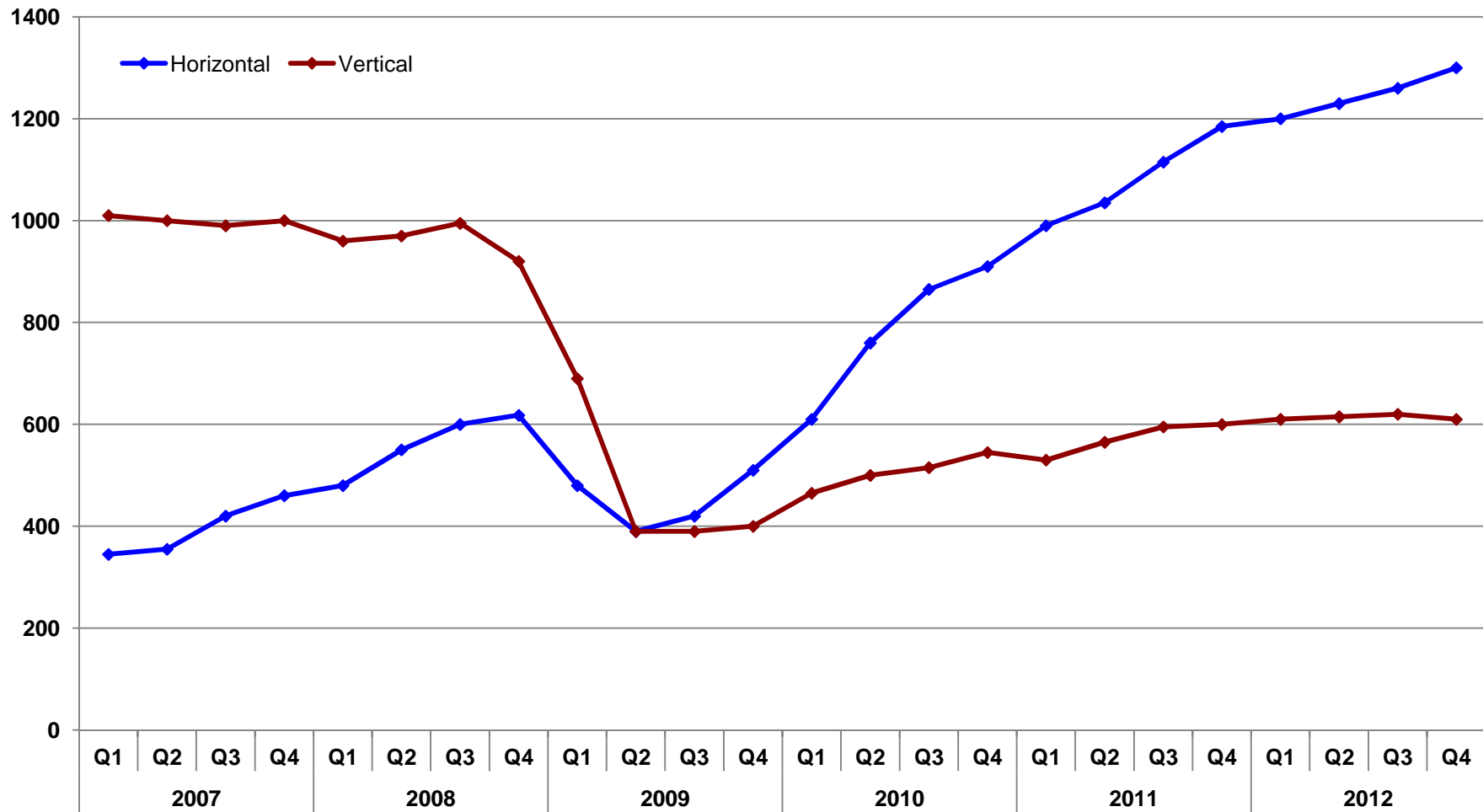


Eagleford



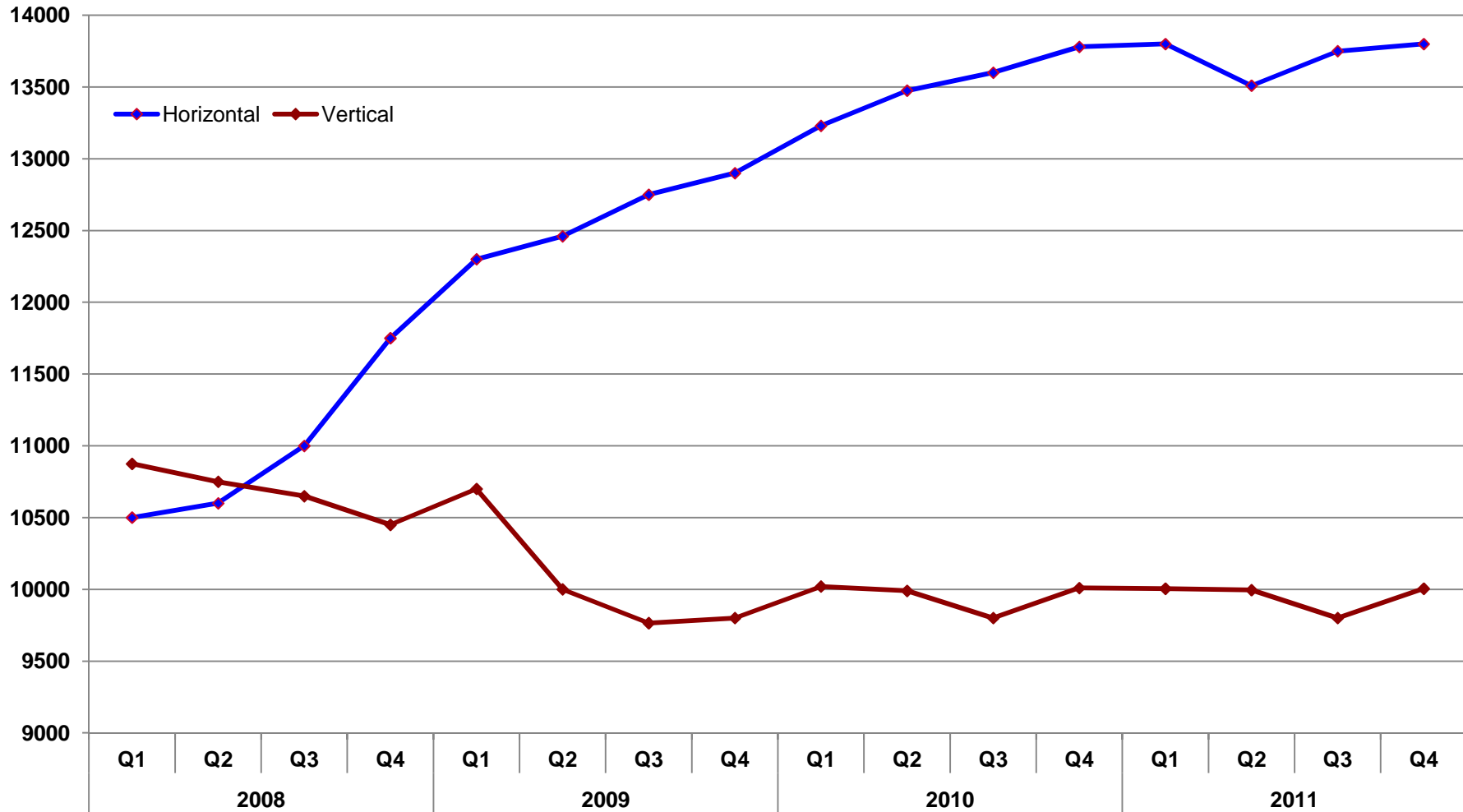
	Eagleford	Woodford	Haynesville	Bakken	Marcellus
Depth (ft)	5,000-13,000	6,000-14,000	10,000-13,500	4,000-11,000	4,000-8,000
Thickness (ft)	50-200	100-220	60-300	10-60	50 - 250
