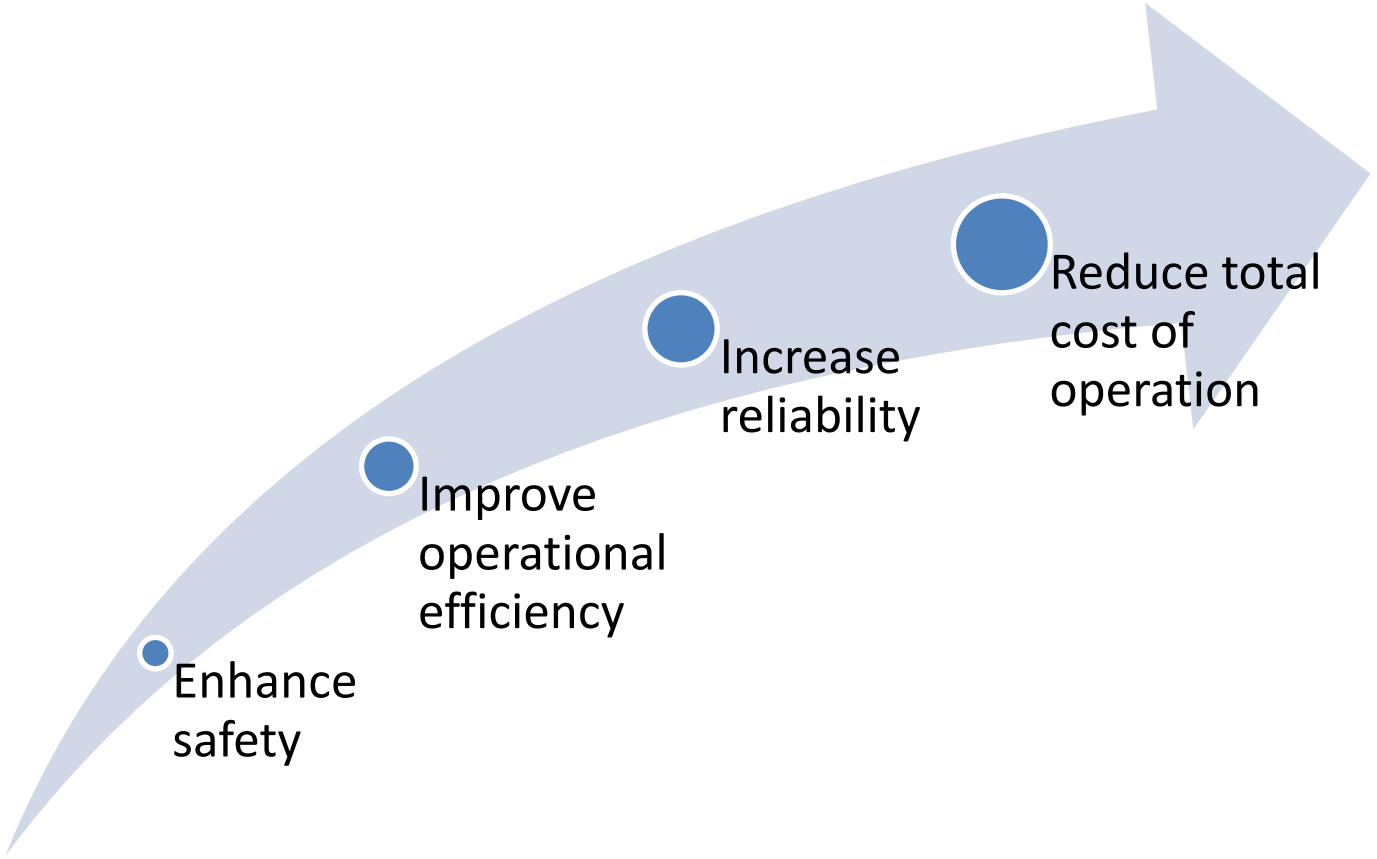
Lowering Total Cost of Operations Through Higher Perforating Efficiency while simultaneously enhancing safety

Introduction of a novel factory assembled selective plug and perf perforating system

Presenter: John ‘JW” Segura, Weatherford
Presentation prepared by: Frank Preiss, DynaEnergetics and John ‘JW’ Segura, Weatherford

- Factory Assembled Perforating System
  - System Targets
  - Technology Introduction
- Field Trials
  - Goals
  - Operational Statistics
  - Identified Benefits
- Opportunities for improvement
- Commercialization

