



GYROSCOPIC NAVIGATION AND THE HDD INDUSTRY

PANEL DISCUSSION and TECHNOLOGY REVIEW





UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS





Robert Lampert

Gyro Project Manager - Sharewell HDD

Over 42 years working with borehole gyroscopic and magnetic survey and steering technology in the oil & gas, HDD and mining industries in all phases; field engineer, engineering development, operations management, business development. Introduced gyroscopic surveys in HDD in 1988, ran first gyroscopic steering in HDD in 1991. Involved in development and commercialization of 5 separate borehole gyroscopic survey and steering systems.



Reno Maynard

Senior Field Technician – Sharewell HDD

Currently the Senior Field Technician with Sharewell HDD. Involved with all phases of the development of the Opti-Trac gyro system since inception including initial field testing, hardware and software development, operating procedures and field technician training program. Prior to the HDD industry spent 17 years in the aerospace and defense industry as an electronic technician/field engineer.



Introduction - Sharewell HDD

Sharewell was founded in 1984 and introduced the Tensor wireline magnetic steering tool in HDD applications in 1985. Sharewell working with Tensor developed the well-known TruTracker secondary verification systems to address inaccuracies inherent with magnetic based steering systems.

For over 38 years, Sharewell has been an innovator and leader in bringing new technologies and products to the HDD industry. With offices and representation in Houston, Texas, South America, Holland, Canada and Australia, and other distributors throughout the world, the company provides services and/or products in virtually every continent. The company was founded on technology and continues to develop new technologies for the HDD industry. Sharewell's full suite of products include the following:

- Magnetic Guidance System (MGS)
- TruTracker
- Opti-Trac Gyro
- Retrievable Opti-Trac Gyro System
- Wireless Electromagnetic Telemetry System (EM)
- Full line of Hole Openers and Bits



UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS



STATE OF THE ART, HIGHLY ACCURATE GYRO SPECIFICALLY DESIGNED FOR HDD

Sharewell HDD is proud to offer it's newest guidance tool to the HDD industry, the Opti-Trac Gyro navigation system.

Designed to be compatible with customers standard bottom hole assembly, the Opti-Trac Gyro can be run in holes measuring 5 7/8" and larger. Special projects down to 3 7/8" pilot hole can be engineered and considered.

In addition to the Opti-Trac Gyro, each tool has the integrated magnetic ShareTracker system to provide secondary position confirmation.

FEATURES

- Fiber-optic north seeking gyro system
- Integrated magnetic ShareTracker system provides secondary position confirmation

BENEFITS

- Gyro sensor unaffected by magnetic interference
- Reliable even in high-vibration environments
- Easy set up and transport, tooling ships in hard cases
- Runs in standard collars with standard BHA's

APPLICATIONS

- Surveying in densely populated urban areas
- Areas where use of secondary magnetic tracking is prohibitive



TECHNICAL SPECIFICATIONS

Outside Diameter	2.125 in
Length	16 ft with pressure 14.75 ft without pressure
Weight	104 lbs with pressure module 90 lbs without
Electrical Connection	1-3/16 in. 12 tpi female (standard wet connect)
Maximum Operating Temperature	80°C
Pressure Rating	12,000 psi (690 bar)
Communication	Bi-Directional
Survey Recording Time	10-20 seconds

SURVEY PRECISION

Inclination	+/- .10°
Azimuth	+/- .15°
Toolface	+/- .10°

COMPATIBLE WITH

Pressure Module	Annular
Retrievable System	Sharewell's proprietary system allows for tool retrieval



281.288.2560 | SharewellHDD.com



Opti-Trac Gyroscopic HDD

System Overview



- Tool overview
 - Gyro module
 - 3-axis Optical Gyroscopes
 - 3-axis Accelerometers
 - Onboard data processing – sends processed data to surface
 - RS-485 serial bus communication
 - Onboard memory – saves 500 hz raw data
 - Two operating modes
 - Gyrocompass
 - Steering (continuous GHARS navigation)
 - Magnetic module (Steering tool)
 - 3-axis Magnetometers
 - 3-axis Accelerometer
 - RS-485 serial bus communication
 - Full magnetic steering capability
 - Secondary tracking (TruTrak)
 - Redundant HSTF and Inclination
 - Electronics module
 - RS-485 communications bus management (tool internal comms)
 - Tool downhole power supply
 - Modem (wireline communications)
 - Battery pack and battery management board
 - Onboard computer and memory
 - Surface power supply/interface box
 - 110V / 550ma (max) wireline V / C
 - Wifi communication with operating computer / RFD
 - 110/220v input power
 - Depth encoder input
 - Mechanicals
 - Pressure housing
 - Approximately 15 feet (4.6m)
 - 2.125" diameter (54mm)
 - Integrated adjustable rubber fin centralization in NMDC
 - Internal vibration isolation (uses proven oilfield MWD technology)
 - Standard 1.25" 8 TPI on bottom (standard OS)
 - Standard NMDC from 4-3/4" and larger
 - Annular pressure (separate sub)
 - Surface computer / operating software
 - Fully integrated operating / reporting software
 - Data acquisition
 - Bi-directional communications
 - Well Planning
 - Real time plots
 - Rig floor display
 - Uses any windows tablet
 - Wifi connection
 - Available with any wifi device (tablet/phone/computer)



Opti-Trac Gyroscopic HDD Design Features



- Independent Gyroscopic and Magnetic steering tool modules.
 - Redundant Azimuth, Inclination and Tool Face data
 - Full secondary tracking capability
- Two operating modes
 - North Seeking for independent azimuth / inclination measurement
 - Continuous Navigation
- Versatile - Small OD pressure housing
 - Operate on small rigs – hole sizes 4-3/4 (with custom NMDC) and larger
 - Opti-Trac Gyro tool installed in standard 4-3/4 and larger NMDC (Can be run in as small as 3-1/2 with custom collar)
 - Mob/Demob – packed in pelican case(s) – easy transport - can be shipped via commercial airfreight.
- Retrievable system
 - Proprietary wireline and orienting mechanism
 - Allows Gyro to be extracted – blind holes



Opti-Trac Gyroscopic HDD Future developments



- Presently in Development:
 - Integrated Electronics / Magnetic module
 - Smaller OD/shorter length
 - Faster data transmission
 - Longer wireline
 - Roll Stabilized Platform (RSP)
 - Faster operation
 - Increased accuracy
 - Intersect capability
 - Beacon secondary tracking
 - Single point on surface
 - Internal pressure (in addition to existing annular pressure)
 - Inclination at bit
- Future Development:
 - Wireless (EM) communication



UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS

PGM

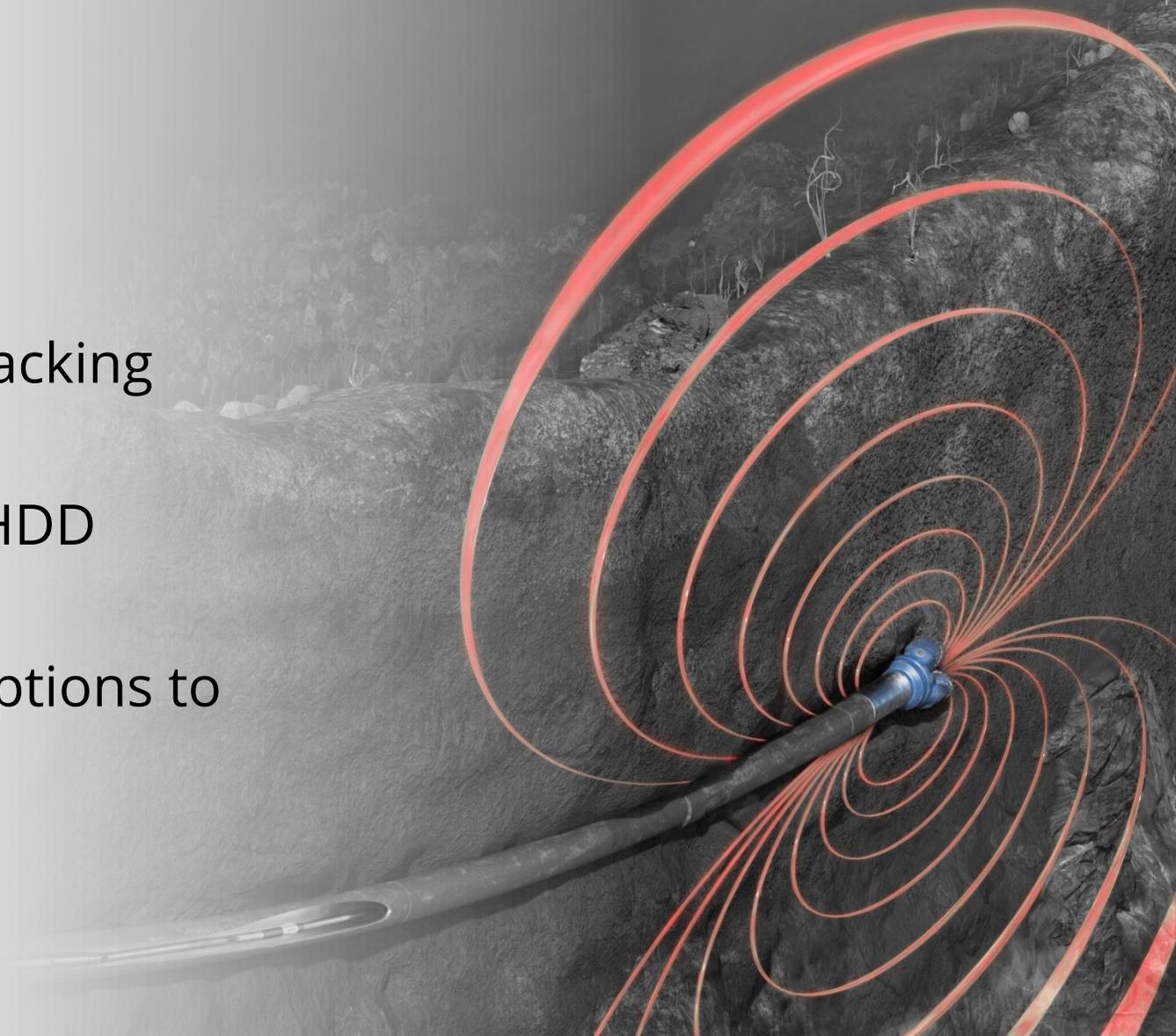
PARATRACK GYRO MODULE





Vector Magnetics

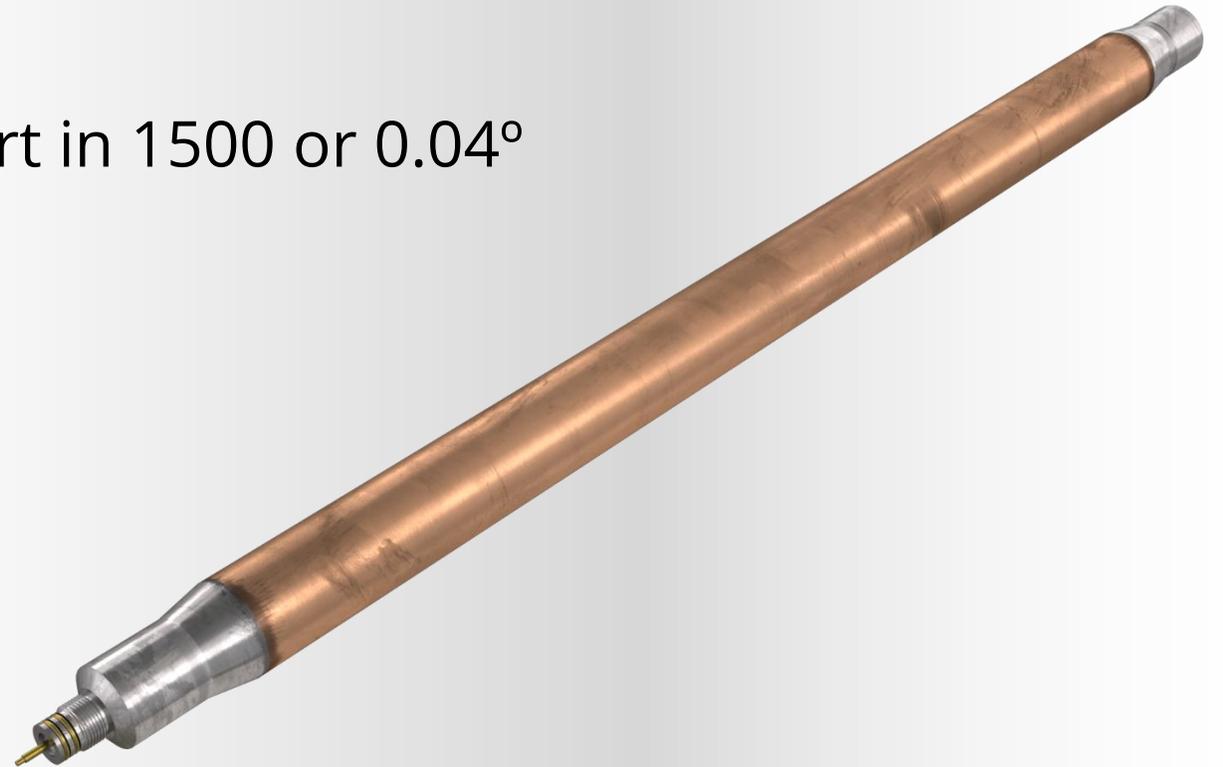
- Founded in 1980
- Experts in magnetic guidance and tracking
- ParaTrack Gyro Module created for HDD
- Creators of surveying and tracking options to fit any need





ParaTrack Gyro Module

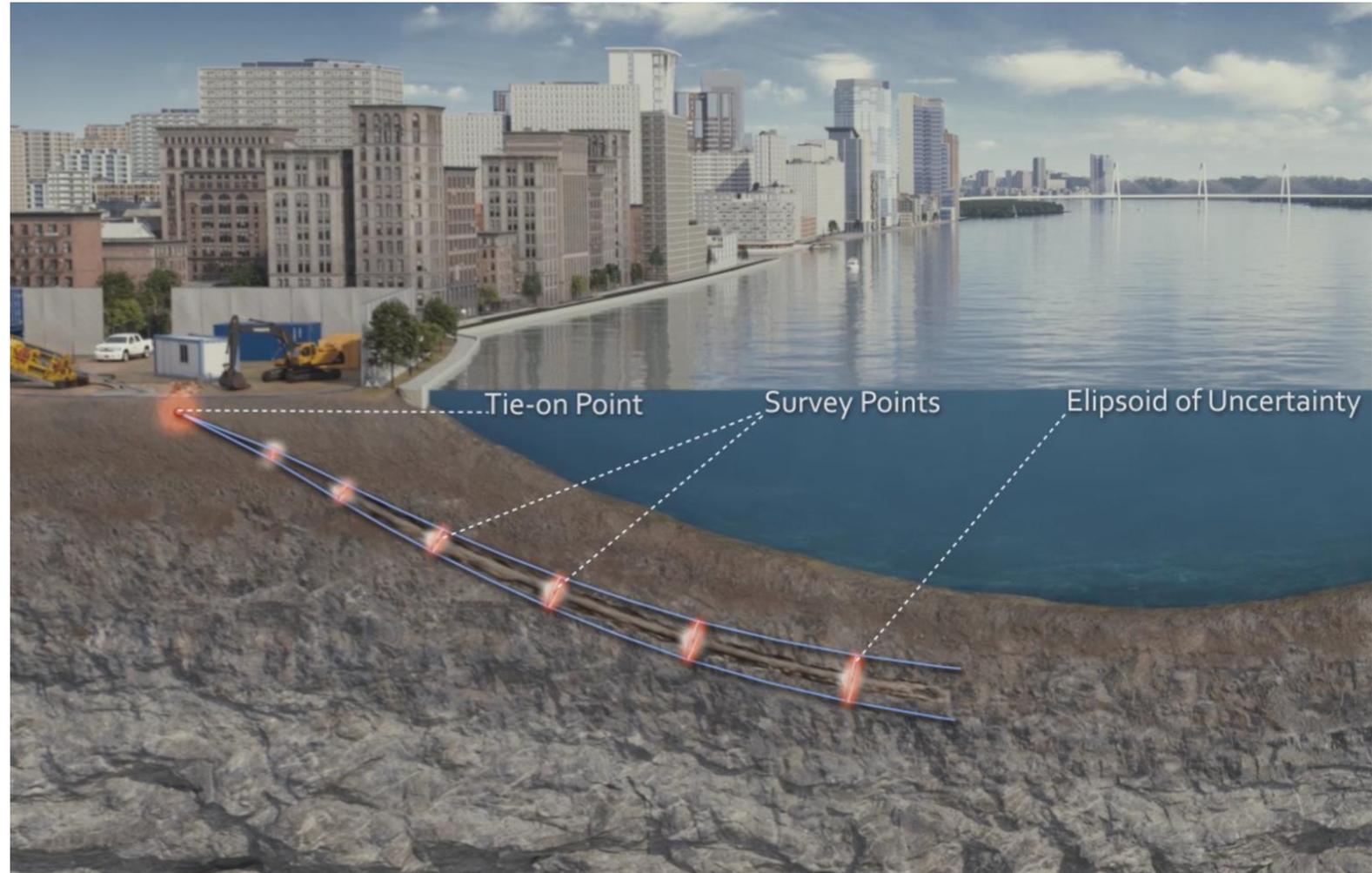
- North-seeking gyro measurement with each survey
- Observed results are accurate to 1 part in 1500 or 0.04°
- Survey time ~3 minutes
- No coil? No problem