Hydrocarbon Type	Oil - Gas	Oil-Gas	Gas	Oil	Gas

USA Drilling Activity by Type



From Spears & Associates, Inc

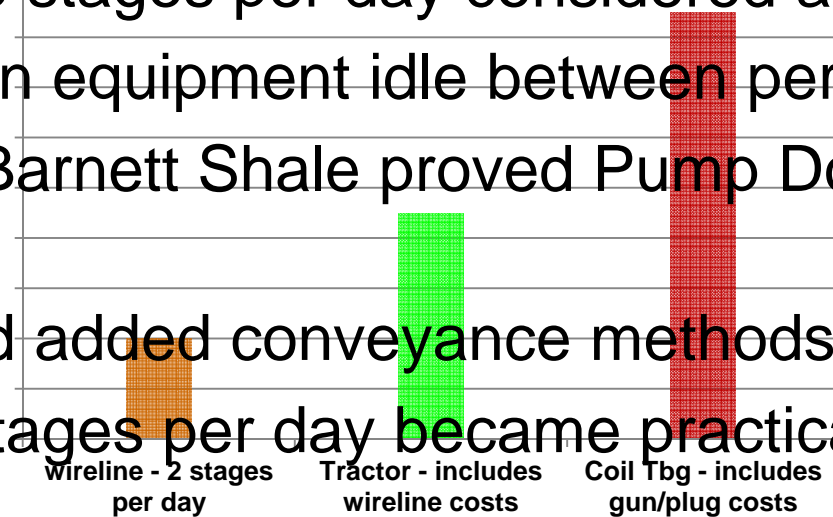
Measured Depth by Well Type



From Spears & Associates, Inc

Why Pump Down Perforating?