FACTORY ASSEMBLED PERFORATING SYSTEM TARGETS



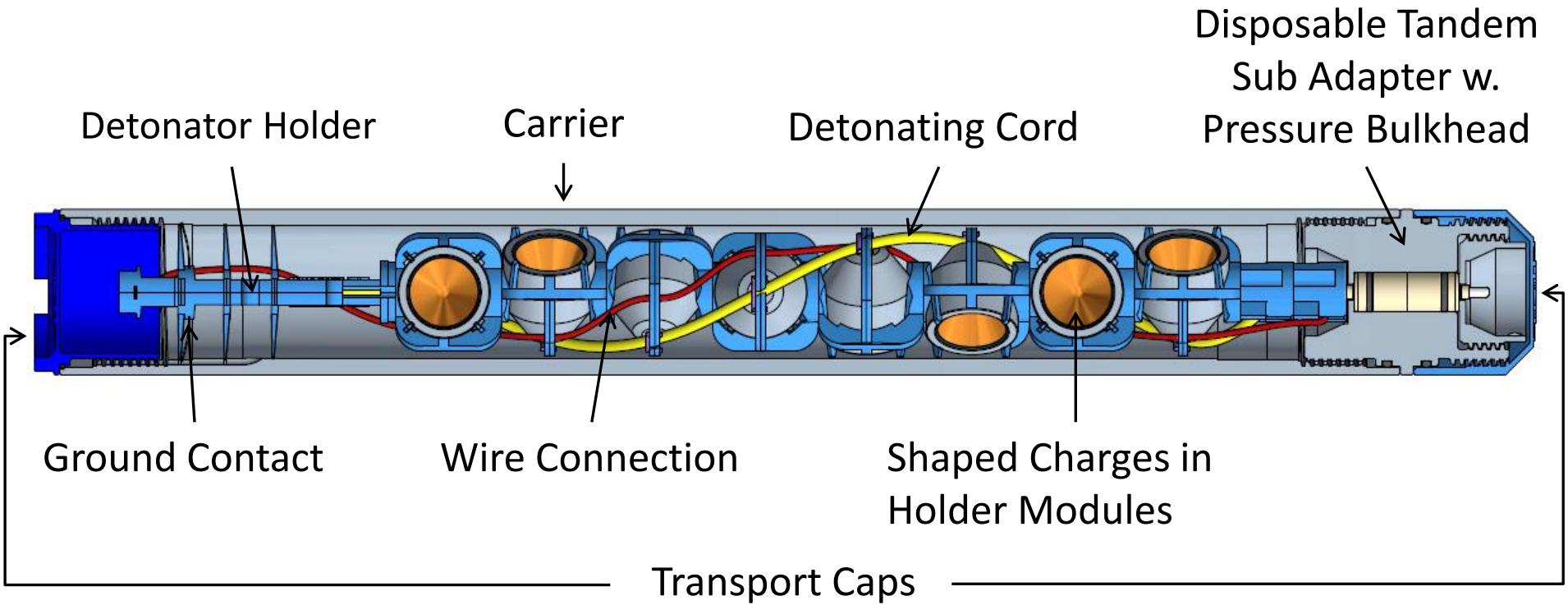
- True RF, stray current and voltage-safe initiator
- No more gun loading at the wellsite
- No detonating cord cutting and explosives remnants at the wellsite
- Minimum explosives handling and field assembly required at the wellsite

- Efficient single trip plug setting and perforating with up to 20 guns
- Does not require any initiator or switch wiring or crimping at the wellsite – 100% plug and go
- Fully disposable, no servicing – maintenance free
- No software needed for selective perforating and plug setting
- Uninterrupted communication with all detonators and igniter while in the well
- Surface tester for complete gun and setting tool system check available
- Reduction in rig up height and total weight

- No gun loading or component servicing at the wellsite
- 0% chance of wrong assembly at the wellsite -> no human error
- No port plug or tandem isolation subs necessary -> reduction in o-ring connections
- Does not require any initiator or switch wiring or crimping at the wellsite -> no human error
- Surface tester for complete gun system and setting tool check down to initiator level
- Uninterrupted communication with all detonators and igniter while in the well

