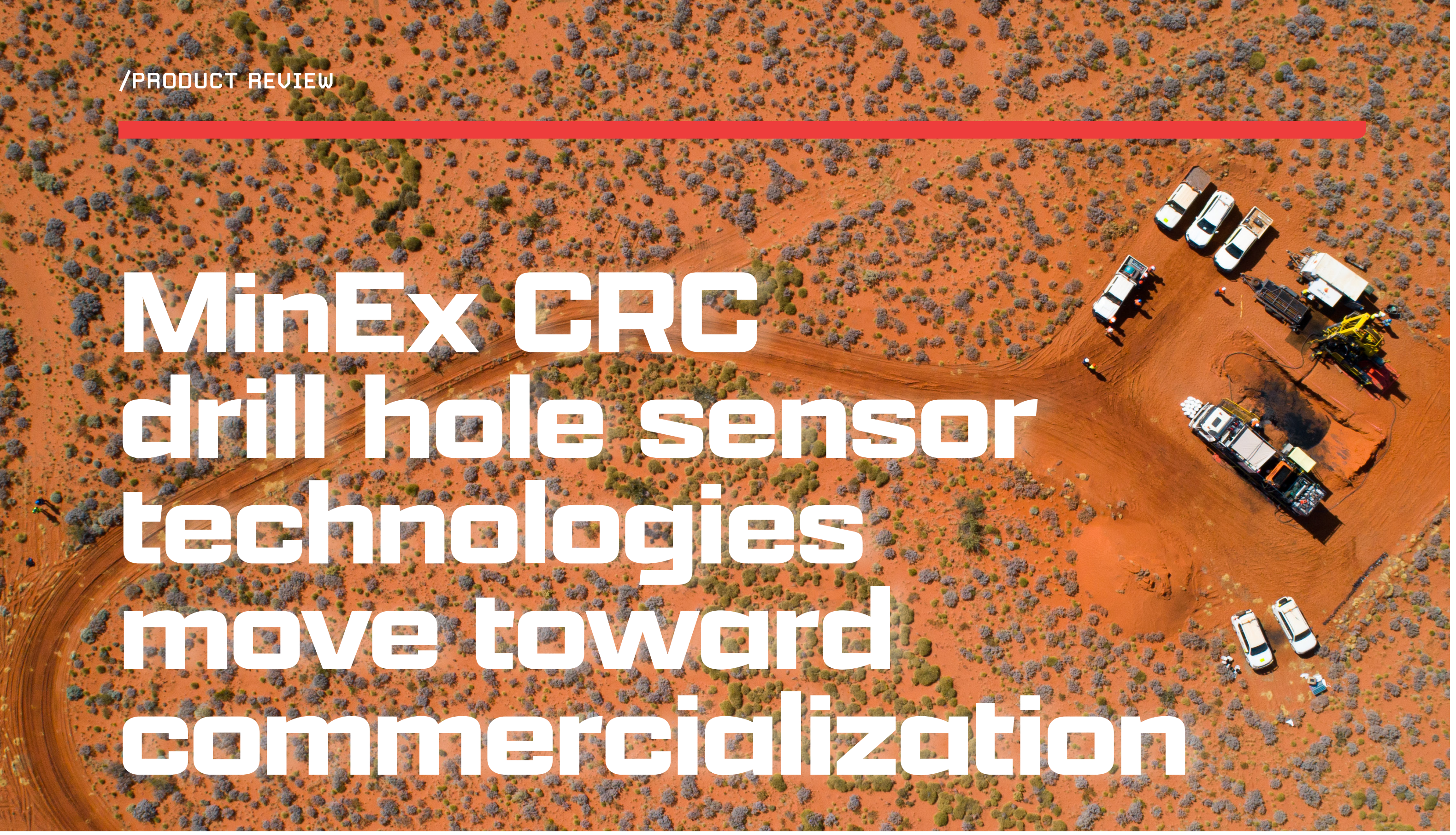


MinEx CRC drill hole sensor technologies move toward commercialization

by Andrew Bailey, CEO of MinEx CRC

MinEx CRC, the world's largest mineral exploration research collaboration, and its sponsor organizations are investing in novel sensing technologies to be deployed in the borehole during drilling operations, aiming to deliver near-real-time exploration data for more efficient drilling and timely decision-making.

Combined with downhole steering and multilateral drilling techniques currently under development in their CT drilling project, these technologies will enable explorers to modify drill targets and alter the drilling trajectory 'on the fly'. This will decrease the cost of drilling (fewer holes and fewer meters drilled) and increase the chances of intercepting target mineralization.