- Horizontal Drilling became practical and economical about 2000
- Initial completions were time consuming and expensive
 - Each stage required tractor conveyed E-Line guns or Coil Tubing TCP type guns.
 - One – two stages per day considered acceptable
 - Stimulation equipment idle between perforation stages
- Work in the Barnett Shale proved Pump Down economic viability
 - Eliminated added conveyance methods
 - Multiple stages per day became practical



Horizontal Multi-Stage Perforating

- Pump Down Services (PDS) offers quick, efficient and cost effective deployment of multi-gun/plug runs for multiple stage completions
- PDS is a common deployment method used in the USA and Canada primarily for guns and plugs but also for other e-line services – method is expanding globally
- Efficient PDS, depending on depths, now allow up to 5 stages per 24 hour day
- A typical single E-Line stage consists of
 - Multiple guns (3 foot - 6 spf carriers)
 - Explosive setting tool
 - Composite plug

Horizontal Multi-Stage Perforating

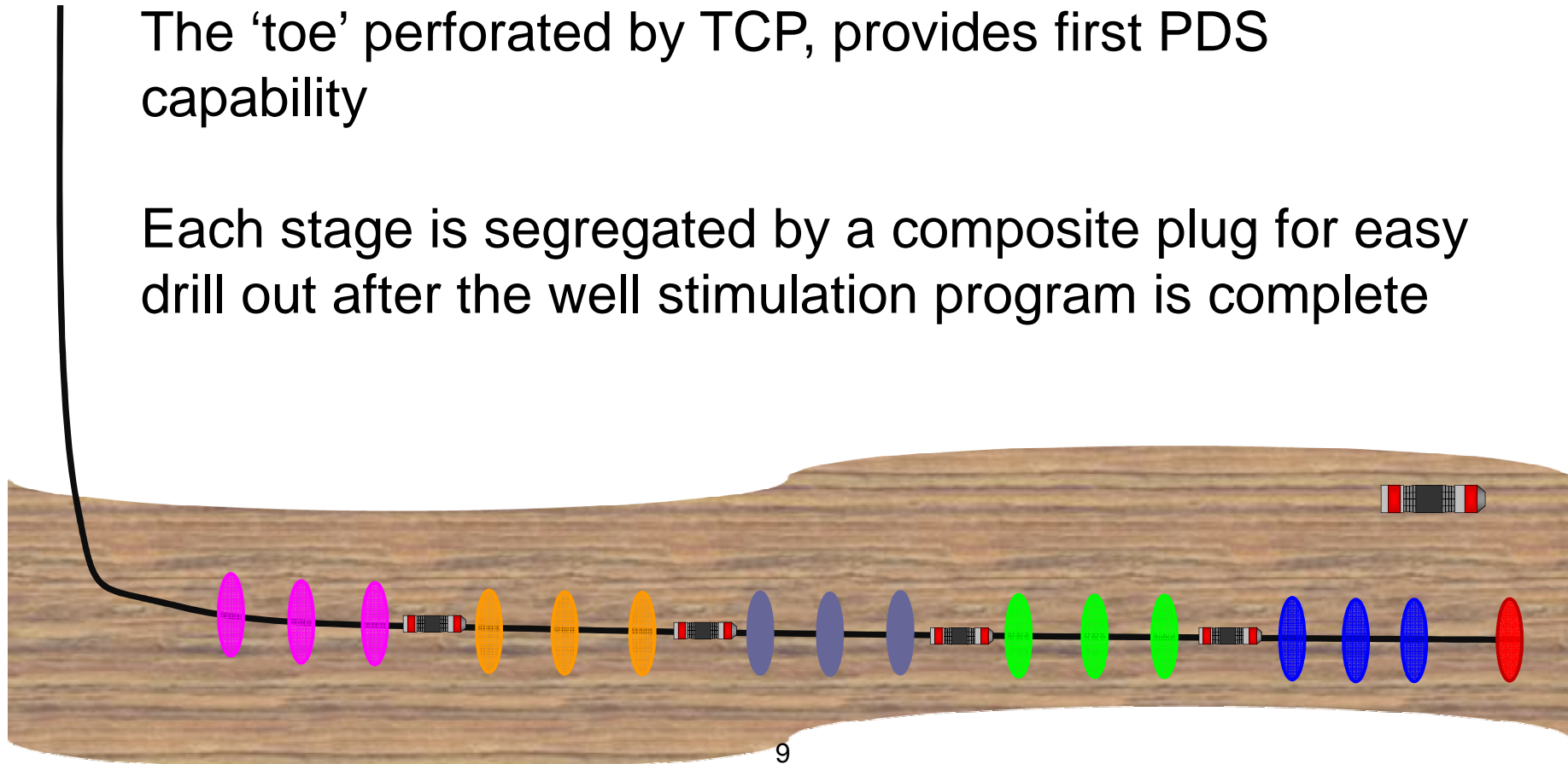
- Well directional data should be available and a Cerberus pre-job well model run to review successful tool deployment and recovery
- PDS requires continuous coordination between E-Line operator and Stimulation providers during the operation
 - Inadequate communication during the pump down service can result in tool string pump off and fishing operations
 - Inadequate flush can allow proppant accumulations in a trough. The proppant can stall and stop the tool string, resulting in a fishing job
 - It is recommended that E-Line units have real time pump pressure and pump rate displays allowing the hoist operator to adjust running speeds (best practice)