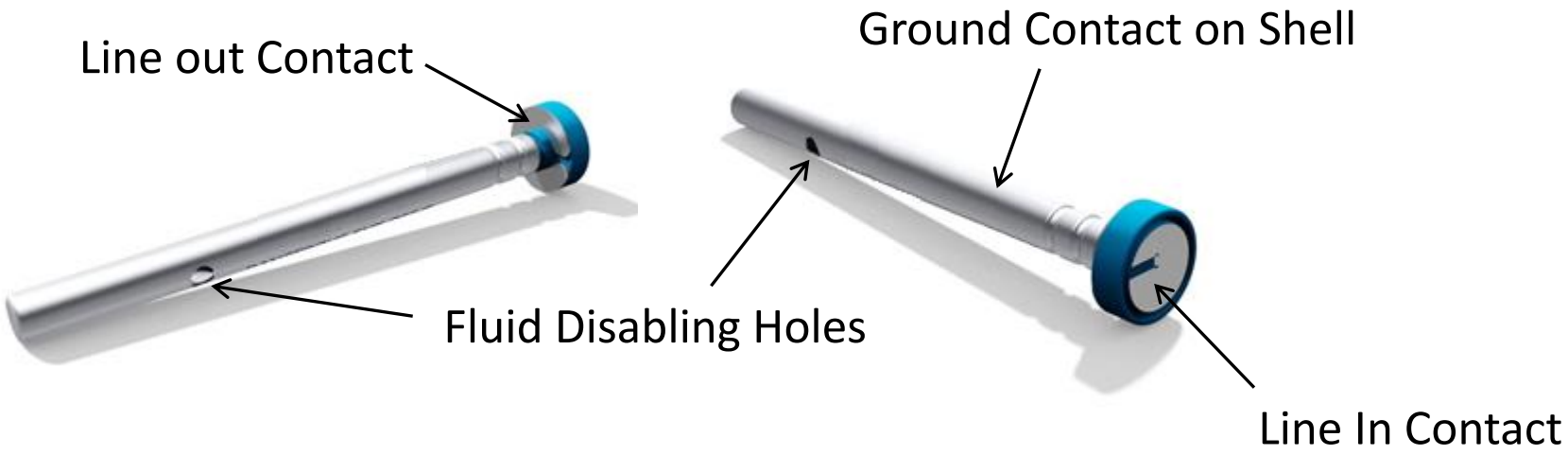
- Factory assembled and quality assured gun system
- Reduce time to cap and connect guns
- Reduce changeover times between runs
- Allow simultaneous surface operations for perforating and fracturing
- Reduce non productive time due to misrun avoidance caused by errors that cannot be detected on surface when using conventional plug & perf systems

