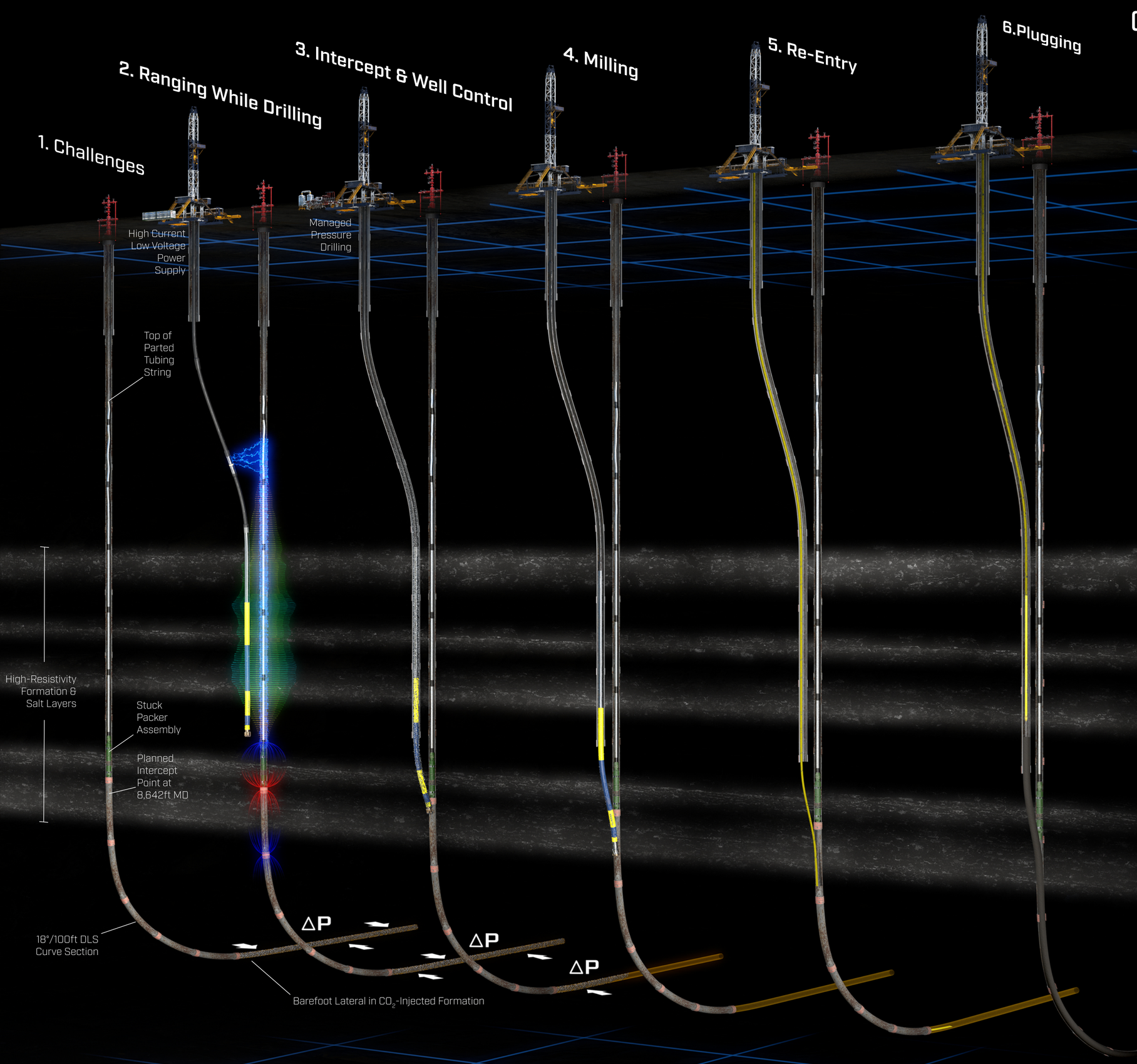
CASE STUDY

DeadAhead™ Ranging While Drilling Utilizing DualLink™ Powered Drill Pipe Enables Technical & Economic Success of Plug & Abandonment via Intercept of a Legacy Well in North Dakota



CHALLENGES

Previous conventional plug and abandonment (P&A) attempts encountered significant difficulties: tubing parted at approximately 1,000 ft during retrieval of the tubing string and packer assembly. Milling attempts to dress the tubing top resulted in further complications and delays. After the conventional methods of workover and fishing took place for an extended period, the surface intervention was abandoned as it was no longer economically viable and had a low probability of success. Accordingly it was decided that a Plug & Abandonment via Intercept would be the most technically feasible and economical solution.