Following advice from end-user mining companies and mining, equipment, technology, and service providers (METS), MinEx CRC have focused their downhole sensing research on electromagnetic (EM) and geochemical logging tools aimed at developing functionality not available in the current market.

Next-generation driller-deployable EM tools

Borehole EM sensors have been part of the mineral exploration toolkit for decades; however, they are only used in a small percentage of drill holes, typically deployed by wireline (requiring a separate deployment by a specialist logging crew) and have functionality limited by the single, or sometimes dual, frequency settings of the source EM field. The MinEx CRC research team, based at Curtin University (Western Australia), has developed a unique downhole 'Swept Frequency' EM sensor system which cycles through hundreds of source frequencies at each measurement location. The tool has been designed for small-diameter mineral exploration drill holes and can be deployed by wireline or as part of the drilling bottom-hole assembly. The latter is a critical aspect of MinEx CRC's approach as it enables the options of logging-while-tripping or logging-while-drilling, thus removing the requirement for a separate logging deployment and significantly reducing the risk of hole collapse between drilling and logging.

The frequency-dependent response from the surrounding geological formation delivers an exceptionally rich data stream, which is ripe, can be used to derive multiple physical properties (conductivity, induced polarization, magnetic susceptibility) and characterize the geophysical response meters from the drill hole.

Over the past year, MinEx CRC have progressed their downhole Swept Frequency EM tool from a laboratory prototype (TRL4) to a field-tested prototype (TRL6), with the successful acquisition of data from a 900 m (2953 ft) drill hole at Curtin University. In parallel, researchers have been conducting controlled experiments in environments with high but well-constrained conductivity contrast (designed to understand the temperature-dependent response of the tool). The data will help create calibration procedures for collecting reliable, high-quality data. MinEx CRC plans to progress the Swept Frequency EM tool to TRL7 this year.

At the same time, the petrophysical logging research team will step up their efforts to develop a novel downhole Time Domain EM (TDEM) tool. A downhole equivalent to conventional surface TDEM methods, with similar waveforms that can be integrated with surface measurements for improving resolution and confidence in subsurface modeling, it will deliver greater depth penetration (tens of meters) than the swept frequency tool. This offers the potential to locate and model off-hole conductors and inform drilling decisions (including trajectory control or kickoff for multilateral drilling from the same drill hole).

Drill hole geochemical logging with Laser-induced Breakdown Spectroscopy (LIBS)

If achievable, in situ geochemical logging of the drill hole has the potential to change dramatically the approach to mineral exploration in three ways. Firstly, by reducing reliance on high-quality sample recovery (thus permitting more cost-efficient drilling techniques), secondly, by generating an objective, multidimensional data stream for automated multiparameter geological logging, and thirdly, by bringing real-time decision making to the drill site.

LIBS has several advantages over alternate downhole geochemical techniques. Among these are:

- It can measure the entire periodic table at relevant detection limits (<10 ppm);
- Pulses of the high-energy laser source can be used to dry or clean the drill hole wall pre-analysis;
- Each analysis is very rapid, so a time-efficient logging strategy can deliver hundreds of analyses per meter. These can be integrated to provide a bulk-rock composition at user-defined intervals or used as input into geochemical and spatial analytics software. The data are conducive to clustering and domaining techniques for automated drill hole logging;
- Each analysis covers a tens of microns in diameter area with the ability to resolve single mineral grains (and simple mixtures of mineral grains). This enables data processing techniques that can be used to determine quantitative mineralogy, mineral chemistry and proxies for mineral texture (e.g. grain size distribution).

If the design, deployment, and data processing challenges for a downhole LIBS system can be solved, MinEx CRC will be able to deliver an extremely rich dataset for rapid, objective, quantitative geological logging of drill holes.

After consultation with end-user and service provider participants, MinEx CRC have focused on delivering a market-ready tool for air-filled drill holes. The LIBS research team based at CSIRO, Melbourne/Perth, and UniSA, South Australia, has progressed the downhole LIBS tool from a concept to a field-deployable prototype (TRL5). Laboratory testing was focused on key technical challenges, including:

