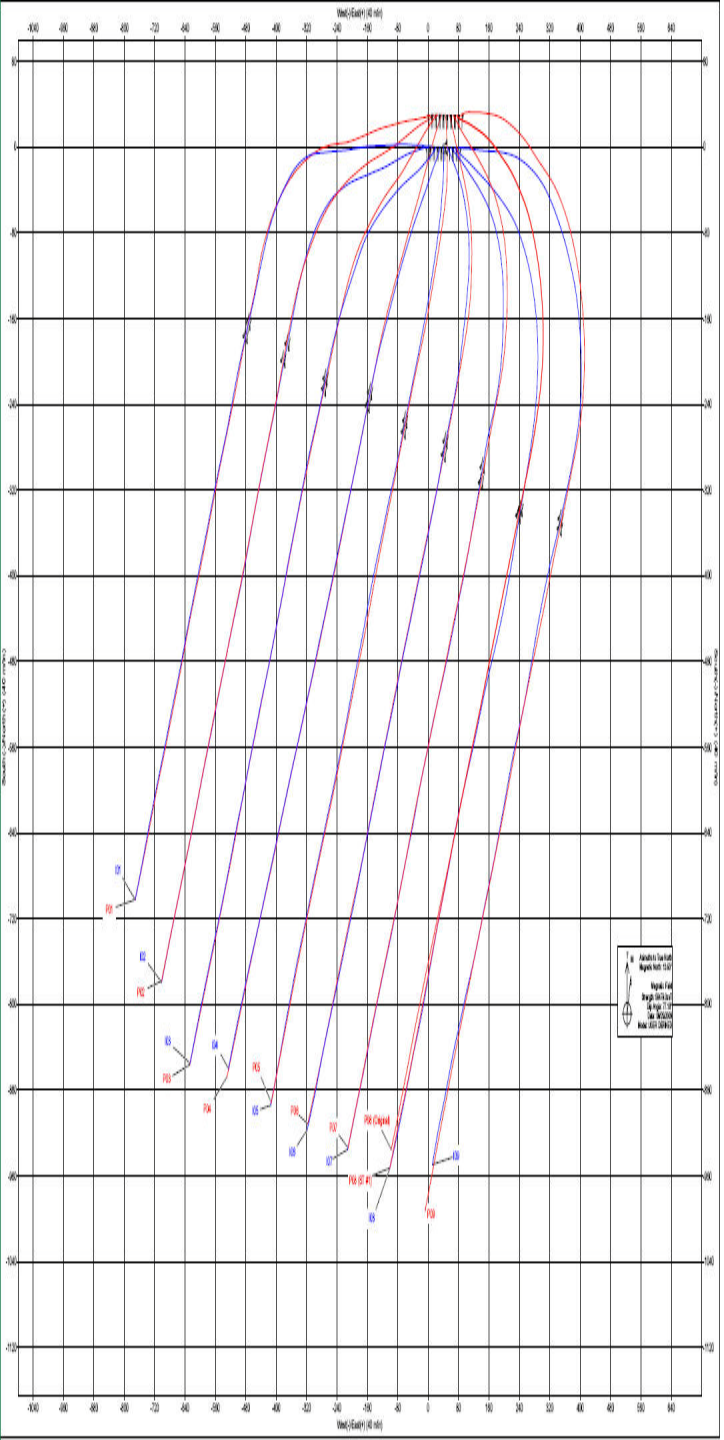

RADAR
Real-time Analysis for Drilling and Advanced Ranging

Well Placement and Ranging Services

Charles Duck

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RADAR
Real-time Analysis for Drilling and Advanced Ranging

The RADAR™ services encompass:

- SAGD (well twinning) applications
- Well Intercept (well kill) applications
- Well Avoidance applications
- Gravity MWD (provide an Azimuth in areas of magnetic interference)
- RADAR Trac (DD wellbore steering) applications

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BHA's For Well Twin, Well Intercept, Well Avoidance

Upper HDS1 Collar - 30 ft

MOP

Pulser

TCM

Upper Directional Sensor

HDAS

Upper Battery Pack

GSM

Lower HDS1 Pony - 14 ft

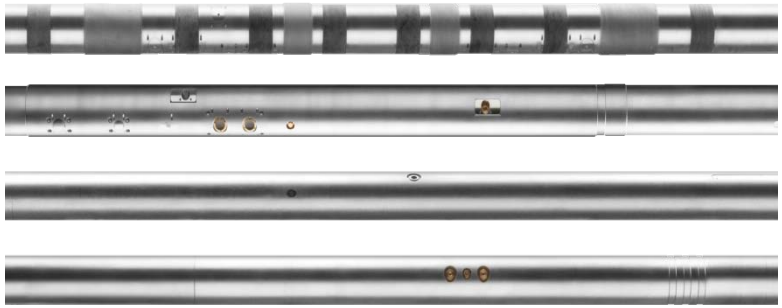
Lower Directional Sensor

HDAS

UGS (Optional)

Datalink (Terminated)

Configurations may include all LWD tools



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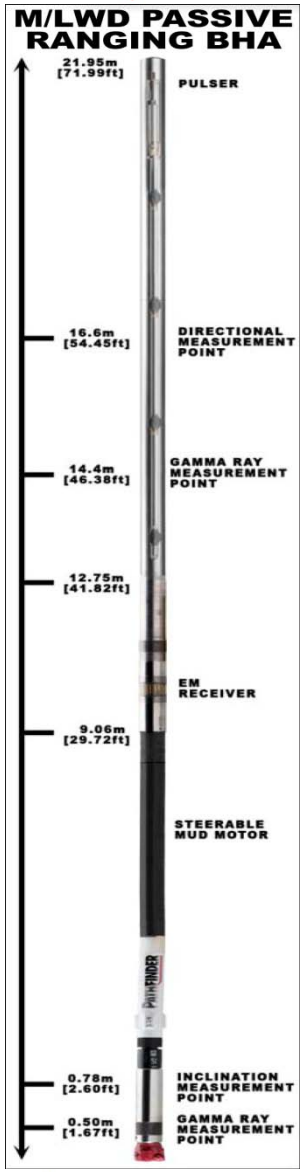
SAGD (well twinning) Features