All Surveys Have Uncertainty

- Calculated positions rely on previous measurements
- Calculated survey positions accumulate uncertainty
- Secondary verification is needed to correct elevation when uncertainty is too large





Secondary Verification

- Integrated in ParaTrack system
- RivCross software manages job
- BTS – solenoid, no coil
- P2 – coil, high precision, low voltage AC, greatest range





At Bit Inclination Assembly

- Precise elevation control
- Rugged design
- Immediate steering feedback
- Li-ion battery with long run time

The ABIA measures inclination directly behind the bit

Plan

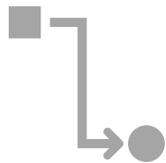




Gyro Review



Accuracy on par with other gyro steering tools



For important decisions, second opinion is best practice



At-Bit Inclination assists in managing elevation

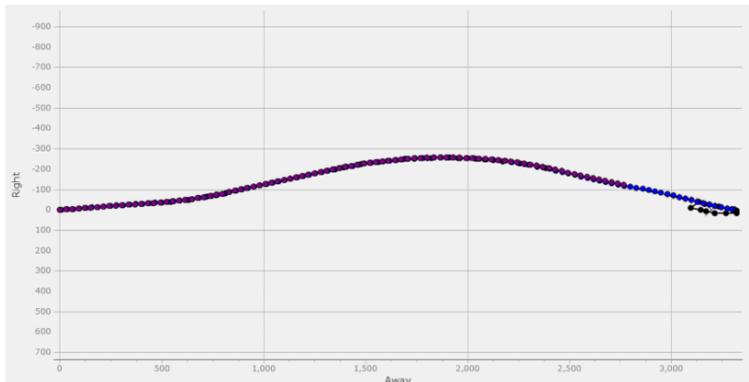


Reduced survey time a priority for future development



Tight Exit Window

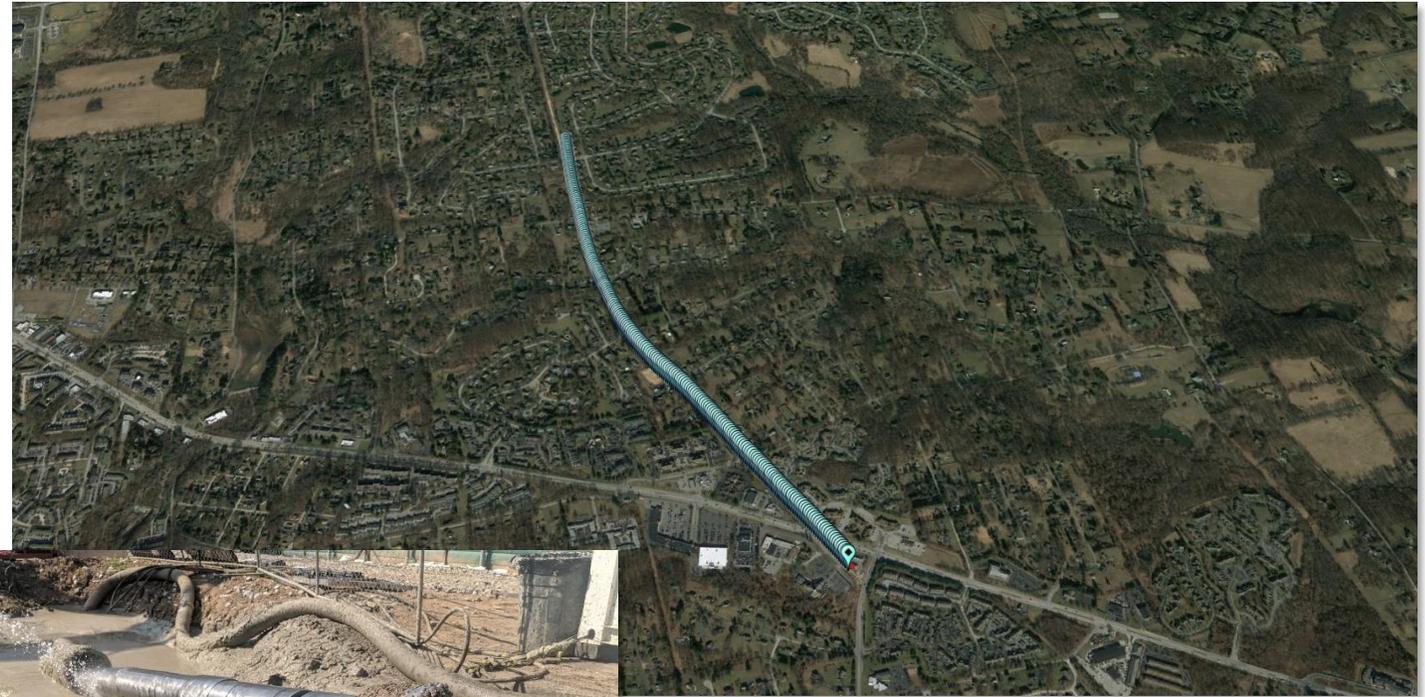
- Crossing length: 3358'
- Crossing depth: 80'
- 35° S-Curve
- Product: 8" HDPE
- ParaTrack tools used:
Gyro, BTS, P2





High Vibration and Hard Rock

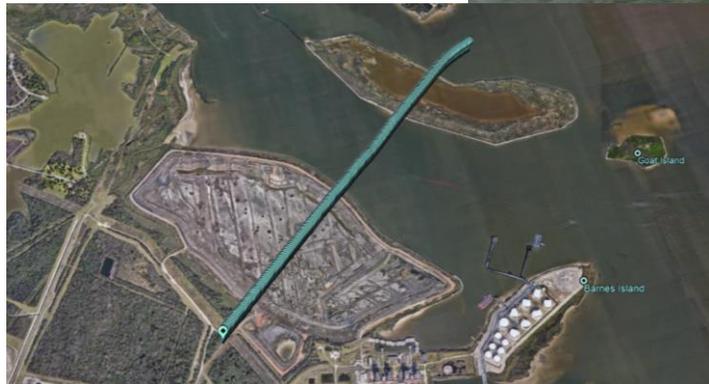
- Crossing length: 6943'
- 4 horizontal curves totaling 34°
- Intersected head on first attempt
- Compressive Strength: 30,000 psi
- ParaTrack tools used: Gyro, P2, ABIA