Intercept well intervention still presented challenges in accessing the target well below the packer:

- A short ~10 ft section available below the packer and above the 18°/100' DLS curve, requiring interception at exact depth.
- High formation resistivity and salt layers negatively impacted Active Magnetic Ranging (AMR) signals.
- Oil-based mud which acts as an insulator, further reducing AMR signal strength.
- Tight zones prone to tool sticking, influxes, or losses, heightening the hazards of stuck tools during wireline operations.

TECHNICAL SOLUTION

DeadAhead™ Ranging While Drilling (RWD) technology was deployed using Reelwell's DualLink™ powered and wired drill pipe, enabling 10x electric current delivery for downhole injection. This generated ranging signal 10x higher as compared to legacy wireline Active Magnetic Ranging systems, effectively overcoming the challenges of high-resistivity formations and the oil-based mud environment. The intervention well maintained a precise 5–10 ft separation while paralleling the target for over 5,500 ft, providing full confidence in relative position, which was required to achieve intercept at the exact planned depth. Upon intercept, 100% losses occurred, confirming hydraulic communication with the target well below the stuck packer. Well control immediately commenced and the target well was killed via bull head operations. The target was then milled for access, followed by running a dual tapered 2-7/8-inch tubing string ~600 ft into the target well to place a compliant cement plug. Regulators were on-site to witness the P&A operations and granted final approval of abandonment.

RESULTS

This project marked a step change in P&A via Intercept operations, showcasing a new suite of solutions that excel in safety, are technologically superior, and provide significant economic benefit. Ranging while drilling with DualLink™ eliminated at least 10 wireline ranging runs, saving 2 weeks of rig time while avoiding high HSE risk activities associated with wireline operations in open hole. The DeadAhead™ system proved to be far more than a faster alternative to wireline; it delivered an unprecedented level of precision and control, achieving an outcome previously unattainable with legacy technology.

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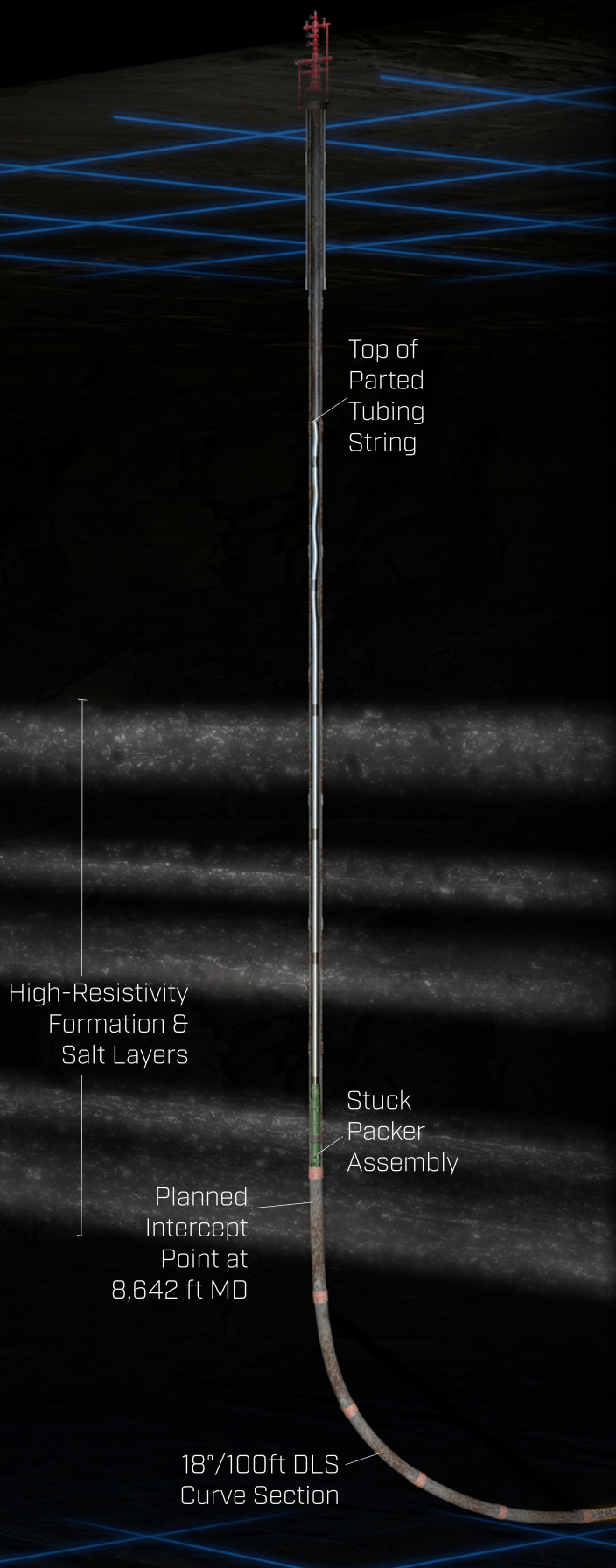
1. Challenges