- Service used for twinning wells (Passive Ranging)
- No Access to target well required
- No additional surface equipment
- Real time accurate survey positioning
- Maintain a constant distance from Target Well
- Reliable and Cost effective
- **Fast Steering Decisions w/ Gamma/Inclination @ bit**



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Well Intercept (well kill) and Well Avoidance Applications

- Intersecting a vertical or sub vertical well
- Drilling a relief well for any well blowout situation
- A well cannot be drilled due to proximity to other wells
- A well with inclination only, poor survey accuracy or is in close proximity to a planned well
- Old wells with uncertain position are jamming a reservoir. What is needed is to follow the wells down near to the reservoir section then deviate to target
- The shutting down of active wells due to close approach causing loss of production

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RADAR™ Well Intercept and Well Avoidance Features

- Detection of the adjacent well by using MWD tools for passive ranging
- Azimuth measurement in areas of magnetic interference
- Distance, Tool Face and direction to the adjacent well
- Three dimensional image and projection of the adjacent well
- Identification of the adjacent well by its Inclination and Azimuth
- Replay of approach and/or separation to help understand the 3D situation
- Real time measurements while you drill
- Confidence and Quality indicators

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RADAR™ Well Intercept and Well Avoidance Benefits

- Focused pre-well planning for accurate well placement solutions
- Increased ROP, data transmitted as you drill
- There is no tripping to run a wire line tool
- Unaffected by high formation Resistivity
- Eliminates the need for specialist down-hole tools
- Identification of wells in a multi well environment
- No generators, current or artificial electromagnetic field required
- No attachment to the adjacent well or wires required to be placed within the well
- Decreases mobilization time as frequently the MWD is already on the rig
- Improves the economics of drilling avoidance and relief wells

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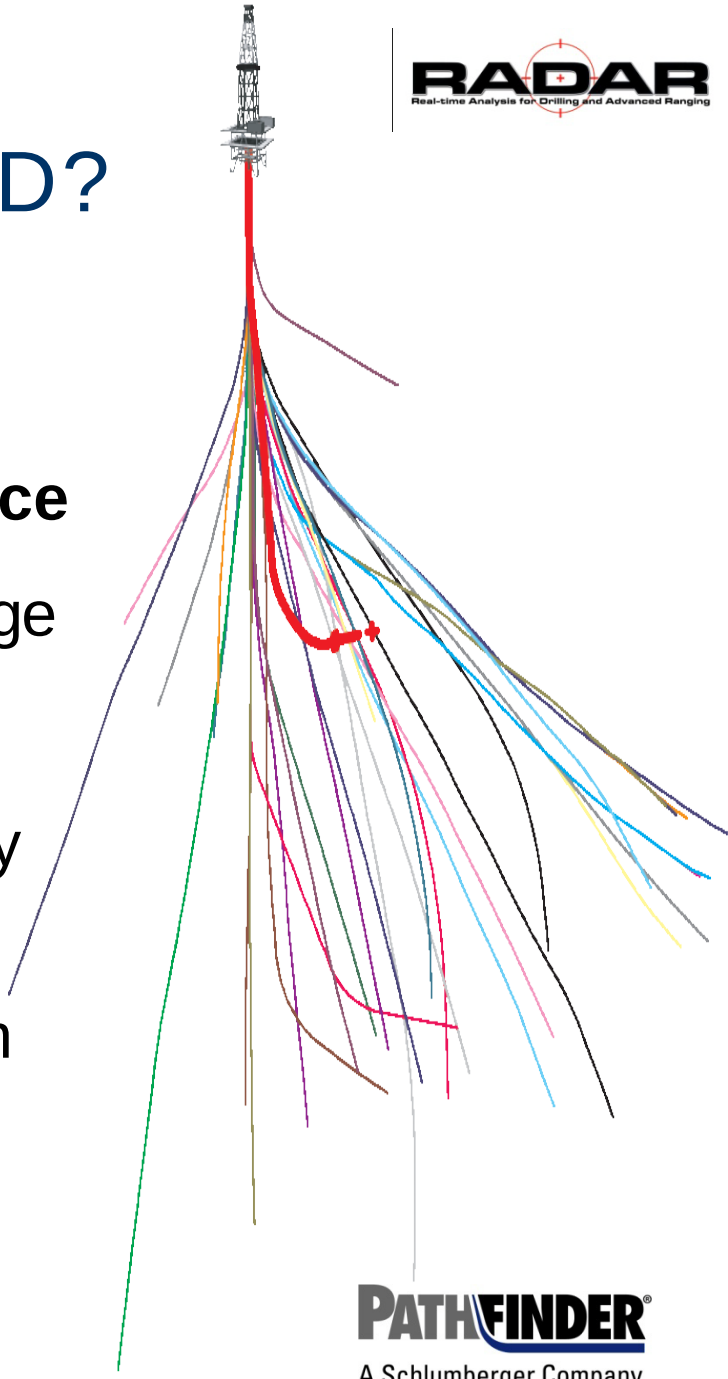
WHAT IS GRAVITY MWD?

MWD Surveying in Magnetic Interference

- Dual MWD Accelerometer Package
- Measures tool/BHA bending
- Inclination calculated in usual way
- Calculates ΔAzimuth tied into reference survey, thus providing an accurate Azimuth or direction



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Why Use GRAVITY MWD?

- In situations where magnetic interference prevents standard MWD operations
- The calculated magnetic azimuth is unreliable resulting in no directional control

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Gravity MWD BHA

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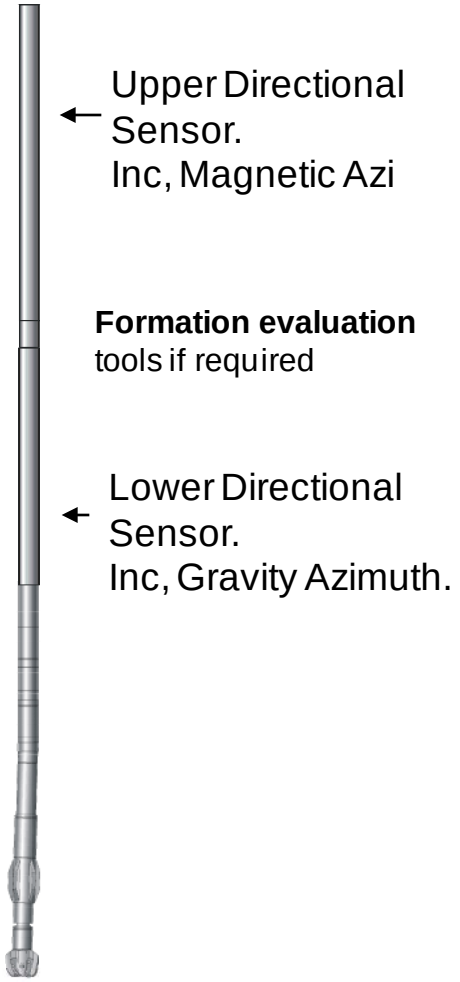
For MWD Azimuth in areas of Magnetic Interference