Factory pre-assembled perforating system



Plug and Go Integrated Switch Selective Detonator

No Wires



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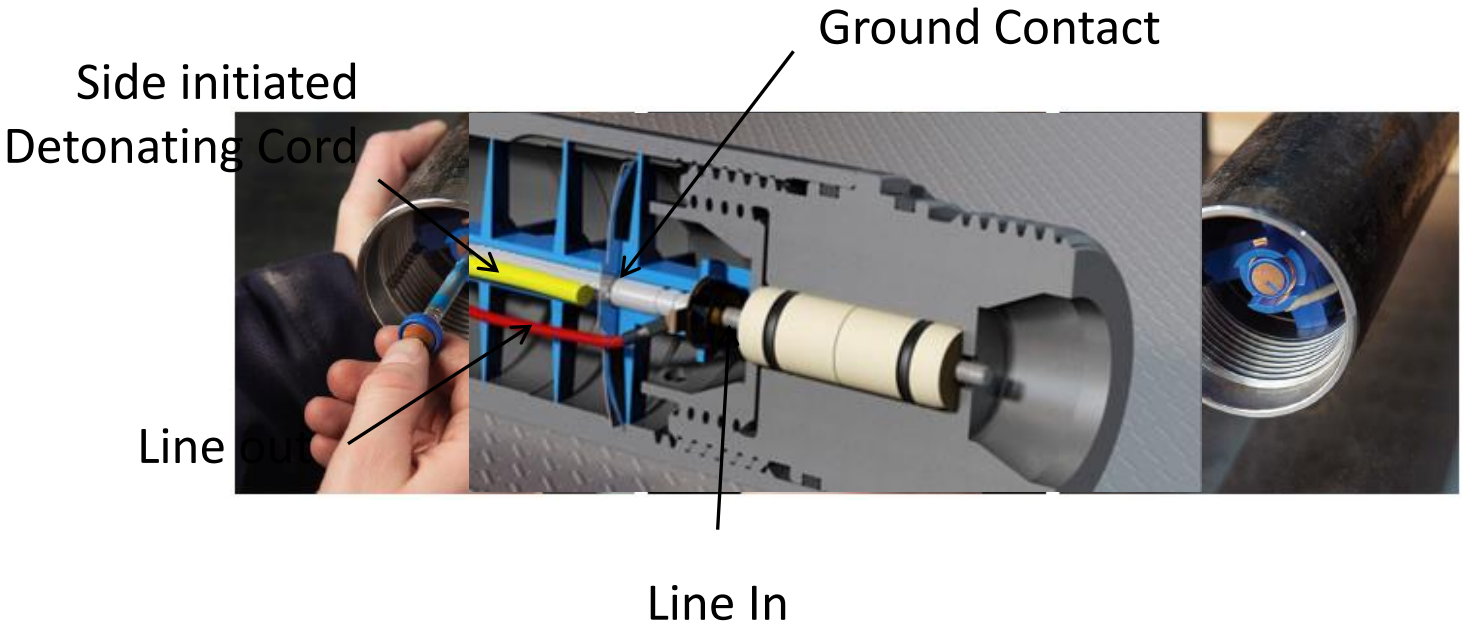
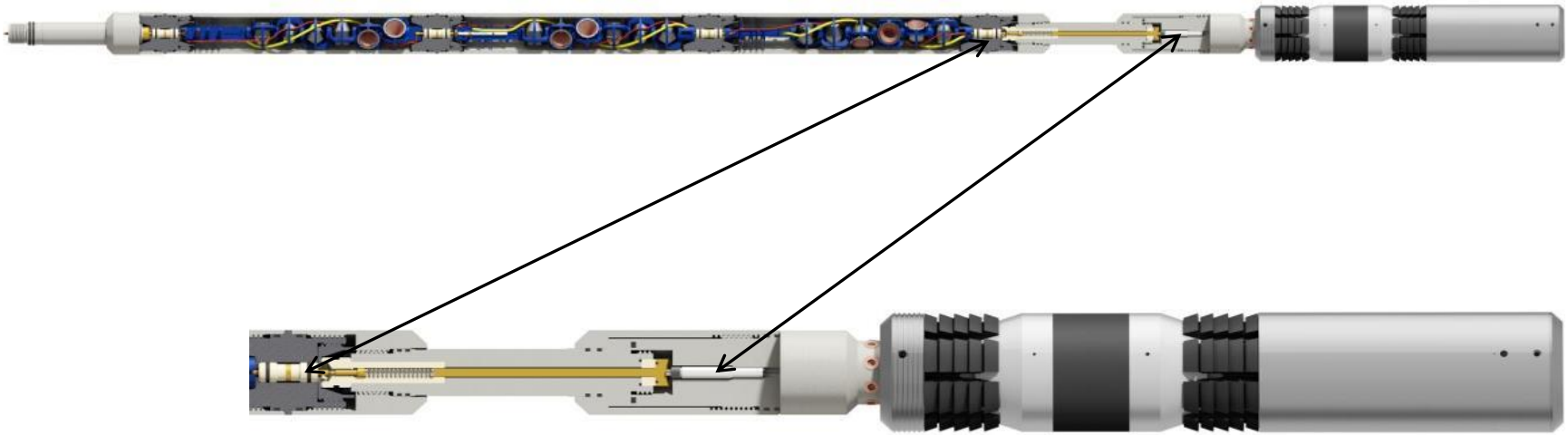
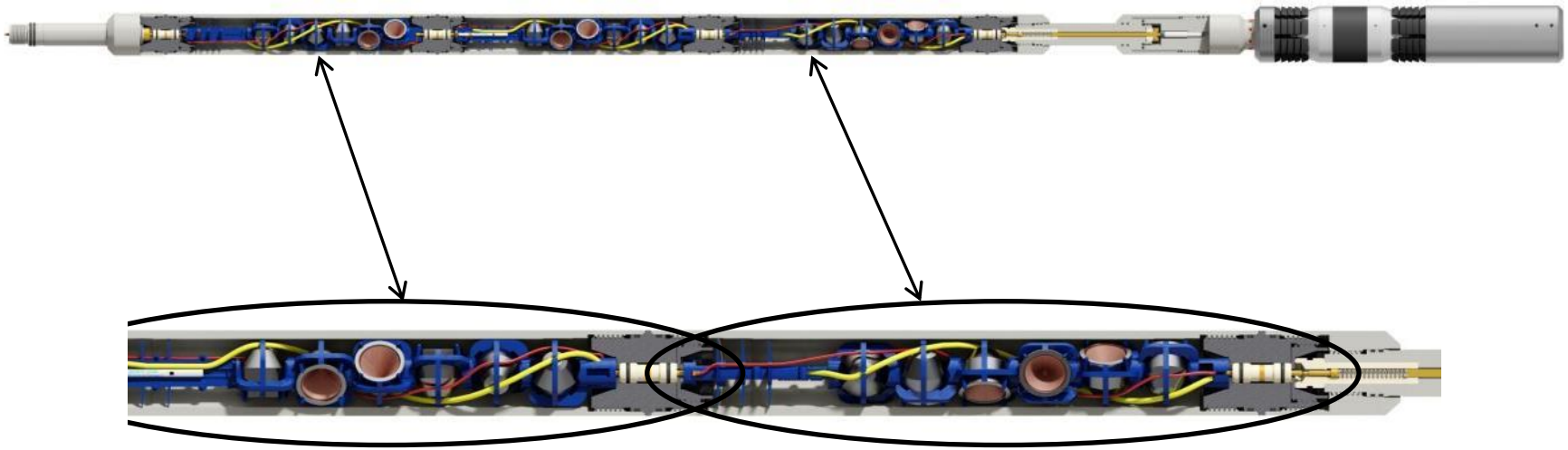
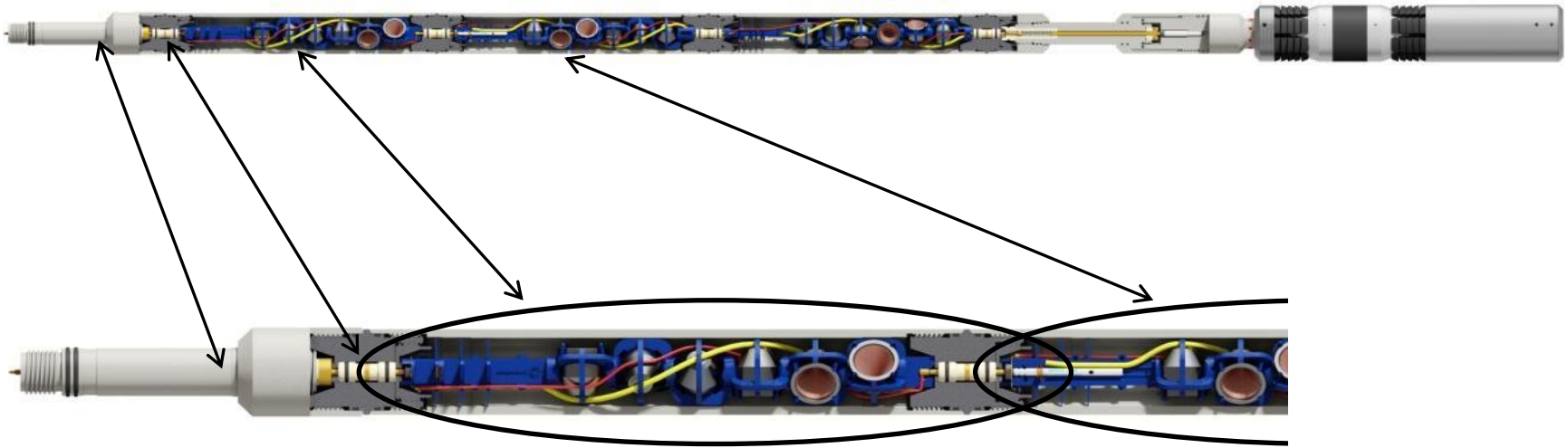