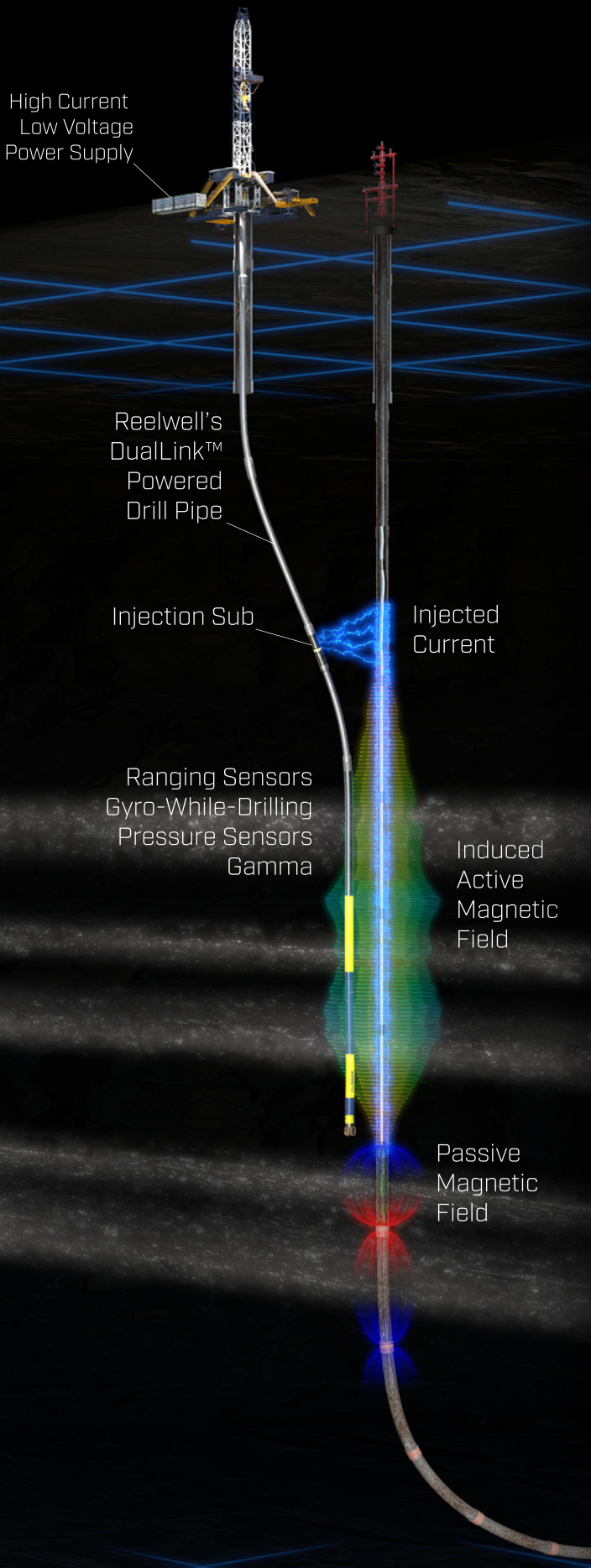


Previous P&A attempt using conventional methods encountered multiple issues, including a parted tubing condition witnessed at approximately 1,000 feet, likely due to embrittlement from prolonged CO_2 exposure. Subsequent remedial operations, such as fishing and milling, led to further complications and delays. After extended attempts using conventional workover and fishing methods, the operation was deemed uneconomical with a low probability of success. As a result, P&A via intercept was selected as the more technically feasible and cost-effective solution.