Operational Requirements

1. Two MWD tri-axial accelerometer sensors.

2. Sensor data stored at the same time but transmitted separately.

3. All formation evaluation (LWD) tools can be included.

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Gravity™ MWD Applications

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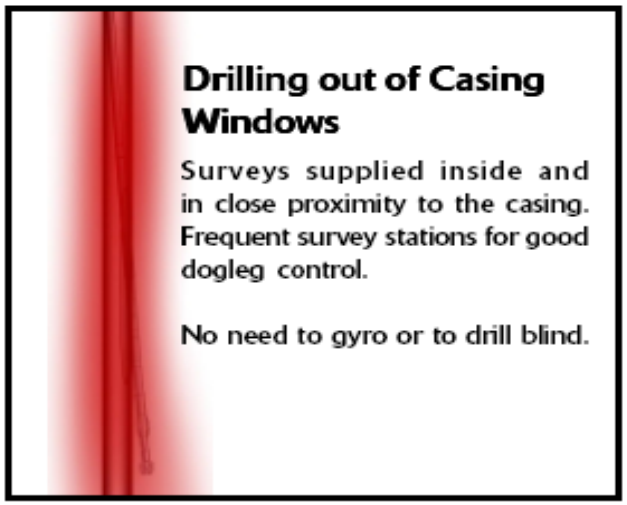
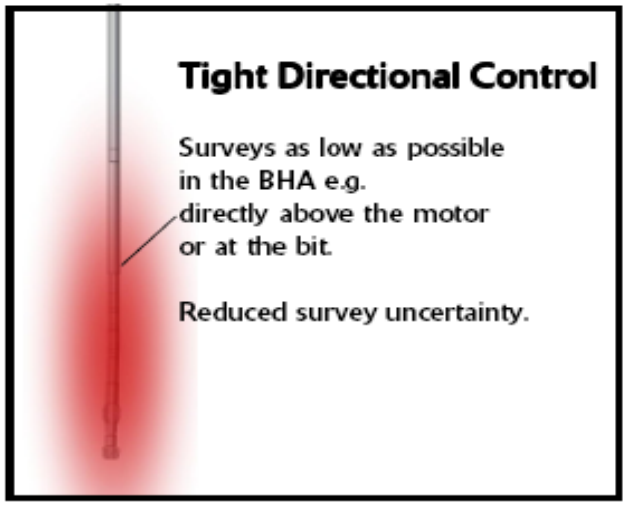


Drilling out of Casing Windows

Surveys supplied inside and in close proximity to the casing. Frequent survey stations for good dogleg control.

No need to gyro or to drill blind.



Tight Directional Control

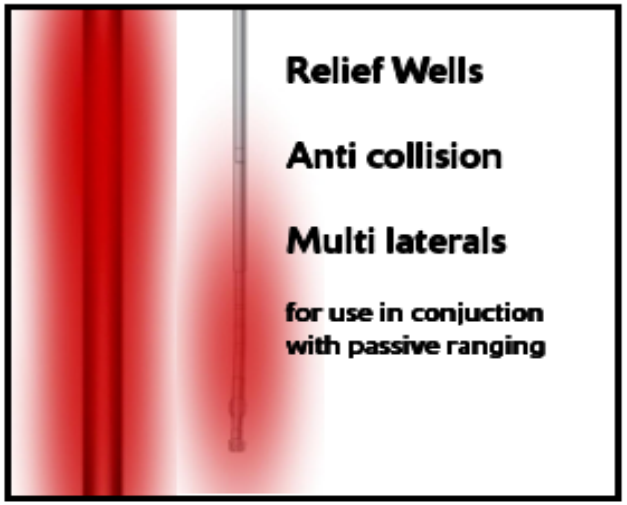
Surveys as low as possible in the BHA e.g. directly above the motor or at the bit.

Reduced survey uncertainty.

Kick Off immediately out of the shoe

No rat hole required and more room to turn your well

Casing Drilling



Relief Wells

Anti collision

Multi laterals

for use in conjuction with passive ranging

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Existing Solution

- Gyro Surveying (In Magnetic Interference)
  - MWD Gyro
    - System is more susceptible to vibration issues
    - Requires addition personnel
    - Measurements may take longer
  - Wireline Gyro
    - Requires additional equipment
    - Requires additional personnel
    - Require additional drilling fluids to maintain borehole
    - Increased rig time

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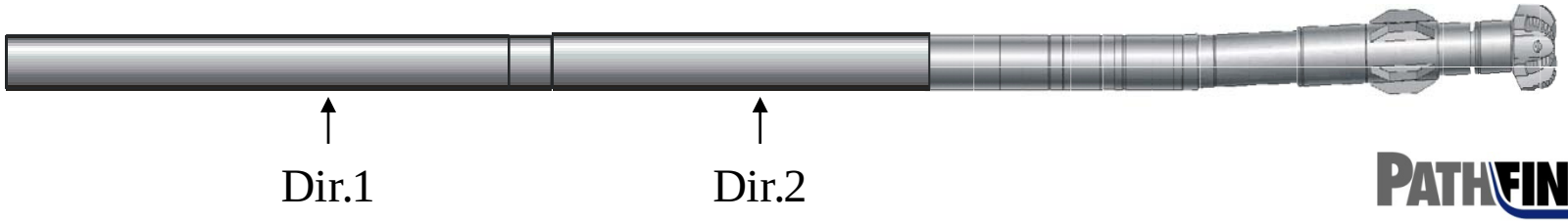
Gravity MWD® Summary

- The Gravity MWD survey solution to the magnetic interference problem
  - Replaces the need to run Gyro systems
  - Requires no additional personnel
  - Improved safety at the rigsite
  - Lowers costs by reducing rig time
- Provides an accurate azimuthal survey in any area of magnetic interference affecting standard MWD azimuthal survey measurement