Big Turn Without Tracking at Exit

- Crossing length: 7033'
- Crossing depth: 150'
- Horizontal Turn: 13°
- Product: 16" Steel
- ParaTrack tools used:
Gyro, P2

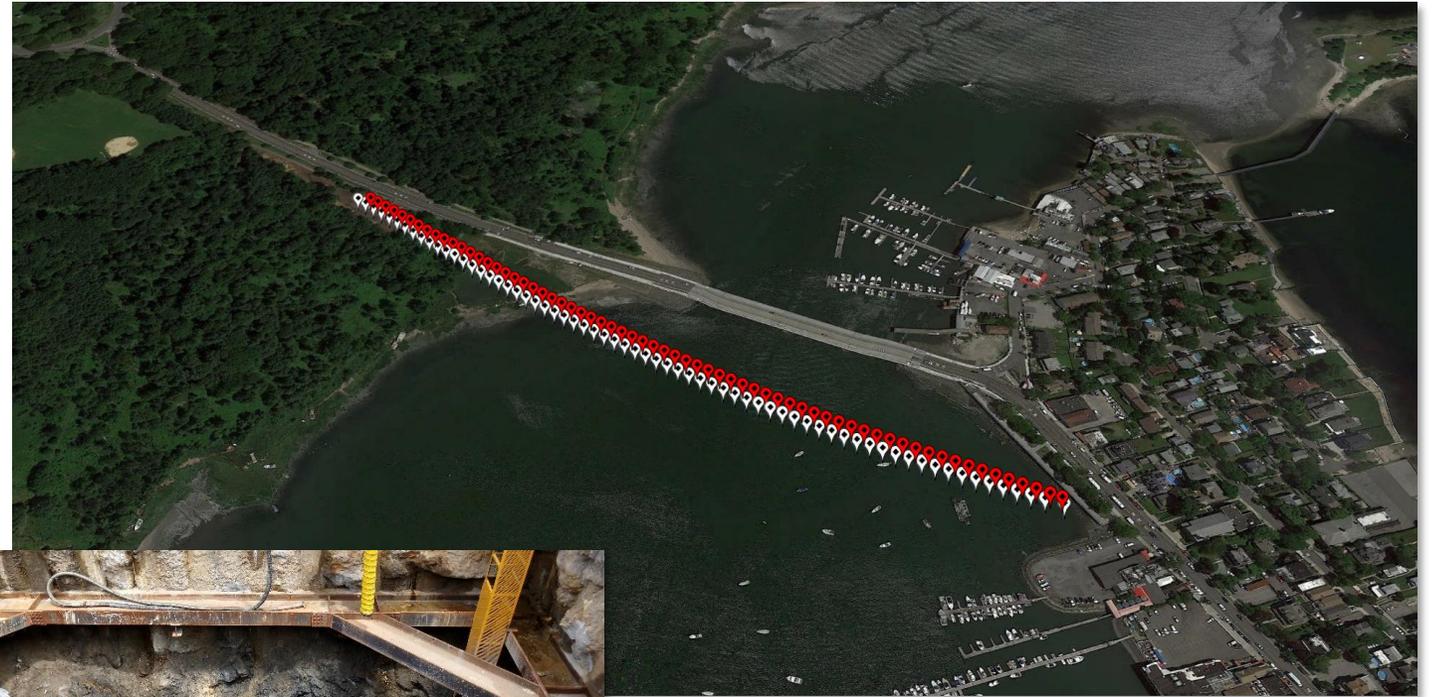


Houston Shipping Channel Crossing



2 Hard Rock Bores w/ Tight Tolerance

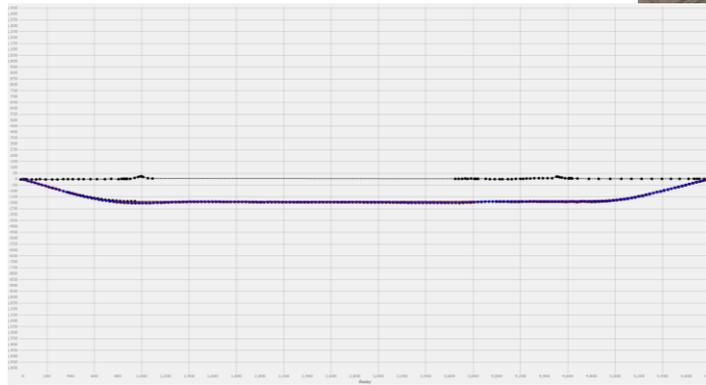
- Crossing length: 2025' & 2070'
- Tolerances: 1' U/D/R/L
- Compressive Strength: 25,000 psi
- Product: 32" Casing for 20" Water Main
- ParaTrack tools used: Gyro, ABIA, P2





Head-to-Head Intersect w/o PMR or Coil

- Crossing length: 5833'
- River Crossing length: 2700'
- Intersected head on first attempt
- ParaTrack tools used: Gyro, P2
- Type: 8" Steel

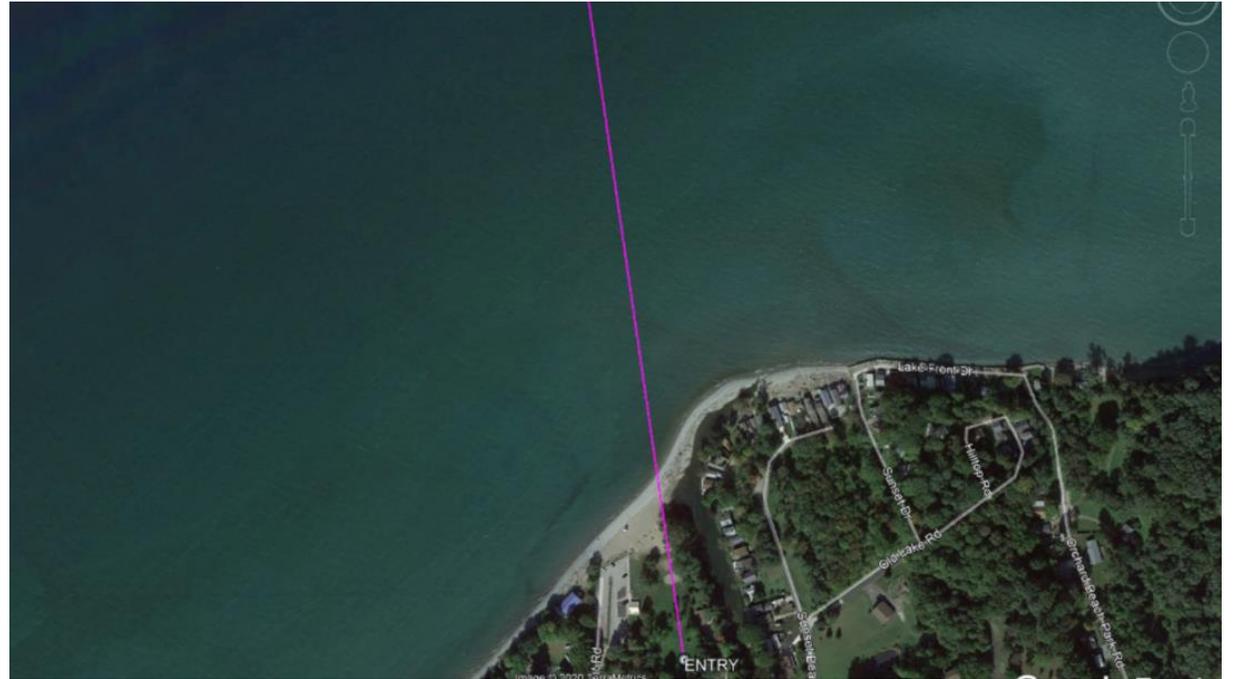


Mississippi River Crossing, Jan. 2021



Accurate Pilot w/o Tracking at Exit

- Length: 2,267'
- Depth: 85'
- Product: 20"
- ParaTrack tools used: Gyro, P2

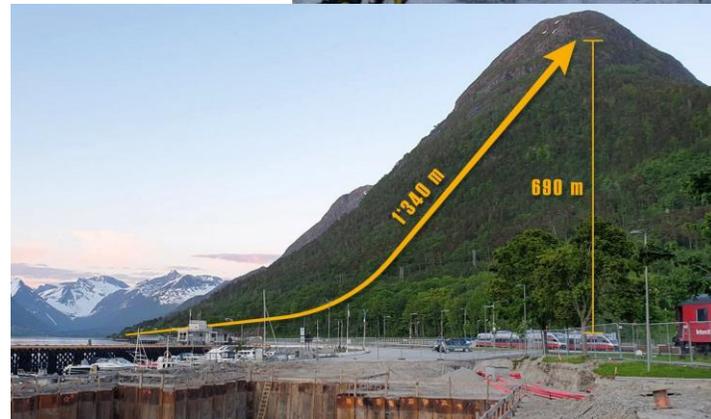


Northeast Pennsylvania Shore Approach



Romsdal Gondola

- Total Length: 4,400'
- Entry Angle: 90°
- Exit Angle: 140°
- Elevation Gain: 2,260'
- Formation: Granite
- ParaTrack Gyro Module, ABIA, LFB