Technical challenges of well remediation using P&A via intercept for this project included:

- High-resistivity formations and salt layers: Active Magnetic Ranging (AMR) signal strength can be significantly weakened by formations with resistivity ranging from 200–500 Ω·m, while salt layers exceeding 2,000 Ω·m further attenuates signals.
- Drilling with oil-based mud (OBM): OBM reduces AMR effectiveness by insulating the 12-inch electrode on the wireline tool from the formation, limiting electrical contact and significantly reducing current that can be injected.
- Salt-related wireline risks: Salt layers are prone to dissolution and plastic deformation, creating a high risk of sticking wireline tools.
- Low-quality target well survey data: Sparse surveys, approximately one data point every 500 ft, contributed to large positional uncertainty of the target well path.
- Limited interception window: Intercept was required below a packer set at ~8,600 ft. About 20 ft below the packer, the well began building inclination at 18° per 100 ft, resulting in a tight 10 ft MD available window for interception between the packer bottom and the kickoff point of the target well curve section.
- High CO_2 pressure: Elevated formation pressures in the lateral section posed well-control challenges upon establishing hydraulic communication during intercept.

2. Ranging While Drilling



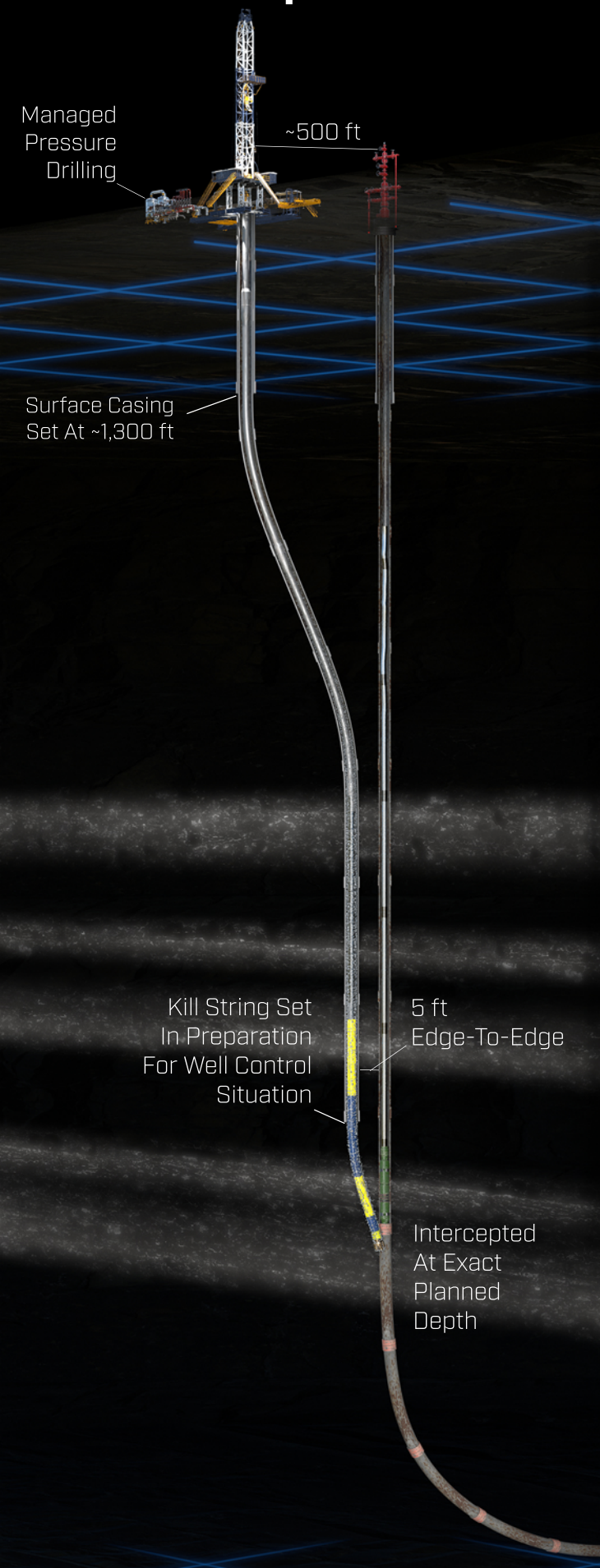
The DeadAhead™ Magnetic Ranging While Drilling system was deployed on this project, using Reelwell's DualLink™ powered and wired drill pipe to inject electric current and generate active magnetic ranging signals. The system integrated ranging-while-drilling sensors, gyro while drilling, and real-time telemetry of annular and pipe pressures along with gamma ray data to the surface.