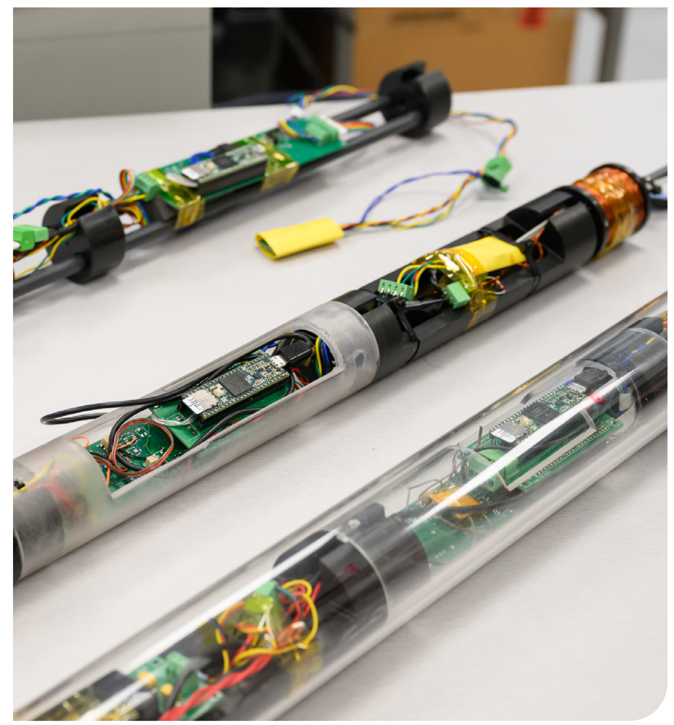
- Optics and spectrometer design to fit within the constrained space of a borehole;
- Ruggedized housing to survive drill hole conditions;
- The requirement to collect analyses while the tool is in motion;
- The likelihood that the drill hole wall will be uneven at the millimeter to centimeter scale;
- The likelihood that the drill hole wall will be wet or dirty.

Additionally, researchers are developing novel calibration and data processing algorithms to achieve high-quality, repeatable data with partial detection limits per million range for multiple elements from the same LIBS spectra. Using the data, researchers are working on algorithms to generate user-defined derived data, such as data clustering, automated boundary detection, integrated bulk-rock analyses, quantitative mineralogy, mineral chemistry and proxies for texture.

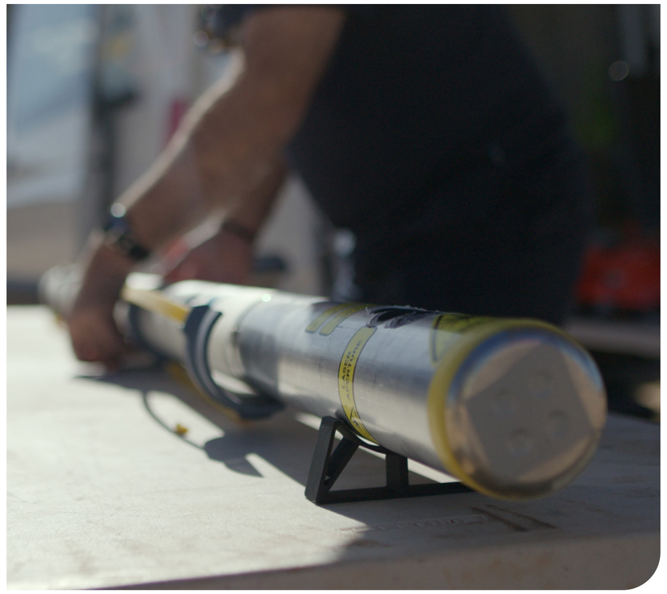
In October 2023, MinEx CRC filed a provisional patent based on their prototype downhole LIBS system, which incorporates a high-powered, variable-focus laser and optics and spectrometers capable of detecting all elements on the periodic table to part per million levels.

The tool has a ruggedized chassis with a diameter of 75 mm (3 in), which fits within most mineral exploration drill holes (all drill holes larger than or equal to NQ diameter). In-hole stabilizers protect the tool from being damaged by the drill hole wall and position the laser at an optimum distance from the wall during analysis. The prototype tool is deployed by wireline (although future versions are intended to be driller-deployable) with a winch system controlled by bespoke software that allows user-controlled logging of velocity and sampling rates. The system also includes an in-field calibration module and additional sensors for monitoring instrument performance.