Horizontal Multi-Stage Perforating

Most PDS completions are perforated in a geometrical spacing

The 'toe' perforated by TCP, provides first PDS capability

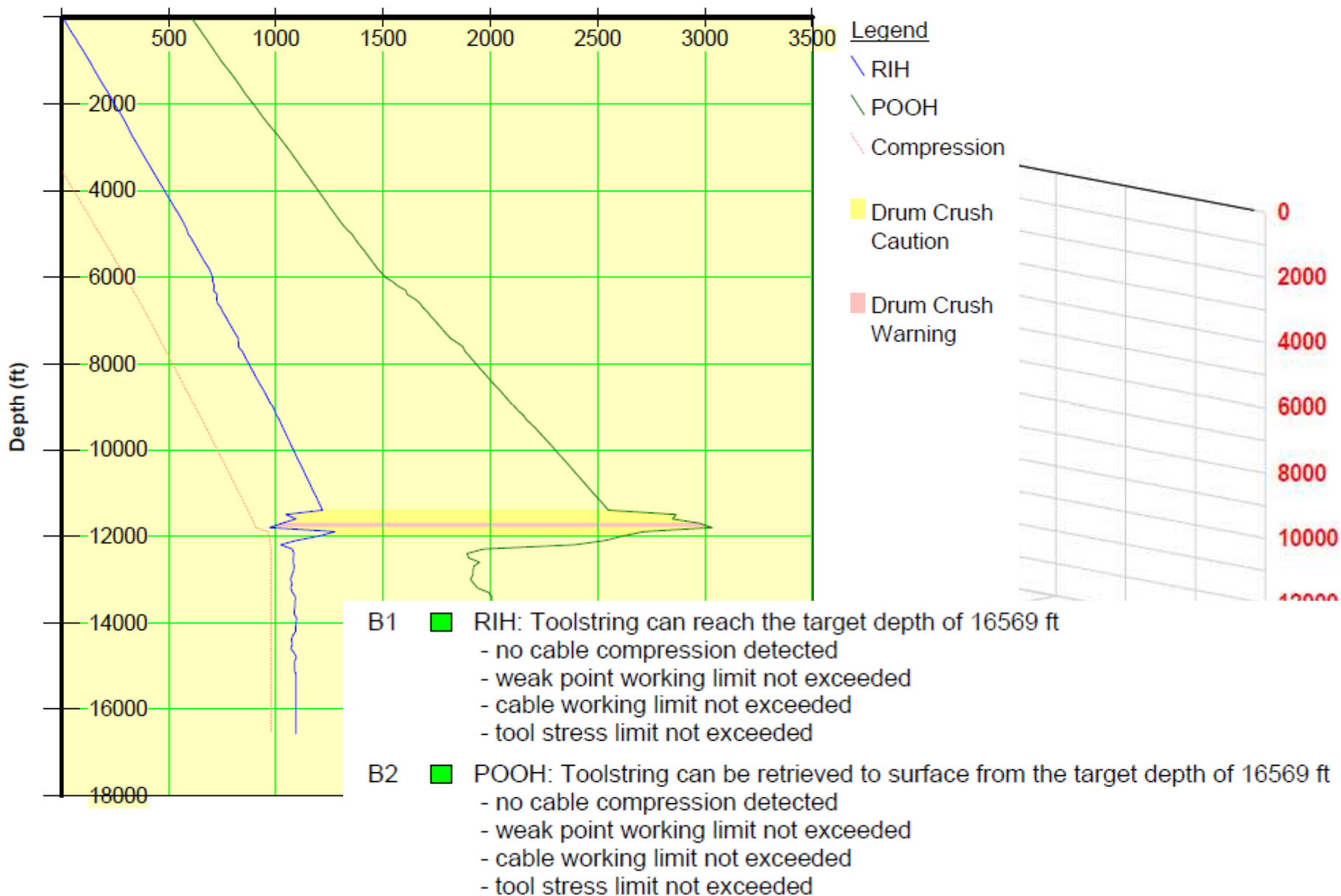
Each stage is segregated by a composite plug for easy drill out after the well stimulation program is complete