The wired drill pipe delivered 10 times more injection current than traditional wireline, with a larger electrode surface area to ensure better formation contact for current transfer. The higher injected current mitigated the attenuated effects of insulating mud and high-resistivity formations, including salt, allowing more current to collect and flow along the target well casing, which resulted in significantly stronger AMR signal strength.

DeadAhead™ provided continuous real-time data without requiring retrieval of the drilling BHA for wireline runs, while maintaining full circulation, rotation, and reciprocation throughout operations. This eliminated wellbore stability and well control risks associated with wireline deployment.

Magnetostatic measurements from the DeadAhead™ system improved confidence in determining relative wellbore positioning by combining these passive ranging signals with Casing Collar Locator (CCL) data to track target well casing connections. This provided assurance of intercepting the target well precisely at the planned depth, all while avoiding intercepting at a target well depth where a collar could be present.

3. Intercept & Well Control



After tracking the target well for approximately 5,500 ft at a 5–10 ft separation and reaching about 350 ft MD before the planned interception point, the drilling wellbore was directionally aligned with the target. At the planned depth at ~8,300ft MD of the intervention well, with an edge-to-edge separation of approximately 5 ft, with the path of the intervention well azimuthally aligned with the target well and with the planned incidence angle at 3°, the drilling BHA was pulled out of the hole and the intermediate “kill string” casing was set.

Subsequently, the kill string casing shoe was drilled out with the intercept drilling BHA. Drilling progressed as per the directional plan until successful contact with the target well at the intended depth was confirmed. Upon interception, a complete loss of circulation occurred, resulting in approximately 100 barrels of drilling fluid lost into the target well. Due to the presence of injected CO_2 in the reservoir, reservoir pressures were substantially elevated. As a result, the target well casing was expected to contain a multiphase mixture of oil, water, and supercritical CO_2, increasing the complexity of managing wellbore pressures during interception.

Real-time Annular Pressure and Pipe Pressure data were monitored before and during the kill operation. The well kill was executed smoothly, and the well was successfully stabilized for subsequent window milling operations.

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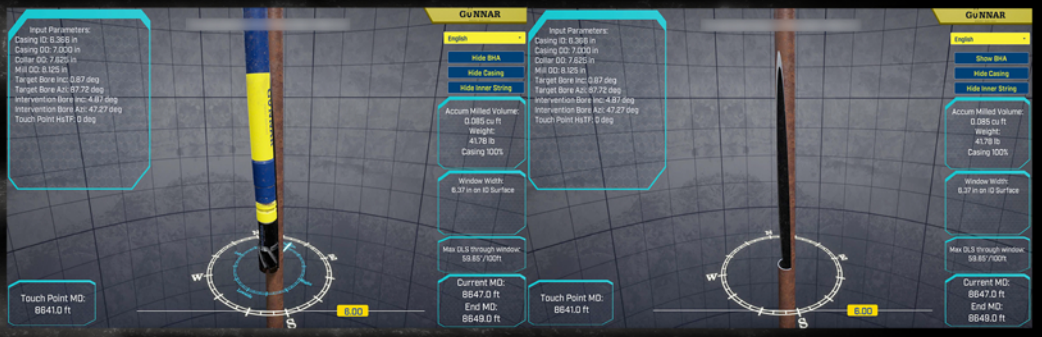
4. Milling

Following successful intercept, the window milling model was updated using the actual survey data from both the target and intervention wells. The updated model yielded the optimal high-side toolface orientation and required milling distance. This ensured a fully opened window while preserving the structural integrity of the target well casing.