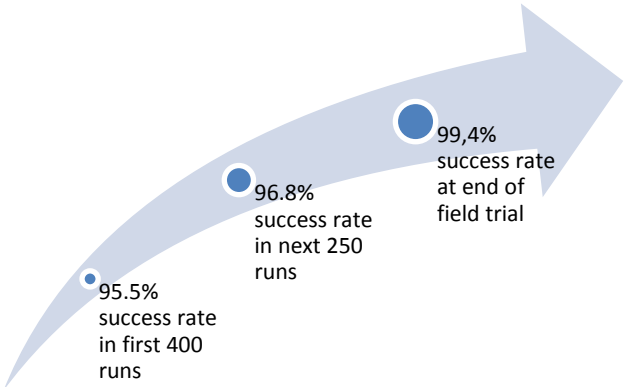




- Prove concept and design of the system
- Test the quality and reliability of the assembly process
- Decide if offsite third party factory build gun loading is practical and provides the required responsiveness
- Measure the value added to horizontal plug & perf completions

- Field trials started in February 2015 and ran for 6 months
- Trials were
  - run by two service companies
  - conducted with eight operators
  - performed in three shale formations (Permian Basin, Eagleford Shale and Marcellus Shale)
- Nearly 6,000 Factory Assembled Perforating Systems were shot
- Over 1,000 stages were plugged and perforated

- Assembly failures occurred at the loading facility
- Through use of the surface tester defective systems were detected at the well site that did not result in a misrun or down time
- The handling experience and misruns resulted in 9 design changes that enhanced the system efficiency
- To detect system problems a Go-NoGo Test Fixture was designed



- Prove concept and design of the system
  - Less shop labor required
    - No gun loading
  - Ease of operation at the well site
    - Efficient delivery of loaded pre ordered systems
    - Plug and go detonator
    - No wires to connect
    - No port plugs to install
    - No subs to clean
    - No explosives remnants

- Prove concept and design of the system continued
  - Safety
    - 100% RF, stray current and voltage-safe initiator for setting tool and detonator for guns
      - No radio silence concerns
      - 3rd party verified and certified RP67 compliant
    - No risk of mishandling or pinching of explosives or wires
    - Easy and fast gun connection at well site
    - Debris from gun can easily be removed leaving blank barrel

- Test the quality and reliability of the assembly process
  - Simple plug-and-go detonator insertion process
  - No wiring to be considered while screwing guns together
  - Surface tester allowed check of completely assembled system and enabled improved trouble shooting
  - Field trial modifications resulted in perforating efficiency increase

- Decide if offsite third party factory built gun loading is practical and provides the required responsiveness
  - 48 hour delivery was accomplished
  - Cluster design changes can be made “on the fly”
  - Modifications from field trials were quickly implemented
  - 100% use of Go-NoGo test fixture for function and quality control of Factory Assembled Perforating System

- 100% check at factory
  - Continuity check to next gun
  - Ground function
  - Mechanical tolerances

- Measure the value added to horizontal plug-and-perf completions
  - Reduced stage completion times by 30 minutes on average
    - Efficiency of surface level transitions
    - No RF related wait times due to simultaneous operations
    - Improved downhole reliability
  - Increased safety
    - Maintain radio communication during all operations phases
    - Eliminate the risk of accidental surface detonation
    - Minimum handling of explosives
    - No explosives remnants

- Currently only available in 3 1/8” gun size
  - Presently 2 3/4” system is in testing and 3 3/8” system is in the design phase
- Perforating charge variety
  - The option of DP and GH charges (both designed with uniform EHD) been extended to energetic liner charge and frac optimised charge
- Gun stacking limited to 20 guns plus plug
  - Enhanced system in trial phase for extension to 40 guns
- Not able to log collars while perforating
  - Presently no solution available

- Since the trial phase, that ended in Q4 of 2015, over 4.000 additional Factory Assembled Perforating Systems have been run
- The present average success rate has developed to 99,86%

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Thank you for your attention.

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A novel selective plug and perf perforating system has been designed, field tested and commercialized in 2015. It was created for completing unconventional wells using an innovative design that improves the operational efficiency, reduces the total cost of operations and enhances reliability and wellsite safety. The new purpose engineered perforating gun design features factory preassembled gun modules with tandem adapters and a plug-and-go detonator for streamlined wellsite assembly, handling, rig-up and disposal. It is specifically engineered for pump down frac spreads with parallel frac and perf operations. The purpose designed intrinsically safe integrated switch detonator allows constant surface communication to all downhole components.

This paper will briefly describe the technology used and then elaborate on the field trial planning, experience and lessons learnt during the over 1.000 horizontal stages completed using over 10.000 guns since June of 2015.