Horizontal Multi-Stage Perforating

- Standard E-Line cable longevity can be poor. New mono-conductor cables incorporating improved torque balanced armor packages have greatly improved cable life in long lateral wells
 - PDS produce very loose cable armor packages when total depth is reached.
 - There is no means to stop during the pump down and apply tension for cable conditioning as in vertical wells.
 - Hoisting cable to surface with heavy tool strings across long laterals produces high torque buildup as the cable transitions through the heel
 - E-Line Swivels are recommended when possible

RIH and POOH



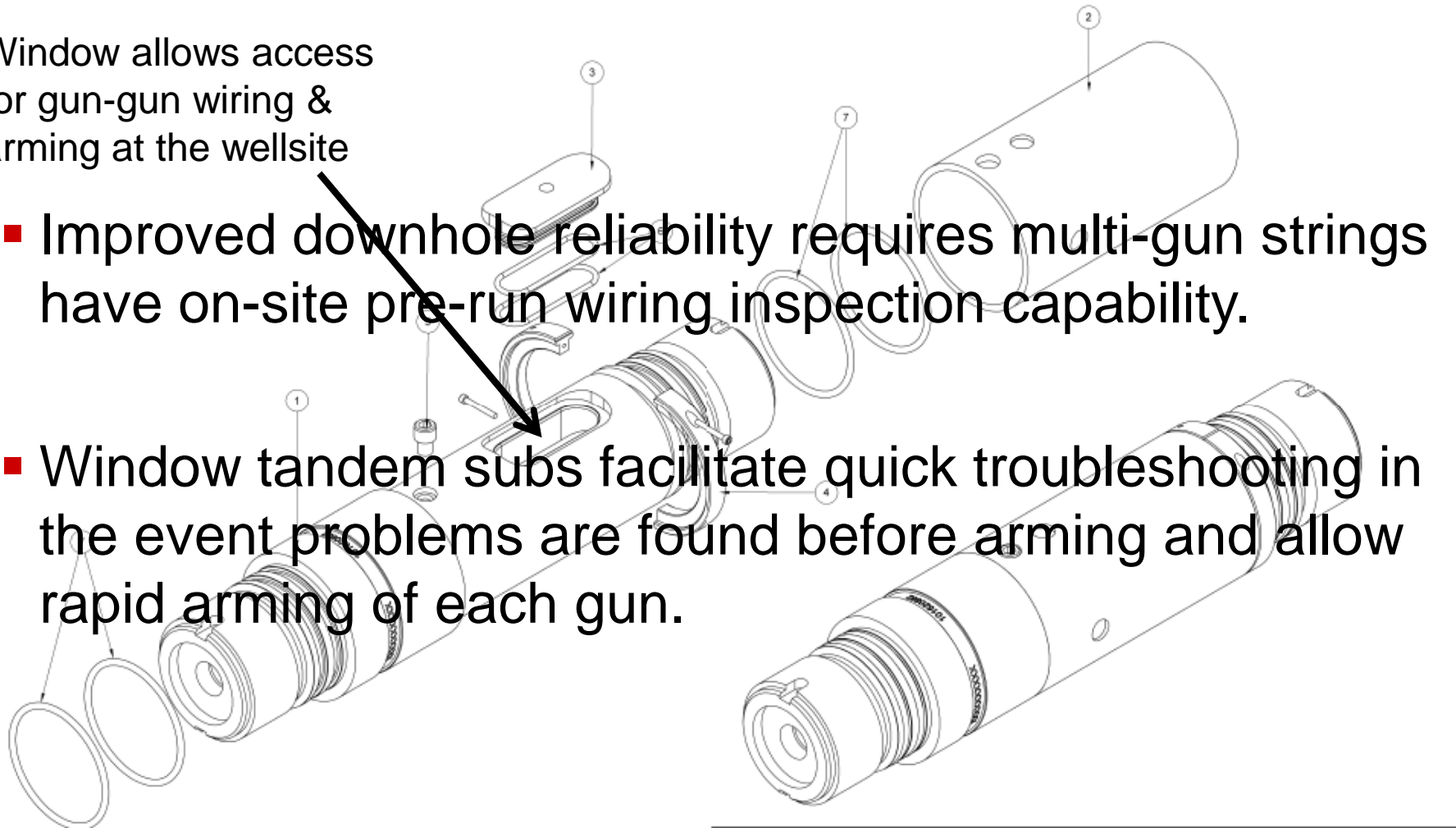
Horizontal Multi-Stage Perforating

- Perforating reliability
 - Pump down operations produce continuous vibration to the gun string during the pump down and subject the gun string to greater repeated shock, transmitted axially along the gun string, as each gun is fired