A custom-designed mill was deployed with a bent mud motor and GWD for precise toolface control. During milling, toolface orientation, differential pressure, and rate of penetration were closely monitored to ensure proper engagement with the target well casing. Ditch magnets placed in the return flow line successfully collected steel cuttings, confirming active milling on the target casing.

Upon reaching the planned milling distance, the milling BHA was retrieved. Inspection showed the mill was in excellent condition, exhibiting minor wear, with no balling, damage, or performance issues, all positive indications of a successful window milling operation.



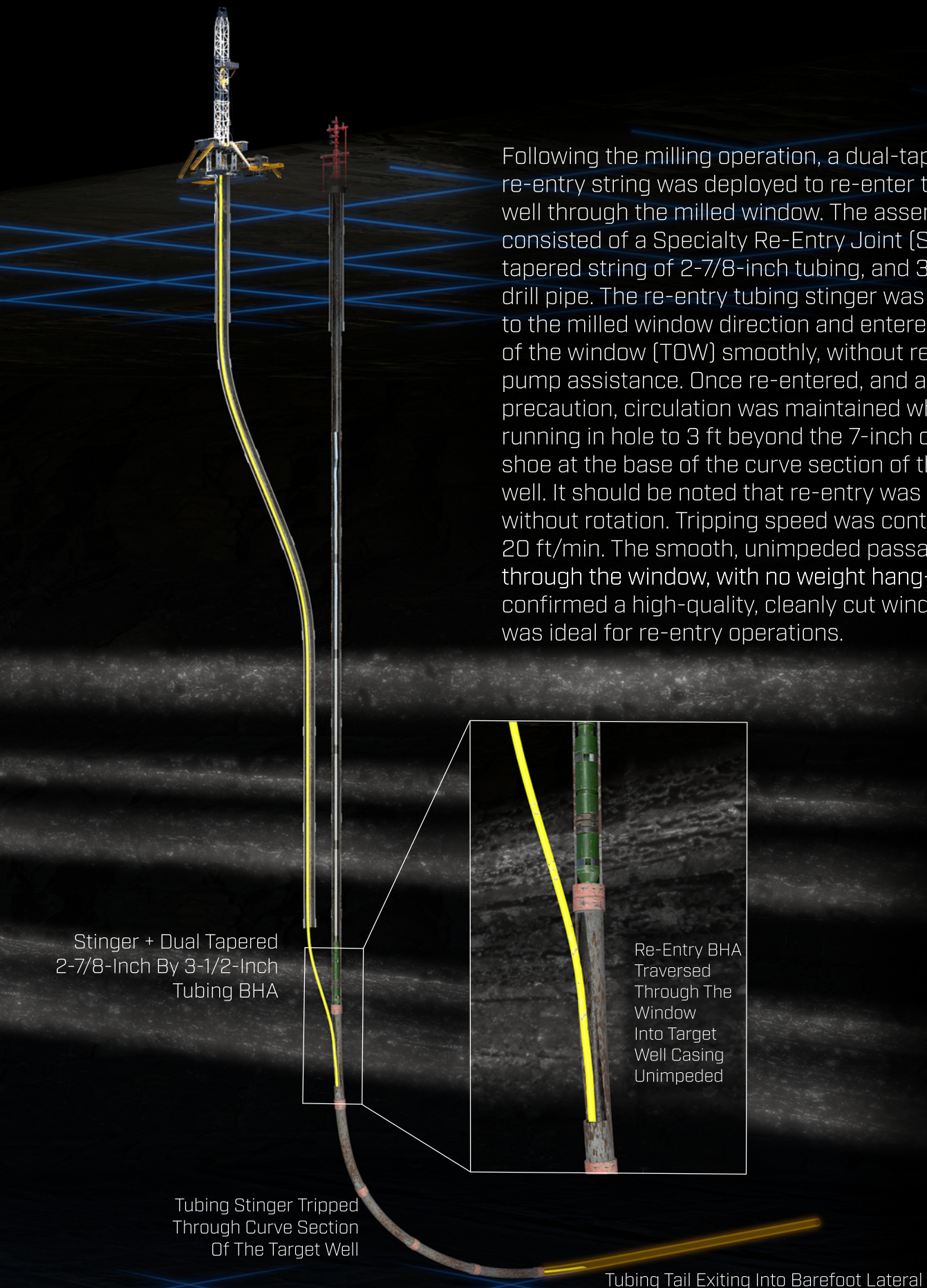
The window milling process is modeled using custom software in the planning phase and continuously updated during operations with data telemetered from downhole