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SAGD In-Situ Development

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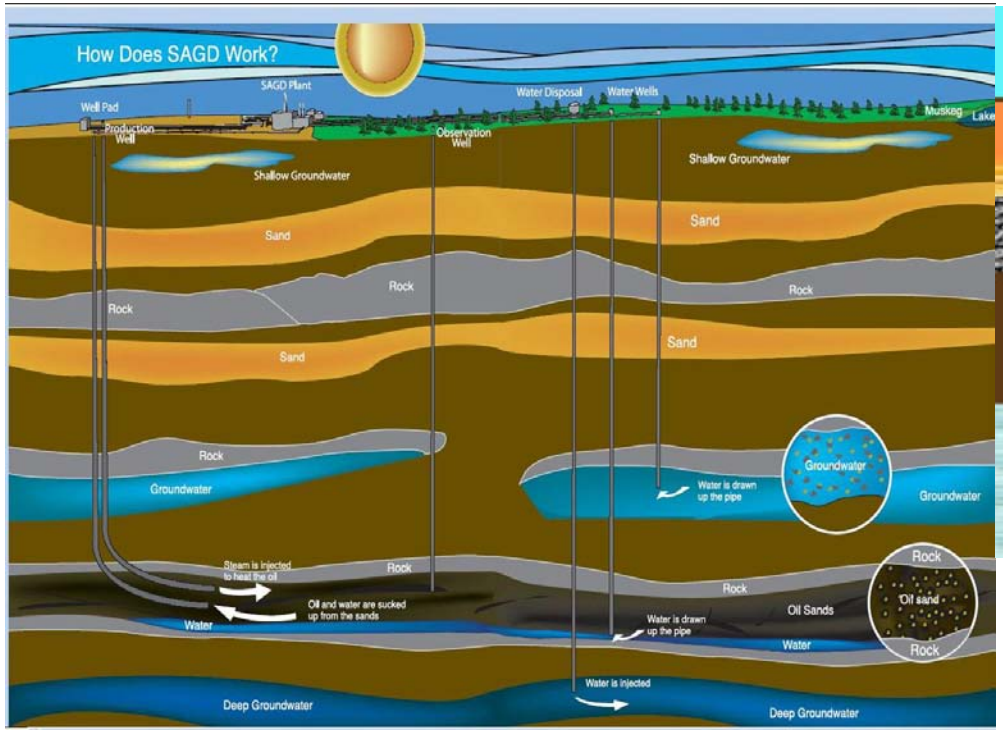
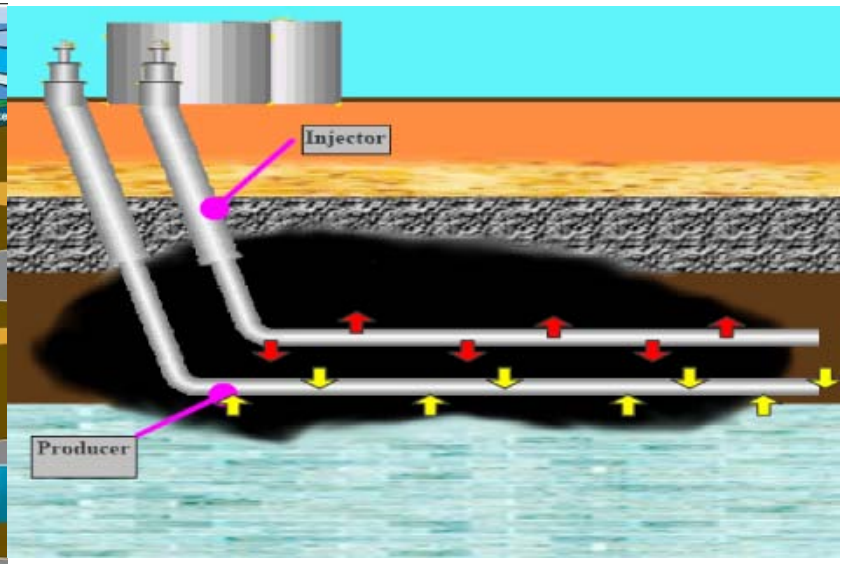
- SAGD (Steam Assisted Gravity Drainage)
- One type of SAGD uses Pairs of Horizontal Wells
  - Accurate geological positioning
  - Precise control of well separation





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RADAR SAGD Case Study

- Cenovus Energy, SAGD well pad
  - Western Area, Foster Creek Area Project
  - Northeastern Alberta, Canada
- Target Fm. – McMurray Fm
  - Pad – 9 well pairs from single pad site
  - Pairs positioned 100 m laterally apart
  - TVD 470-550 m
  - Horizontal lengths 500-1000 m