 - Gun to gun wiring practices and select fire reliability, based on normal vertical perforating practices, were poor in the beginning
 - Applied best practices and equipment standardization greatly improved NPT.

Horizontal Multi-Stage Perforating

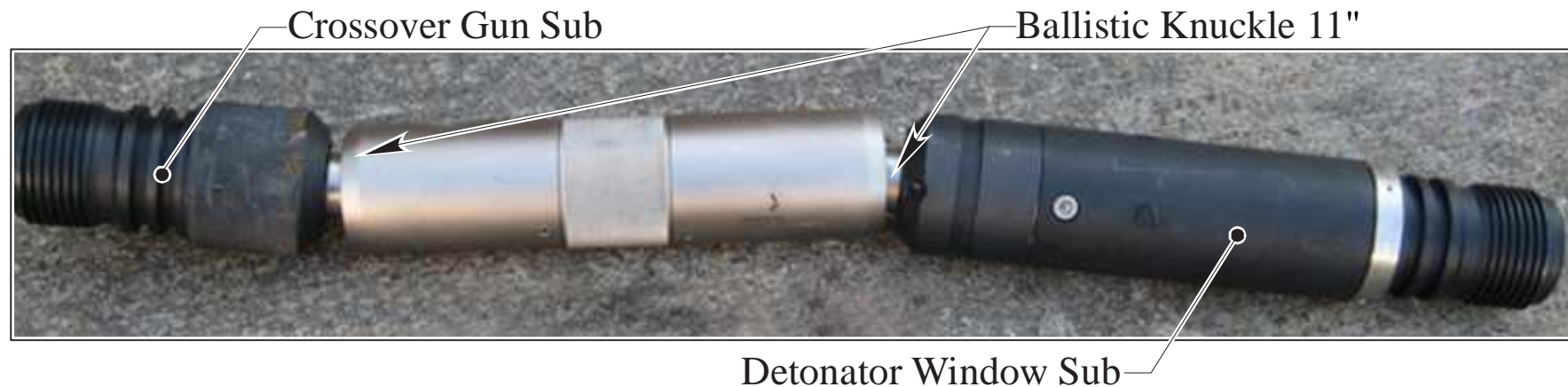
Window allows access for gun-gun wiring & arming at the wellsite

- Improved downhole reliability requires multi-gun strings have on-site pre-run wiring inspection capability.
- Window tandem subs facilitate quick troubleshooting in the event problems are found before arming and allow rapid arming of each gun.



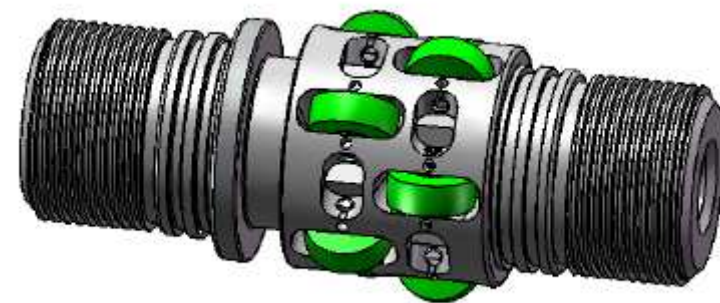
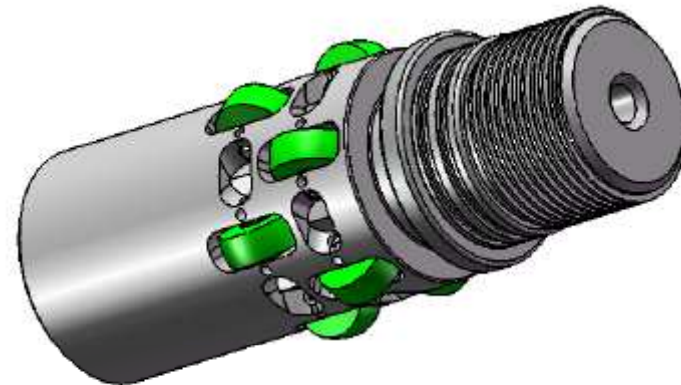
Horizontal Multi-Stage Perforating