Custom Mill, Before RIH

After Milling Completed

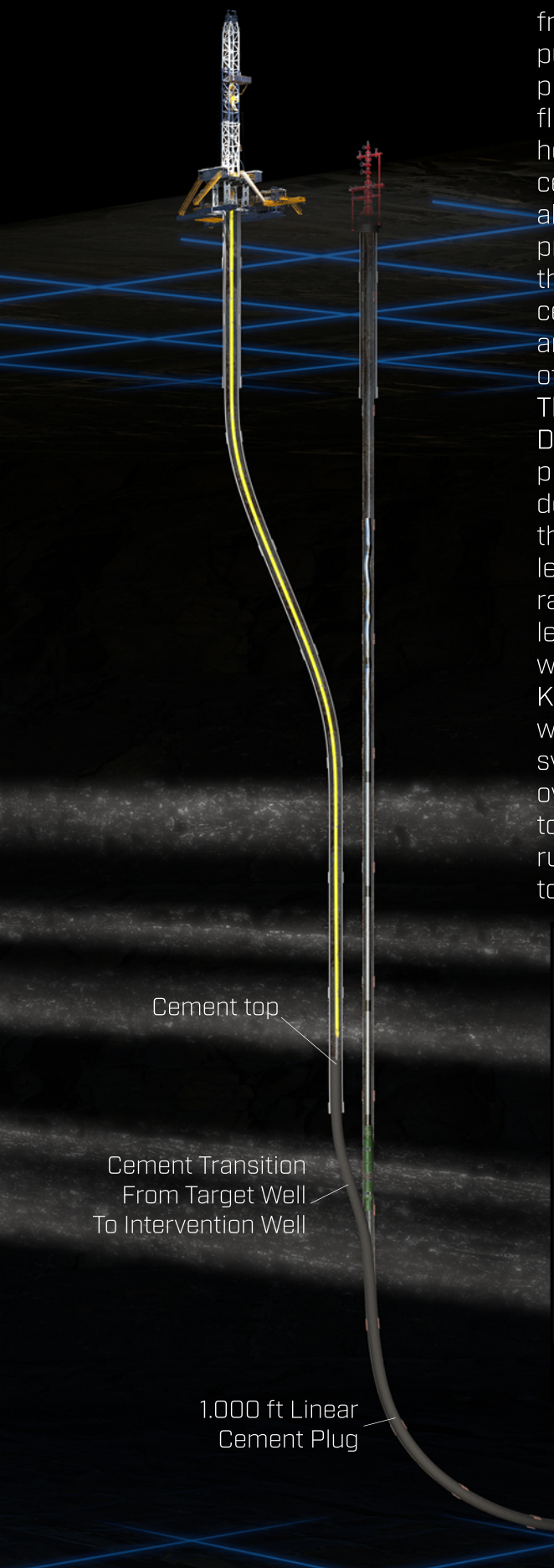
Recovered Steel Of Milled Cuttings On Ditch Magnets

5. Re-Entry



Following the milling operation, a dual-tapered re-entry string was deployed to re-enter the target well through the milled window. The assembly consisted of a Specialty Re-Entry Joint (Stinger), a tapered string of 2-7/8-inch tubing, and 3-1/2-inch drill pipe. The re-entry tubing stinger was oriented to the milled window direction and entered the top of the window (TOW) smoothly, without requiring pump assistance. Once re-entered, and as a precaution, circulation was maintained while running in hole to 3 ft beyond the 7-inch casing shoe at the base of the curve section of the target well. It should be noted that re-entry was achieved without rotation. Tripping speed was controlled to 20 ft/min. The smooth, unimpeded passage through the window, with no weight hang-ups, confirmed a high-quality, cleanly cut window which was ideal for re-entry operations.