Romsdal, Norway



Precise Exit in Dense Urban Environment

- Crossing Length: 2925'
- Railroad crossings
- Several utilities and pipelines crossings
- 37-degree horizontal curve
- Product: 12" steel pipe



Carrollton, TX



UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS

David Mohler

davidmohler@vectormagnetics.com

Michael Rybak

michael.rybak@inrock.com

VECTOR[™]
MAGNETICS

INROCK[®]



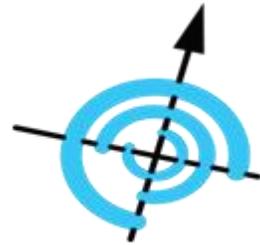
**Prime
Horizontal**



UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS

Brownline



Drillguide
GYRO STEERING TECHNOLOGY





UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS



James (Jim) Cloud, Jr.

President - Brownline USA (formerly SlimDril International)

Over 31 years experience as surveyor and downhole equipment provider.

Served as its President since 1998.

Brownline is the leading provider of Gyroscopic Navigation services.



Rollin Boyd

V.P. of Operations - Brownline USA (formerly SlimDril International)

Involved in the HDD Industry since 1982 with experience in the Engineering and Development of Downhole Tooling. Served as

Manager for a large HDD Contractor as well as VP/Manager of

Brownline, a worldwide leader in Survey/Guidance Services and Downhole Tooling.

Brownline is a Member; DCA, NASTT



INTRODUCTION

OPERATIONS -- **Browline USA** (SlimDril)

- SlimDril International, Inc. provided goods and services in HDD & Oilfield since 1982. Under new management in 1998, providing Equipment and Magnetic Guidance Services for the HDD Industry.
- As SlimDril; involved with numerous HDDs using Oilfield style Gyros for “Check Shot” verification of borehole location (w/varying degrees of success)
- In 2007 SlimDril began providing survey services using the **Drillguide Gyro Steering Tool** manufactured by Browline in the Netherlands. Eventually discontinued providing MGS Services to concentrate solely on the Drillguide GST.
- In 2017, Browline acquired SlimDril is now doing business as Browline USA.

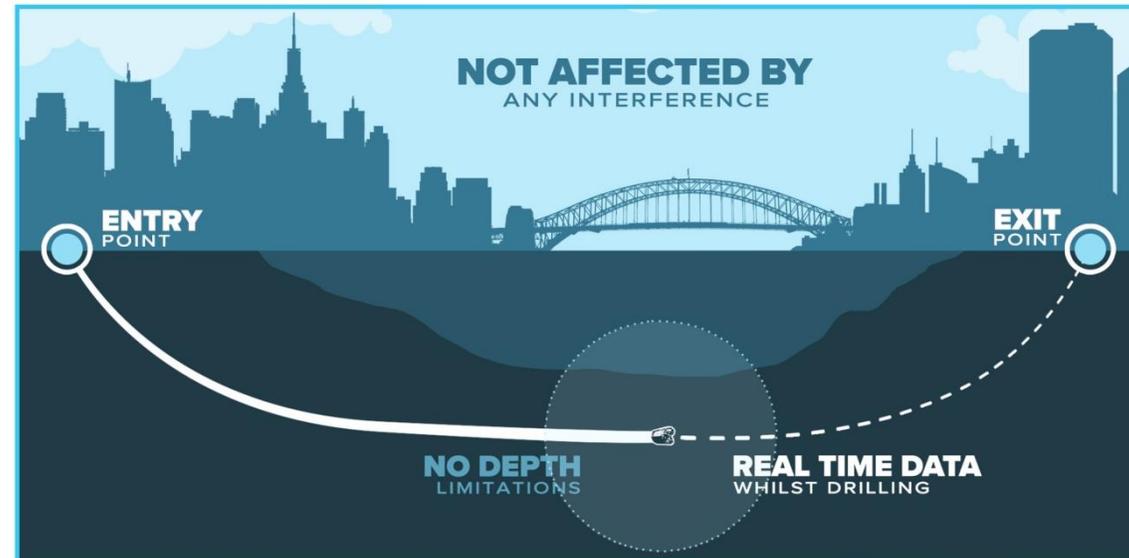


UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS



Gyro steering tool



Brownline's Drillguide Gyro Steering Tool (GST) allows for any HDD project to be completed with extreme accuracy, in a safe and cost efficient manner. Whether a project involves installing underground utilities in congested or remote and nearly inaccessible areas, under lakes, rivers or roads or in environmentally sensitive areas; the Drillguide GST is the best option for any HDD project.

The Drillguide GST provides continuous measurement while drilling, requires no surface access and has no restriction on depth. The industry leading sensor technologies (0.04° on Azimuth and 0.02° on Pitch), have been developed to achieve higher accuracy and to eliminate many of the problems associated with conventional measurement systems. The Drillguide Gyro Steering Tool distinguishes itself from all other conventional HDD steering systems and locators.



UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS

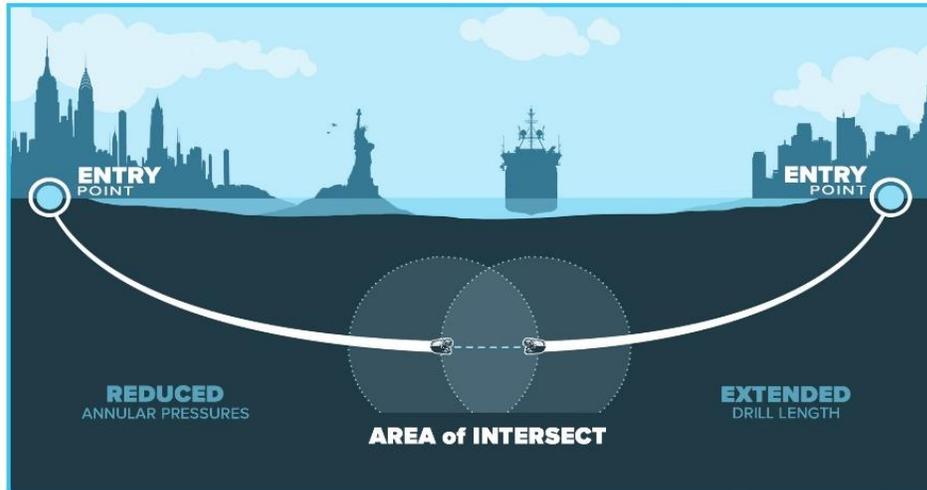
2012; Introduction of the **Drillguide Radar Intersect** Technology. Successfully completed over 100-projects. Lengths up to 13,000ft.

2013; Introduction of the **Drillguide GPS Tracking**. Provide for secondary locates along the bore path.



Radar

Intersecting technology



As HDD projects become longer and more complex, the potential risks of inaccuracy, drilling fluid loss and high pullback loads & stress increases.

To mitigate these occurrences, Brownline has developed the Radar system for intersects, which is used in conjunction with the proven Drillguide GST.