- Gun to gun knuckles capable of surviving ballistic concussions have been developed for gun strings requiring greater flexibility to pass



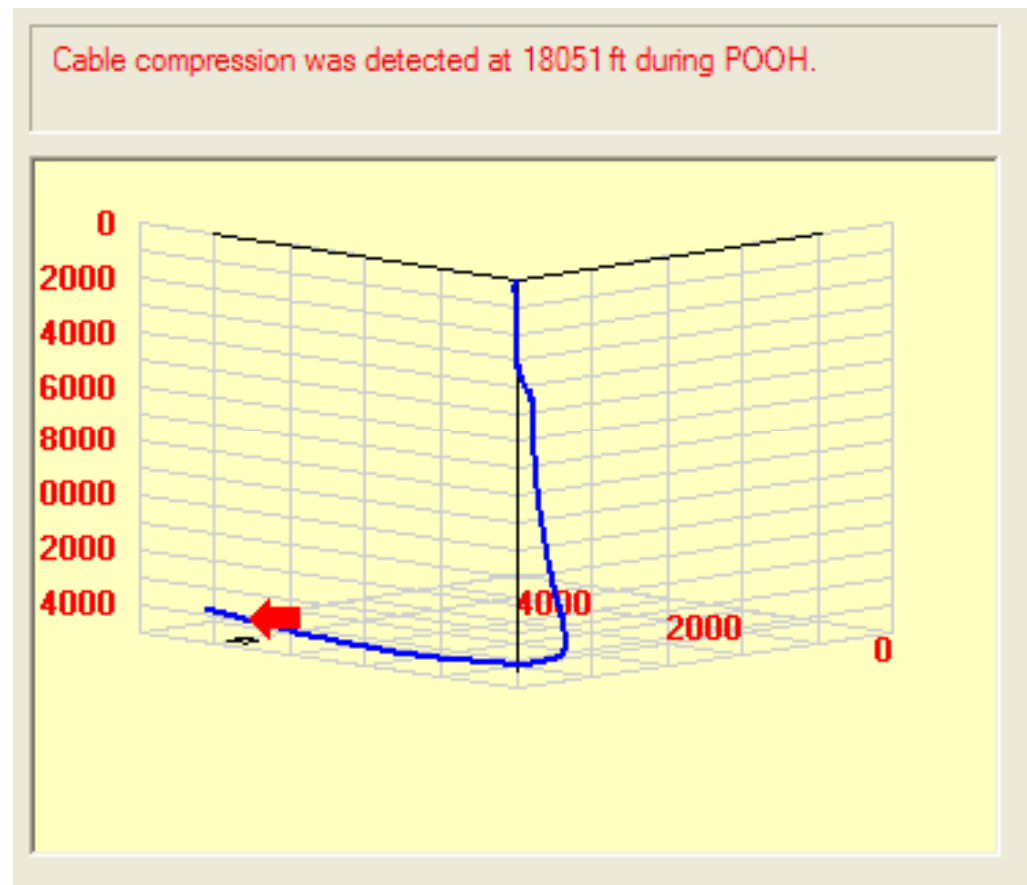
Horizontal Multi-Stage Perforating

- Roller Subs help reduce friction of the tool string when being pumped downhole
- Can reduce pump rate and pressure needed by up to 50%
- Cerberus modeling should always be used before adding roller subs



Horizontal Multi-Stage Perforating

- Well deviation showed 'toe up' at 108 degrees.
- Addition of roller subs would have allowed roll back (down slope) of tool string with possible cable severance when perforating.