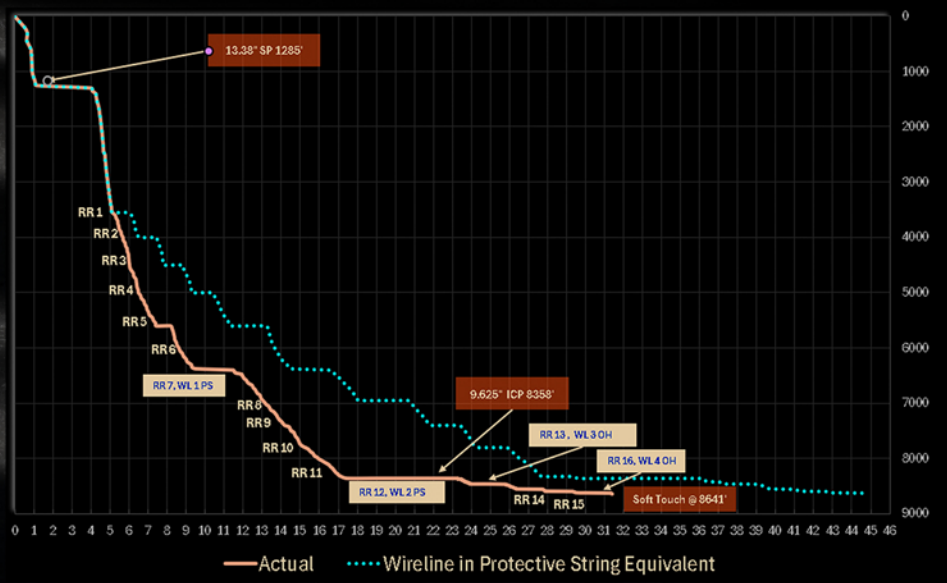
6. Plugging



Following successful re-entry, cementing operations commenced from the bottom of the intermediate casing of the target well, pumping a 1,000-ft linear cement column to establish a permanent plug. The cement fully covered the casing below the intercept point, flowed across the milled window into the intervention well's open hole, and extended back up inside the intervention kill string. After cement placement, the stinger BHA was pulled out and positioned above the cement for an 18-hour wait-on-cement period to ensure proper setting. Once cured, the cement top was tagged within 2 ft of the predicted depth, with no signs of slumping or channeling. The cementing operations were supervised by regulatory authorities, and final regulatory approval was granted once the successful tag of the cement top was witnessed by the regulators.

The deployment of the DeadAhead™ Magnetic Ranging While Drilling system with Reelwell's DualLink™ powered and wired drill pipe successfully achieved an exact intercept at the planned target depth, demonstrating exceptional control and precision in steering the intervention well trajectory relative to the target well. This high level of accuracy was made possible by continuous, high-density ranging data, which eliminated uncertainties associated with sparse legacy surveys on the target well and ensured precise alignment with the target well at the narrow 20-foot window below the packer.

Key operational benefits included a substantial reduction in both wireline runs and open-hole exposure time, as the DeadAhead™ system delivered a continuous stream of relative positional data over more than 6,000 feet without requiring trips to deploy wireline tools. By eliminating the need for approximately 10 wireline ranging runs, the deployment of the DeadAhead™ technology is estimated to have saved nearly two weeks of rig time.



Day vs Depth, RWD vs Wireline Comparison

Acknowledgements

Gunnar Energy Services would like to express our sincere gratitude to ExxonMobil for our collaboration on this project. This partnership enabled the first field deployment of DeadAhead™ Ranging While Drilling technology. While achieving the project objectives, this deployment also provided invaluable opportunities for learning, and has effectively demonstrated the viability of P&A intercept as a dependable and cost effective solution for wellbore abandonment and plugging. Based on this success, GES will double our efforts towards the continuous improvement of our technology and products, and in delivering the best possible services and results to our customers in the future.

We also extend our heartfelt thanks to our valued partners—David Erdos and Ken Miller (Erdos Miller), Danny McCall and Justin Laribee (Di Drill Survey Services) and Ian Silvester (Reelwell)—for their unwavering collaboration and expertise.

Last but not least, we express our deepest appreciation to our exceptional team, including but not limited to Dan Eby, Arthur La Porta, Georgy Rassadkin, Chad Moss, Pong Pipatwit, Nabil Khan, Joe Burke, Jordan Timbs, Trevor Woolridge, Hamzi Abou-Morad, Ted Hebert, Teehran Francis, and Trey Letzkus, for their dedication and hard work, which made the achievements outlined in this case study possible.