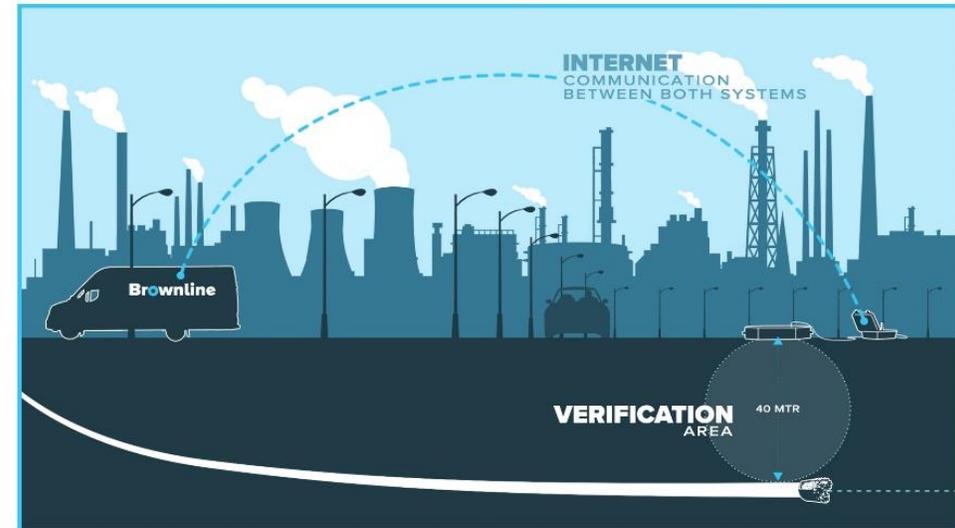
The industry leading technologies of the Radar and Drillguide GST allows for safe and accurate intersects in any location.

As the drill heads reach the intersect area, the Radar systems are activated. The active communication between the two systems and real-time monitoring ensures that the position of the systems is calculated accurately and allowing for an efficient and perfectly executed intersect.



GPS track

Surface tracking technology



The increasing demand for longer drills requires a solution for combining an already accurate and straight drill path with an accurate punch out. To mitigate these challenges, Brownline has developed the GPS track system. The system uses the technologies of the GPS track and Drillguide GST for secondary verification of the location of the drilling assembly.

Brownline's GPS track incorporates industry leading technology (accuracy of 1.5% of depth) which allows for additional verifications of the drill trajectory along the bore path and centimeter-accurate punch out location.



UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS

As the BHAs approach the point of intersect, and/or when overlapped, Drilling is stopped and the RADAR or PMR system is activated.

RADAR - Each system transmits multiple ACTIVE signals which are, in-turn, received by the opposing system.

PMR - One System searches for a Passive Magnetic Signature of the steel included in the opposing BHA.

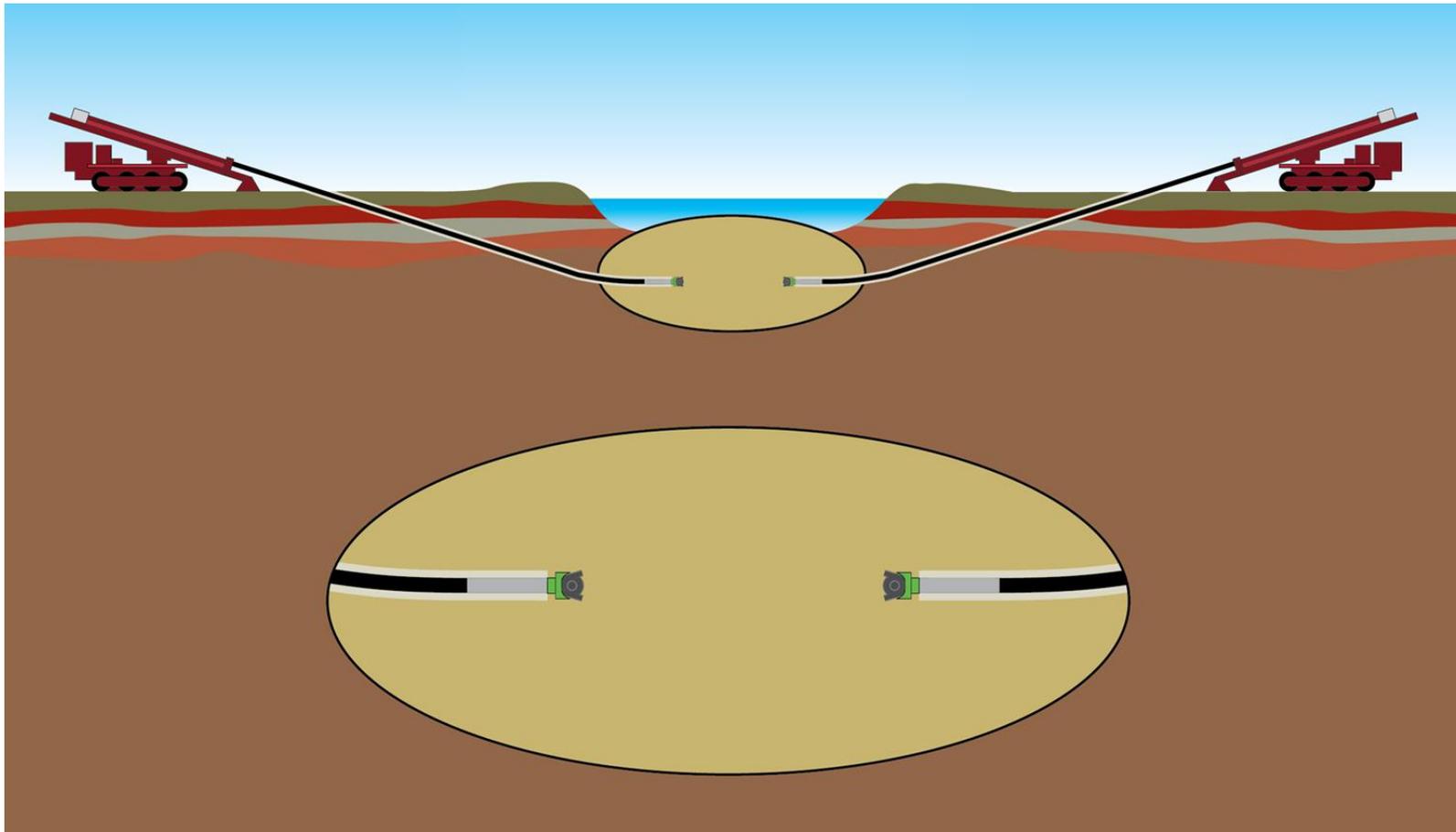
**Magnetic Signatures are affected by outside magnetic anomalies and are weaker at further distance

As required, additional PMR or RADAR Locates are taken to confirm the closure between the boreholes.



The two computer Systems are linked via Wi-Fi and the Software calculates the X, Y & Z relative position of each BHA. This position is stored on each computer and the Surveyor and Driller receive real-time updates.

Seldom are additional shots required.



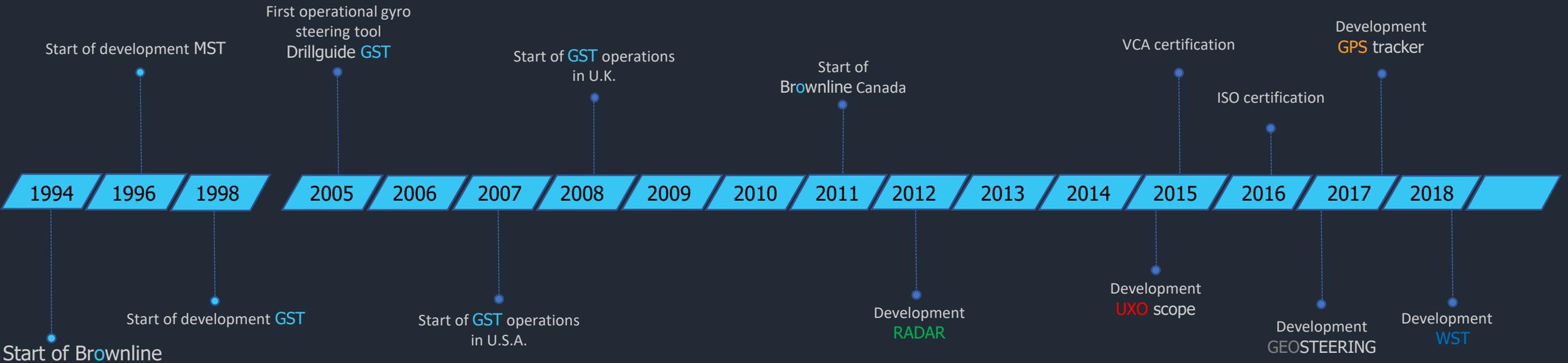
PMR

The shot data is analyzed and a Surveyor determines the position and distance to the opposing BHA based on the data.

