Digital Trigger: Safe, On-Demand, Efficient and Recordable Perforating on Slickline

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Perforating and Remedial Services Global Domain Champion Slickline Services
Slickline Services

- The benefits of Slickline conveyance
  - minimal footprint, logistical simplicity
  - operational efficiency
  - simplified well control and wire management
  - environmental friendliness
  - cost effectiveness

- Inherent limitations
  - limited visibility and clarity of toolstring actions and status
  - limited depth precision
  - limited capability
  - over dependence on slickline operator’s experience level
Digital Slickline

Standard core
- Sandvik 0.108” and 0.125”
- 5R60 Stainless Steel
- Temperature range -40 C to 150 C (-40 F to 302 F)
- Pressure range 0 - 10,000 psi
- Breaking strength 1870 lbs (108) and 2500 lbs (125)

Insulation Specification
- Proprietary polymer compound
- Non reactive, H2S resistant

Sour Service Cable
- Engineering on Sanicro H2S Ongoing

Telemetry NOT power
LIVE Digital Slickline Services — the Platform

**Digital Slickline Surface Equipment**
- Standard winch / drum / pulleys / stuffing box
- Surface Transceiver and PC

**Digital Slickline Cable**
- Sandvik 5R60 stainless steel alloy
  - 0.108” (0.138” OD after coating)
  - 0.125” (0.153” OD after coating)

**Digital Slickline Core Tools**
- Cable head
- Basic Measurement Cartridge
  - shock / tension / deviation / movement
- Depth Correlation Cartridge (GR/CCL)
X'over To 5/8" SR

Wired Jar

Dset1, Dset2, Dset3

GeoLock

Digital Pressure Gauge

Interactive Jar

Controlled Release device

Centralizer

Extended Battery

Flex Joint

Sinker Bar

Optional Accessories

Optional Tools

Mechanical Slickline Tools

Act

Dset1, Dset2, Dset3

GeoLock

Surface Controlled Trigger

Perforating Guns

Pipe Recovery Devices

Fluid Sampler

Optional Accessories

Nuclear Density

Gradio-manometer

Quartz Temperature Capacitance

In-Line Spinner

Fluid Sampler

Perf

PL

Surface Controlled Trigger

Fullbore Mechanical Spinner

OPTIONAL ACCESSORIES

OPTIONAL TOOLS
Historical Slickline Perforating

- No real time correlation
- Often requiring a parameter run
- Limited application

Diagram:

- Timer + Temperature + Pressure = Detonation
- Fire command allowed
- Plateaus = 15 psi from average
- 2-minute plateau
- 1-minute, 1.5-minute, 2-minute delays
- Arming delay (5 minutes to 4 hours)
- Triggers = > 32-psi pulse
Explosive Device Operations - Requirements

- Safe
- Efficient
- On Depth
Perforating SOP and Certification Path
Trigger Overview
Safety Features

A pressure switch grounds the initiator wires when the tool is at ambient pressure.
A fuse is placed between the initiator firing battery and initiator and is used under the following conditions:
The D-Trig uses dual microprocessors for complete system control. In the case they disagree on system status the fuse is activated.
Safety Features

Should the Basic Measurement Cartridge battery voltage, powering the D-Trig electronics, drop too low the fuse is activated.
If no communication is received from the up hole surface system for 2 hours the fuse is automatically activated.
Safety Features

The D-Trig firing electronics are decoupled from all other electronics systems with optocouplers providing complete electrical isolation.
Safety Features – User Override for Fuse
Elimination of Conventional Detonators

- Can be used with Cat 4* EEDs/detonators.
- Intrinsically RF safe
- No Primary High Explosives

*SPE 74178
Real Time Data: Historical Shot Detection
Perforating Real Time Data

<table>
<thead>
<tr>
<th>Core App Tools</th>
<th>Optional App Tools</th>
<th>Tool Description</th>
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<tbody>
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<tr>
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<td>DCR</td>
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<td>D-Trig</td>
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<td>Trigger Module</td>
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Explosive Device
- i.e. Gun
- Cutter
- Plug Setting Tool

Chart:
- Depth
- Deviation, Surf Tens, Head Tens
Perforating Real Time Data

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Depth

GR, CCL
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- Explo: Device
- i.e.: Gun
- Cutter
- Plug Setting Tool

**Graph:**
- Press, Temp vs Time
- Depth vs Pressure, Temp

**Perforating Real Time Data**
# Perforating Real Time Data

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**Graph:**
- **Press, Temp, Head Tens, Shock**
- **Time**
Imagine this Simple Scenario

Punching Tubing for Well Recompletion
Real Time Data – Gulf Of Mexico, 6 ft of Strip Guns Punching Tubing

- Temperature drops as cooler annular fluids passes gun assembly
- Head tension increases 40 lbs after shooting gun and assembly yo-yo after shooting evident
- Pressure drops approx 140 psi after shooting. Yo-yo evident
- Shock of shooting gun clearly seen on accelerometer
Case Study US Land Real Time Program Change

The Program

Intermediate Casing 7"
Tubing 2 7/8"
Sleeve
Tubing joint
Blast Joints
Upper Perforations Interval
Sleeve
Nipple
Packer
Lower Perforations Interval
CIBP
Production Casing 4 1/2

The Reality

Gamma Ray
Cable Velocity
Collar locator
Shoe detected (gs)
Shock detected (gs)
Hole deviation (deg)
Bottom hole temperature (deg)
Bottom hole pressure (psi)

2 7/8" Tubing Joint
OTIS XA Sliding Sleeve
2 7/8" Blast Joints (5)
Case Study – Real Time Program Change

- Control

- Confirmation

Perforated Interval
Program:

Isolate C Sand
  Bridge Plug
  50’ Cement Plug

Perforate B Sand

Depth accuracy critical therefore memory triggers not used

Historically done with a combination of eline and slickline operations

$80,000 estimated customer savings
Potential to use a smaller vessel
Real Time Data

Gun

Cement
Bailer
Example
Job Summary

**DSL runs**

<table>
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<tr>
<th>Operation Type</th>
<th>Total Number of runs</th>
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<tr>
<td>ACT</td>
<td>74</td>
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<tr>
<td>BAIL</td>
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<tr>
<td>BP</td>
<td>14</td>
</tr>
<tr>
<td>BUILD-UP</td>
<td>8</td>
</tr>
<tr>
<td>DC</td>
<td>21</td>
</tr>
<tr>
<td>DSET</td>
<td>33</td>
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<td>PERF</td>
<td>20</td>
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<tr>
<td>PLT</td>
<td>4</td>
</tr>
<tr>
<td>TGC</td>
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**Operation Type Explanation**

- ACT: Act Runs (Gauge Cutter, impression Bock, SSV Shifting,...)
- BAIL: Cement Bailer Using the DTRIG
- BP: Plug Setting with pyrotechnic tools and DTRIG
- BUILD-UP: Pressure Temperature Survey
- DC: Depth Correlation using the DCC
- DSET: Set using the DSET tool
- PERF: Perf using the DTRIG
- PLT: LIVE PL using the DSL tools
In Summary

- Step Change in Perforating Safety
  - Guaranteed shot detection
  - Never return to surface with an armed gun

- Step Change in Data
  - Data richness in standard configuration
  - Will enable real time detailed analysis and job records

All with the advantages of slickline conveyance to better service operator needs