Case Study - Field Description

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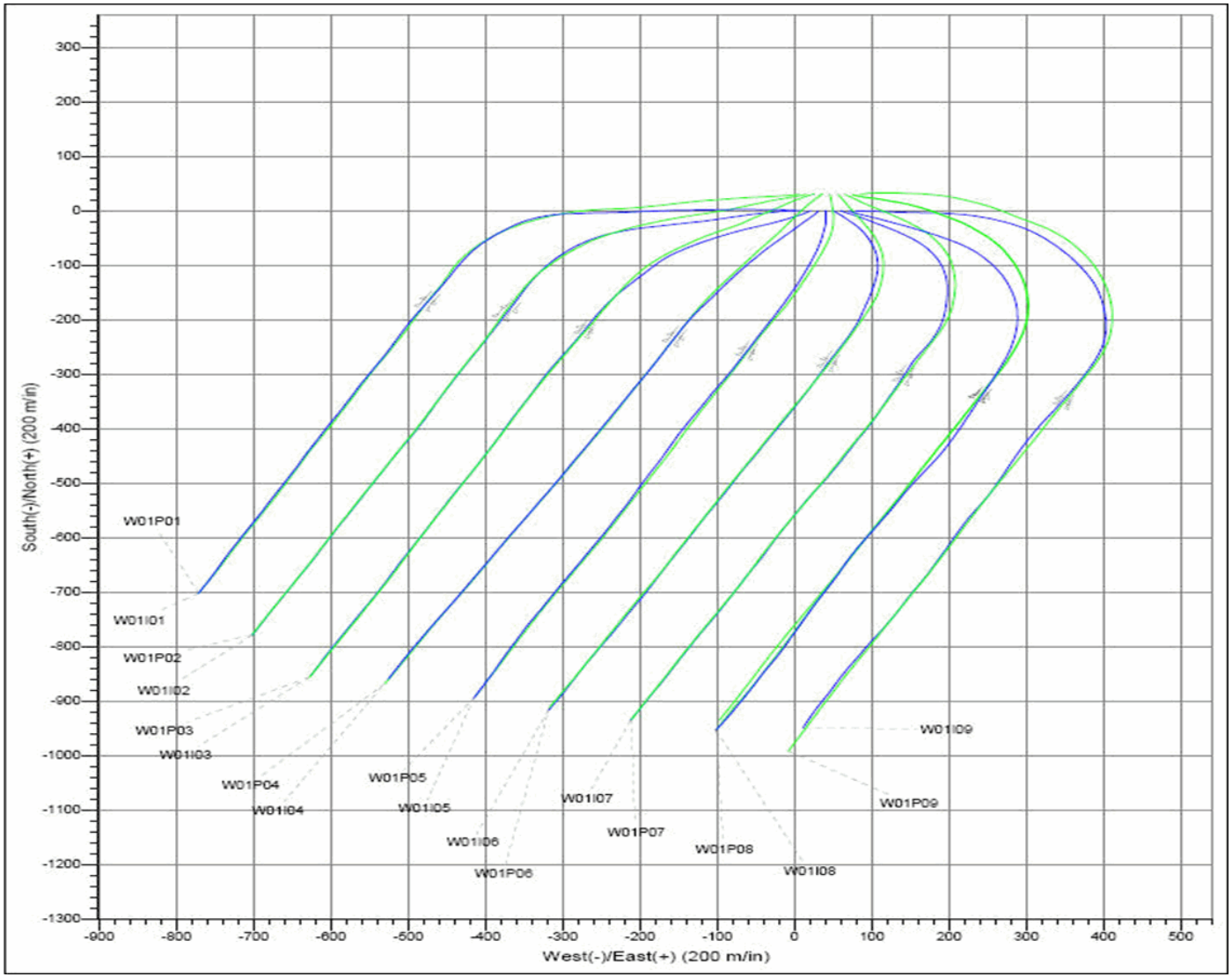

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Case Study - Field Description

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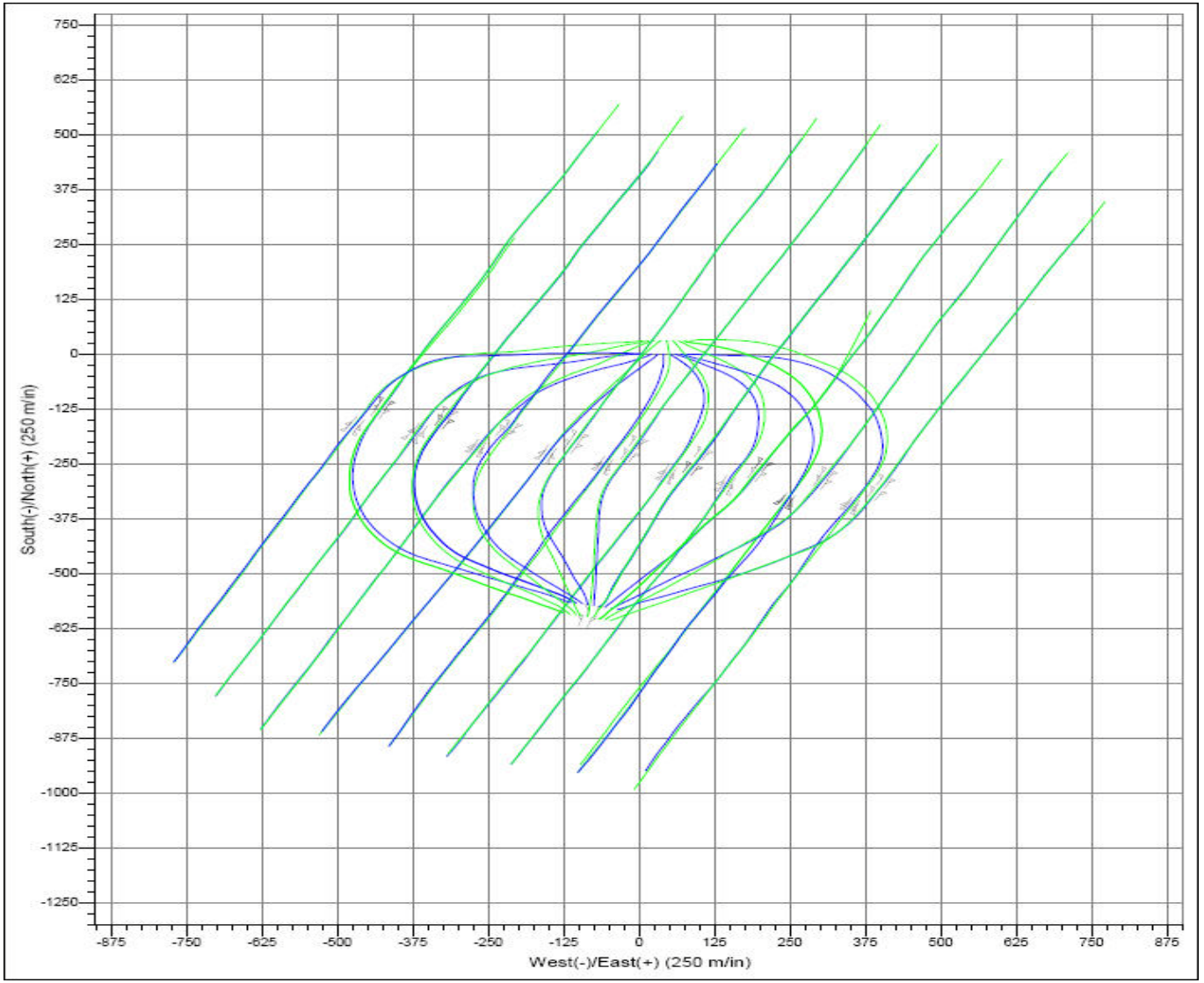