Information is verbally given to the opposing rig.

Additional shots are often required to confirm closure between boreholes is achieved.

Brownline IN TIME



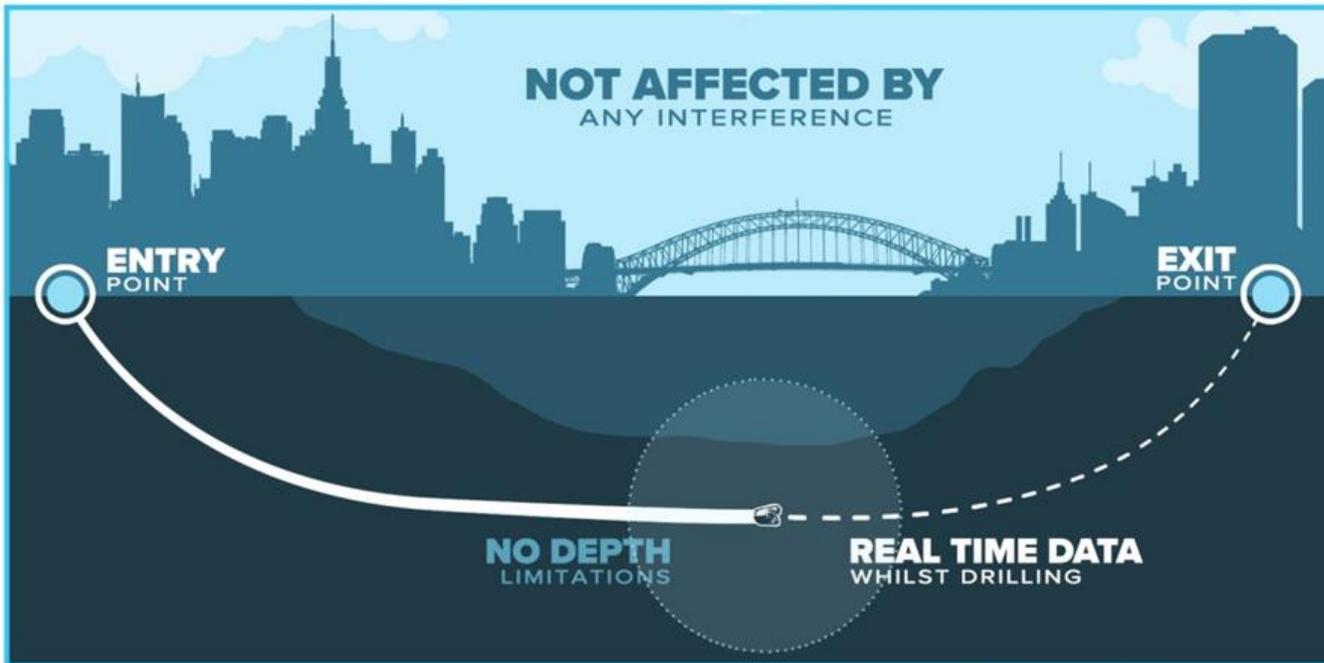


UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS



Gyro steering tool



Drillguide GST

Introduced in 2005

Highly accurate Optical Gyros

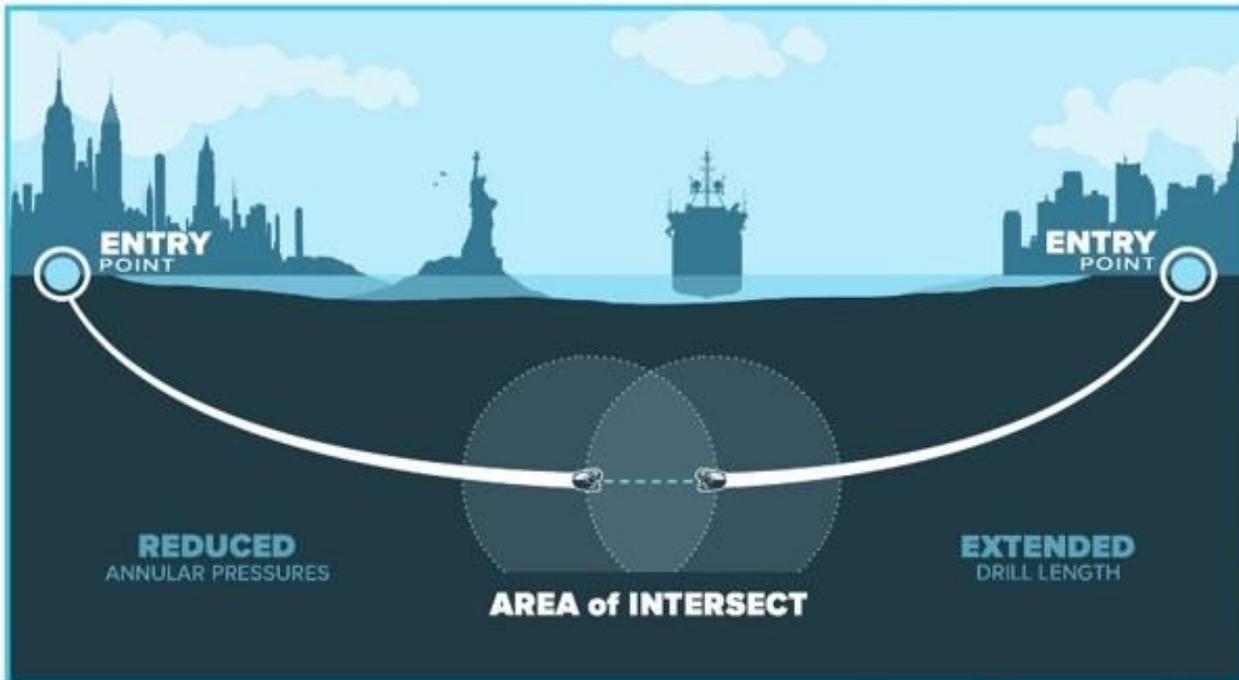
Provides Real-Time monitoring

Easy to use Software

Comprehensive Drillers Screen



Intersecting technology



Drillguide Radar

Introduced in 2012

ACTIVE Signal

Software communication from each side

Provides Real-Time monitoring

Easy to use Software

Comprehensive Drillers Screen

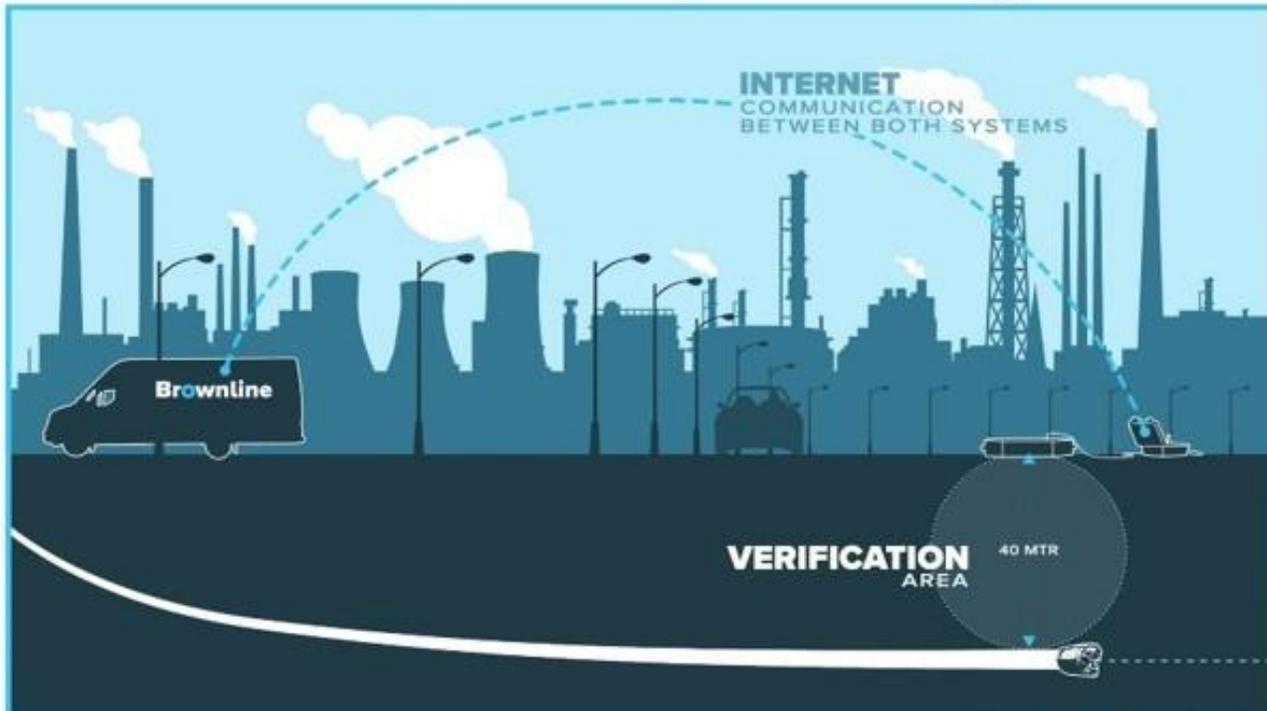


UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS



Surface tracking technology



GPS Track Tool specifications

Small version (S)

Unit dimensions	27" x 23" x 8" - 70 cm x 60 cm x 20 cm (LxWxH)
Net Weight	50 lb - 23 kg
Maximum measuring range	82' - 25 mtr

Large version (L)

Unit dimensions	40" x 35" x 8" - 100 cm x 90 cm x 20 cm (LxWxH)
Net weight	121 lb - 55.5 kg
Maximum measuring range	131' - 40 mtr

Net weight control unit	34 lb - 15.5 kg
Standard cable length	13' - 4 mtr
Positional verification accuracy	1.5% of the dept

GPS Track can only be used in combination with Drillguide GST

Brownline

Sunset Ln. 34275
77423 Brookshire
Texas, United States
+1 (281) 391 5800
USA@drillguide.com
www.drillguide.com



GPS Track AQUA Tool specifications

Unit dimensions	40" x 40" x 16" - 100 cm x 100 cm x 40 cm (LxWxH)
Net weight unit	220 lb - 100 kg
Net weight control unit	34 lb - 15.5 kg
Maximum water depth	1640' - 500 mtr
Standard cable length	328' - 100 mtr
Tracking depth from seabed	131' - 40 mtr
Adjustable height	16" - 40 cm
Positional verification accuracy	1.5% of the depth

GPS Track AQUA can only be used in combination with Drillguide GST

Brownline

Sunset Ln. 34275
77423 Brookshire
Texas, United States
+1 (281) 391 5800
USA@drillguide.com
www.drillguide.com

The **Drillguide GST** is a modular, allowing multiple add-on systems to provide multiple Options possibilities



Radar

Intersect System
Lower Mud Pressures
Longer Drill Lengths



GPS track

Accurate Entry & Exit Locations
Safer in Congested Corridors
Longer Drill Lengths



UXOscope

Bomb Detection Sensor
Ensures a Safe Drilling Location



WST

Smaller Rig Systems
Long Life Batteries
Secondary Tracking using GPS Track



WoB

Enables Precise Hole Control
Faster and More Efficient
Longer Motor & Bit Life



UNDERGROUND CONSTRUCTION TECHNOLOGY

THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS



8-1/2" - 215 mm WoB Tool specifications

Tool OD	8-1/2" – 215 mm	
Tool length (shoulder/shoulder)	3' – 92 cm	
Thread connection pin/box	6-5/8" FH	
Thread connection downhole	6-5/8" FH	
Recommended make-up torque	42,000 ftlb – 57 kNm	
Net weight	485 lbs – 220 kg	
Hole/drill bit size	10-5/8" – 12-1/4" – 250 - 300 mm	

	Push/Pull	Torque
Range	0 - 143,000 lbs / 0 - 65 t	0 - 44,000 psi / 0 - 60 kNm
Accuracy	+/- 5%	+/- 5%

Minimum bending radius	590' – 180 mtr
Maximum flow rate	780 gl/min – 3000 ltr/min