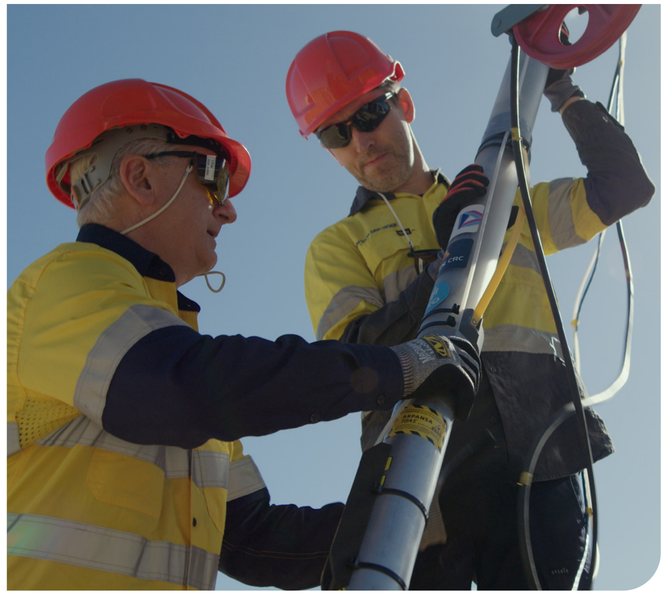
With the support of MinEx CRC Participant IMDEX Limited, June 2024 saw the first within-hole trials of the prototype tool collecting over 220 logging meters (722 ft) in shallow drill holes at the Australian Automation and Robotics Precinct (AARP), Western Australia. Multiple logging runs were conducted in the same drill hole with varying parameters (wet vs dry walls, with and without autofocus mechanism, with and without air jets for cleaning). Specific intervals were doped with elevated concentrations of target elements Cu and Li. The tool returned geologically sensible data under various operating parameters and could detect and measure Cu and Li concentrations



↑ MinEx CRC Downhole Swept Frequency EM tool



↑ MinEx CRC Laser-induced Breakdown Spectroscopy (LIBS) tool



↑ MinEx CRC LIBS tool deployment during field trials in Western Australia

in the doped intervals. The results are used to refine the tool design, including a redesign of the optical front end and deployment process. MinEx CRC plans to progress the downhole LIBS tool to TRL7 by 2027, working in parallel with potential industry partners to ensure that the final product is technically sound (robust and delivering high-quality data) and commercially viable (delivering valid data within an affordable and profitable business model).

Towards logging-while-drilling and real-time trajectory control

The MinEx CRC downhole EM tools and downhole LIBS geochemical tool are enabling technologies that can contribute to an overarching stretch target of MinEx CRC that spans multiple research projects and exemplifies the portfolio nature of its research—to deliver logging-while-drilling and real-time trajectory control within a safe, environmentally-friendly, and cost-effective CT drilling platform.

Several technical hurdles remain. Tools intended to operate during active drilling must withstand the extreme conditions—high pressures, abrasion (both from drilling fluids and cuttings and from physical contact with the drill hole wall) and severe vibrations caused by the drilling process. These challenges will be easier to overcome for the EM tools (designed to operate underwater and with a relatively high tolerance for physical stress) than for the downhole LIBS tool (currently designed for use above the water table and relying on finely-tuned mirrors and lasers that are prone to disruption by physical stress). The downhole tools have been designed to offer commercialization potential as standalone products, with the option of being deployed by wireline or as logging-while-tripping tools. The latter allows the driller to collect end-of-shift or end-of-hole data for within-program decision-making without a separate wireline deployment.

Equally important to the vision of real-time trajectory control is the ability to accurately locate and steer the drill bit while drilling. This is the subject of ongoing research for CT drilling engineers working in collaboration with UK-based drilling technology provider AnTech Limited. MinEx CRC's strategy is to miniaturize a bottom-hole steering assembly, whose larger version is proven to occur during Phase 3. Additional resources were provided by MinEx CRC Participants to build a field prototype in 2024, with a series of field trials planned for late 2025.

If steering while drilling proves not to be viable, MinEx CRC will revert to their fallback strategy to deliver multiparameter drill hole logging combined with accurate location of the drill bit and the ability to drill multiple deviations from the same drill hole. During 2024, UniSA-based drilling engineers conducted successful trials of hardware and operating procedures to 'kickoff' from an existing drill hole, creating the potential for multiple deviations from the same collar location. The trials were conducted in soft formations (at UniSA Mawson Lakes Campus) and hard formations (at Kapunda in collaboration with MinEx CRC Affiliate EnviroCopper). The procedure involves setting a casing wedge at the required depth and drilling a pilot hole using a full-face bit and reamer developed in collaboration with Hardcore Diamond Products. To demonstrate the viability of the 'kickoff', the drill hole was re-entered with a diamond coring bottom-hole assembly and 3 m (9.84 ft) of drill core were collected from the new trajectory.

This is a passive approach to achieving an outcome comparable to steering while drilling, namely that the driller can control the drilling trajectory in response to geological and geophysical data while the hole is being drilled. The component technologies to enable this vision have now been designed and built by MinEx CRC and are at various stages of field testing. Each has a standalone commercialization potential, and in combination they have the potential to deliver a profound improvement in drilling functionality, cost, and success, measured by meters drilled per discovery. C

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