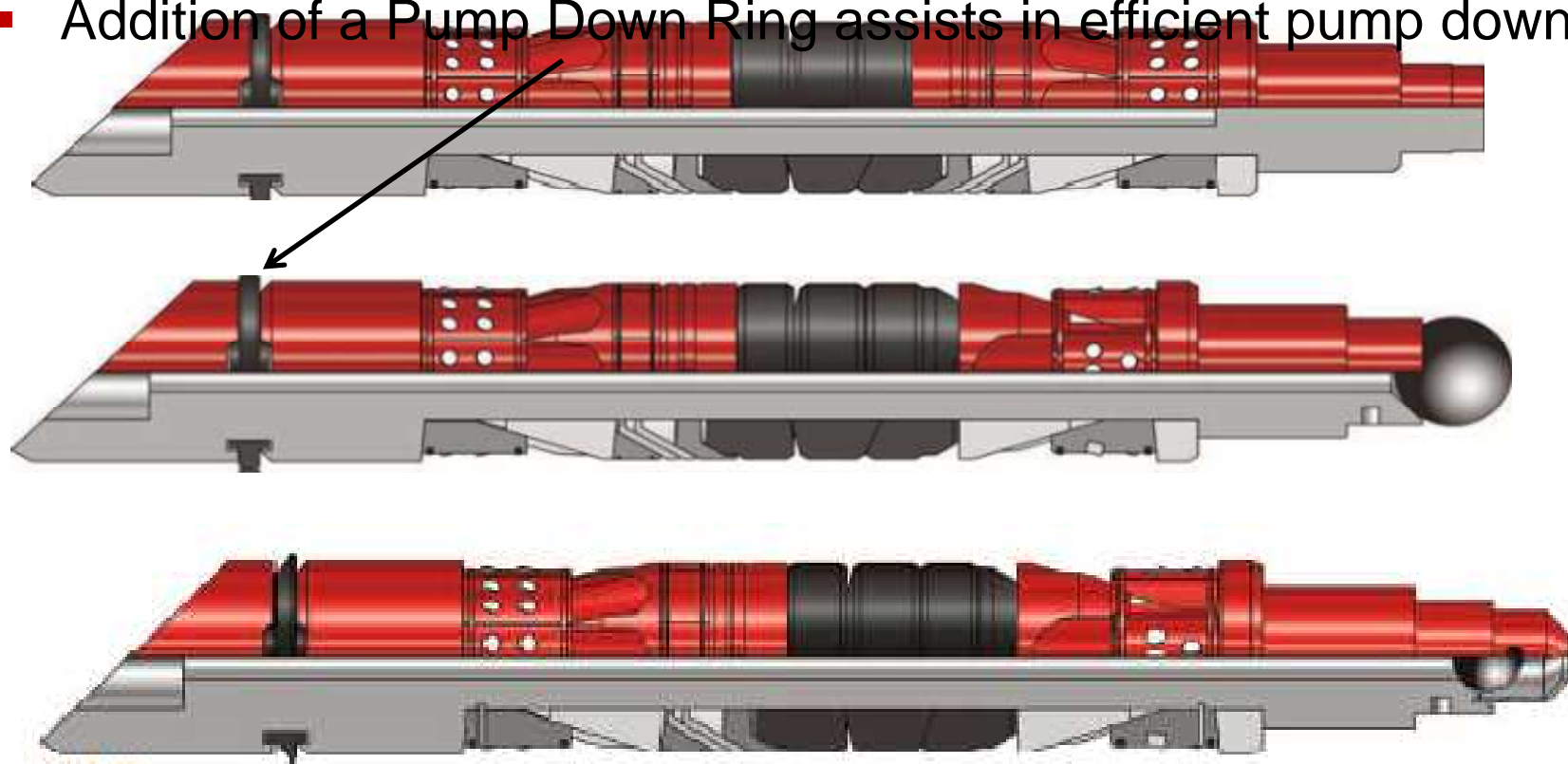


Horizontal Multi-Stage Perforating

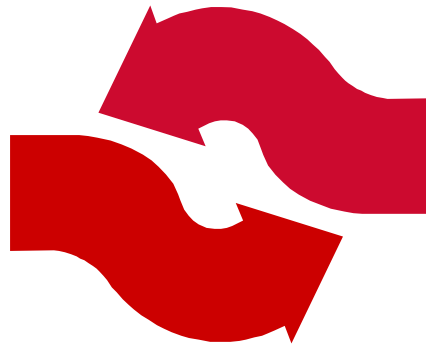
- Setting tools.
 - PDS typically require multiple explosive setting tools to be available at the well site.
 - There has not been any tool brand or model which performs better than others
 - Segregation of tool assemblies and regular inspection of all components has become a best practice.
 - Higher pressure rated setting tools now available to meet the demands for high pressure PDS
 - 20 k psi (1379 bar)
 - 25 k psi (1724 bar)

Horizontal Multi-Stage Perforating

- The Caged Ball Frac Plug was developed specifically for horizontal wells.
- Full Composite Plugs are the only type used in PDS.
- Addition of a Pump Down Ring assists in efficient pump down



THANK YOU



Questions and Answers