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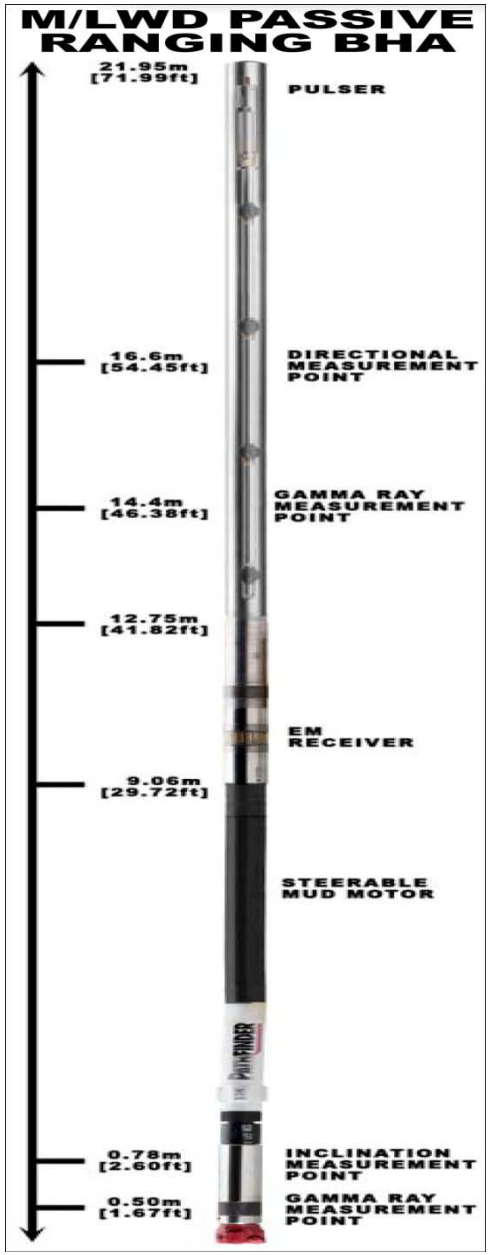
Case Study – Ranging BHA



- MWD BHA includes an **at bit** Gamma ray and dynamic Inclination measurement
- Steerable motor assembly or RSS
- Redundant upper Gamma ray
- Standard MWD (azimuthal, inclination, TF) system
- LWD – Res, Por, Imaging, ect

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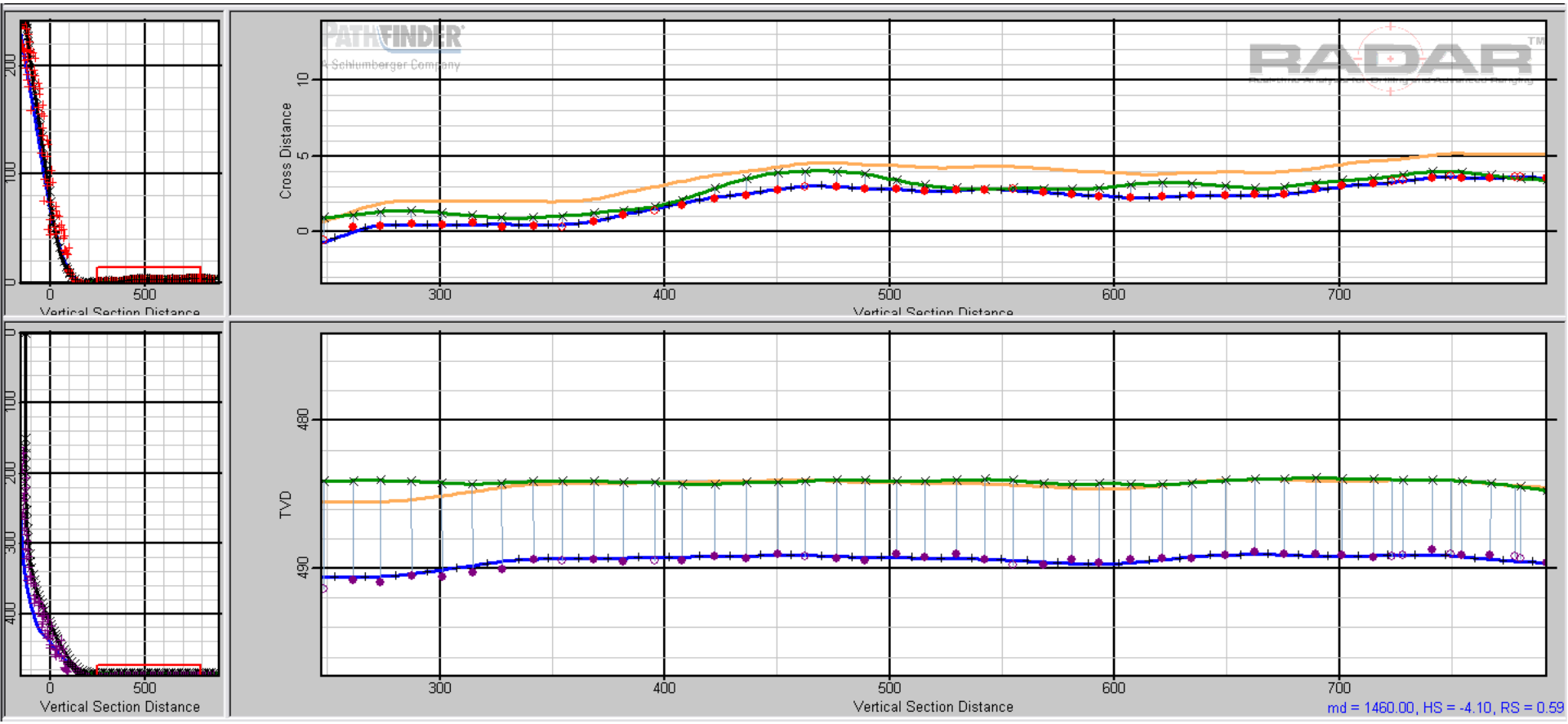
Case Study – Well Pair



Vertical hole 444.5 mm (17.½”), 339.7 mm (13 ⅜”) Csg.
Intermediate 311.1 mm (12 ¼”), 244.5 mm (9 ⅝”) Csg.
Horizontal hole 222.2 mm (8 ¾”), 177.8 mm (7”) Csg.