Maximum allowed inner mud pressure	1150 psi – 8000 kPa – 80 bar
Maximum allowed torque (on tool housing)	42,000 ftlb – 57 kNm
Maximum allowed push/pull (on tool housing)	110,000 lb – 50 t
Maximum allowed temperature (on tool)	158° f – 70° c
Maximum allowed vibration (on tool)	20-g up to 200-Hz
Electric power (input on surface)	230V-50Hz / 110V-60Hz
Electric power (output to downhole tool)	56 Volt DC

Drillguide Weight on Bit Sensor

To be introduced to the US market in 2022

Provides Real-Time monitoring

Displays on GST Drillers Screen

Drillguide Wireless Steering Tool

To be introduced to the US market in 2022

Secondary Tracking w/ **GPS Tracker**

Enhanced Battery Technology

Successfully completed 400+ projects - Europe.



3-3/4" - 95 mm Wireless Steering Tool specifications

Tool OD	3-3/4" – 95 mm
Tool length (shoulder/shoulder)	14.1' – 431 cm
Thread connection pin/box	2-3/8" IF
Recommended make-up torque	4450 ftlb – 6 kNm
Net weight	350 lbs – 160 kg
Hole/drill bit size	4-1/4"/4-3/4" – 110/120 mm
Minimum bending radius	330' – 100 mtr
Maximum flow rate	100 gl/min – 400 ltr/min
Sensor(s) Accuracy	Azimuth 0.3° / Pitch 0.1° / Toolface 0.5°
Shoulder to sensor distance	2.6' – 80 cm
Annular pressure sensor position (distance from pin shoulder)	1.6" – 4 cm
Annular pressure sensor range	0 to 1450 psi – 10000 kPa – 100 bar
Maximum allowed inner mud pressure	1015 psi – 7000 kPa – 70 bar
Inner mud pressure sensor range	0 to 1450 psi – 10000 kPa – 100 bar
Electric power (output to downhole tool) -Wired	48V DC
Electric power (maximum output from downhole tool) - Wireless	±24V AC
Maximum allowed torque (on tool housing)	4450 ftlb – 6 kNm
Maximum allowed push/pull (on tool housing)	22,000 lb – 10 t
Maximum allowed temperature (on tool)	158° f – 70° c
Maximum allowed shock (on tool)	50 g (half sine wave)



CONCLUSION

- **Gyroscopic Navigation is an emerging market within the HDD industry and will continue to grow with it. It is believed that Gyroscopic Steering Technology will someday be considered the new standard for a major portion of the HDD Guidance sector of the industry.**
- **Gyroscopic Steering Technology will continue to expand and improve with even higher demands and the need for higher accuracy in any drilling conditions or design factors.**
- **Engineers, Owners, and Contractors need to have accurate information and ask the right questions when specifying Gyroscopic Steering technology needed for their upcoming projects.**
- **As more steering companies enter the Gyro Steering sector, it will be even more important to know the exact specifications and project history of each tool being presented. As discussed and seen in this presentation, not all Gyroscopic tools are equal. Each has its advantages and limitations.**



DISCUSSION

Questions for the Panel

Panel includes Technical and Operational Personnel

Audience Participation.



- Precision pilot hole guidance for HDD in challenging surface locations
- Compatible with the full line of ParaTrack HDD guidance tools
- No specialized handling or personnel required
- Available for purchase worldwide