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Case Study – Wellbores

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- Well pair with gaussed casing in the Producer
  - Single entry well placement RADAR Ranging solution

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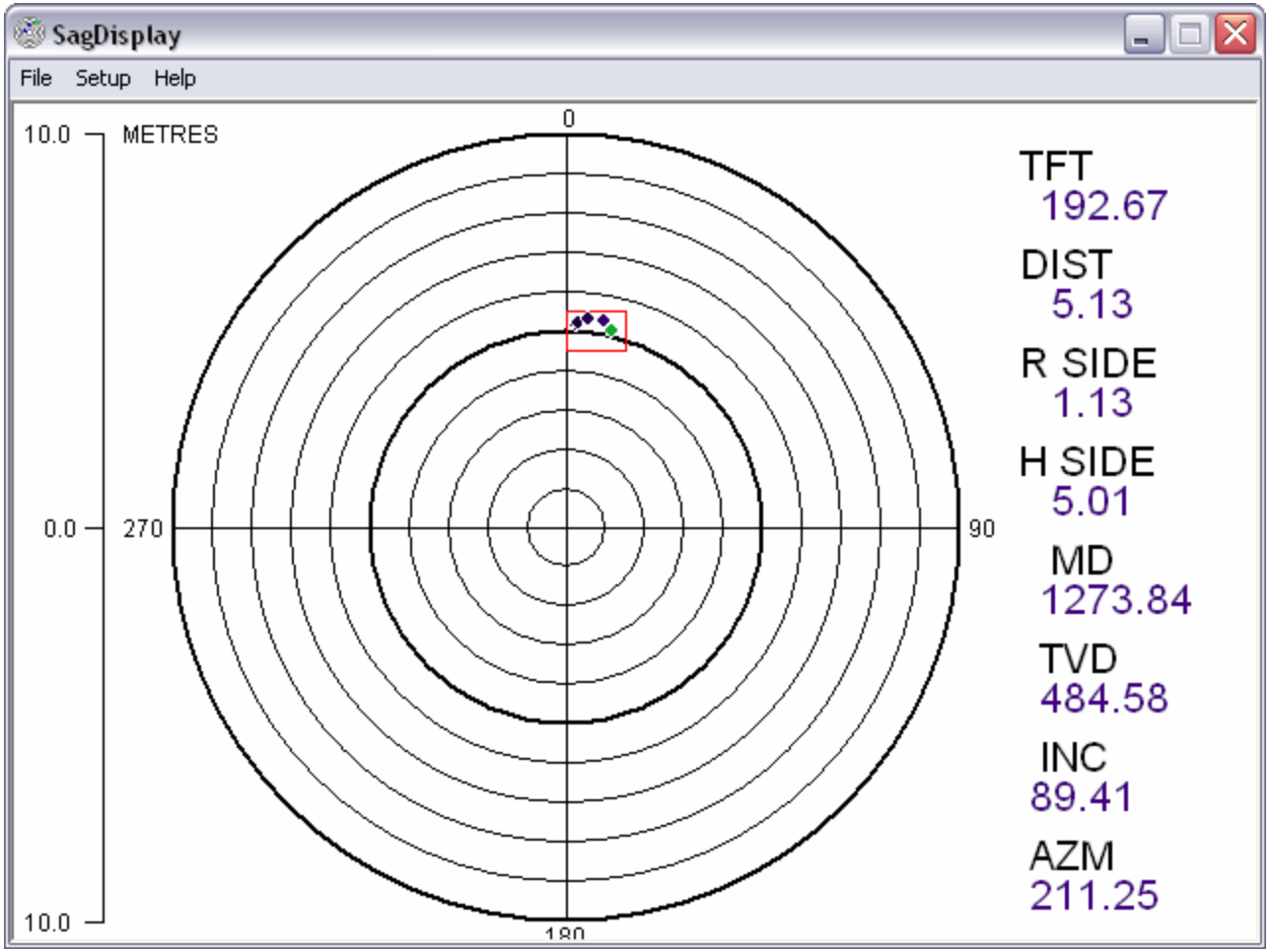
RADAR RT Ops Display



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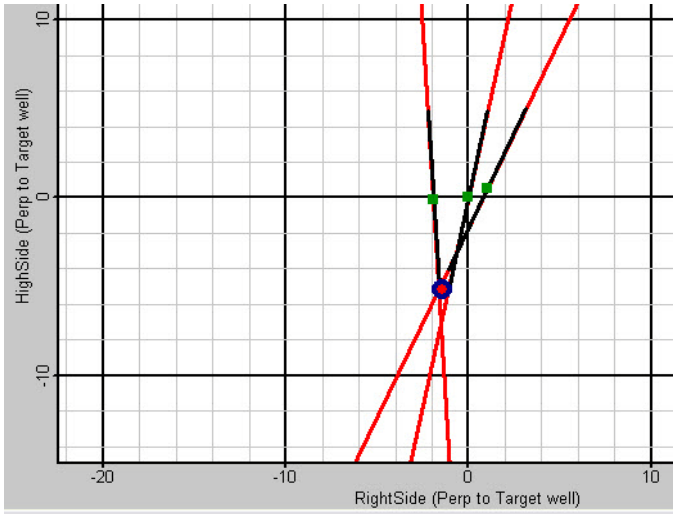
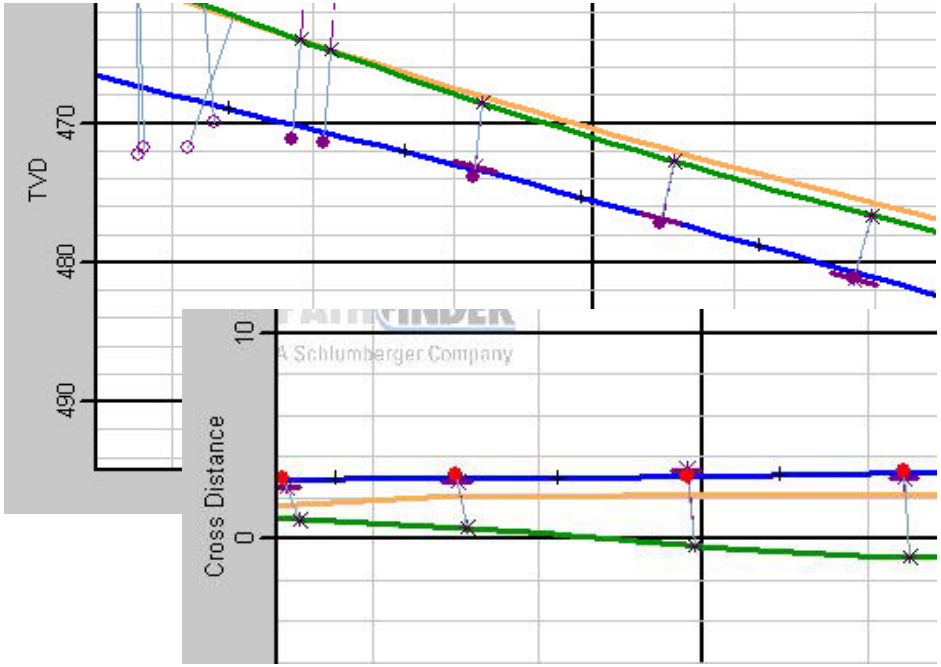
Methodology Validation

- Verification of radial distance can be checked using vector triangulation.





Well section	Triangulation vs RADAR error (m)	Well Relationship
Build	0.09	Diverge
Build	0.08	Converge
Lateral	0.08	Cross
Lateral	0.15	Cross
Lateral	0.10	Cross

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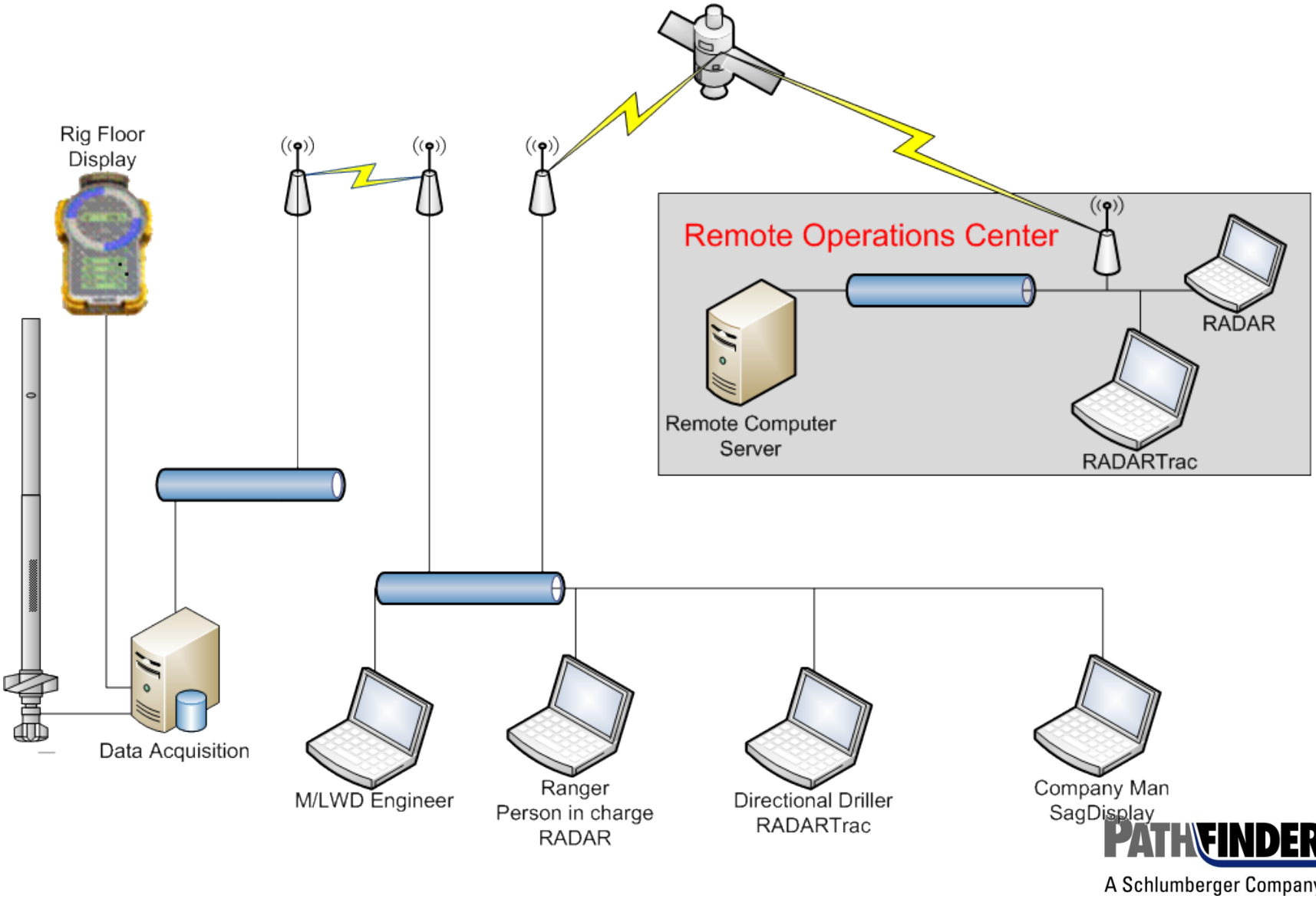
RADAR – Placing the wells

- Drilling a SAGD well - a Cooperative Team Enterprise
  - M/LWD engineer
  - Ranging Officer
  - Directional Driller
  - Driller
  - Customer representative
- The data and interpretation results flow easily thru the system
- The team members local and/or remote
- Expert assistance available

RADAR Extended Configuration



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Real-time Analysis for Drilling and Advanced Ranging

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Summary

RADAR
Real-time Analysis for Drilling and Advanced Ranging

- RADAR a systematic approach to correctly placing SAGD well pairs
- Results are wells placed closer to nominal plan
  - Single entry solution
  - Better meets customer well placement objectives
  - Minimize well bore tortuosity (improve casing runs)
- Demonstrate the use of several technologies within RADAR (MSA, Gravity MWD, Ranging)
- Correct placement of well geometry simplifies future field development and improves project economics

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iPZIG

RADAR
Real-time Analysis for Drilling and Advanced Ranging

Imaging PayZone Inclination Gamma (iPZIG)

- 4 ¾”, 6 ¾”, 8” nominal collar size
- 16 sector Gamma ray Image @ bit
- Magnetic Detection @ bit, Ranging @ bit. (in Dev.)
- MWD @ bit - azimuth, inclination, TF, RPM (in Dev.)
- +180 hrs battery life and upgrade to HTHP capability (175 C & 25,000 psi)

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