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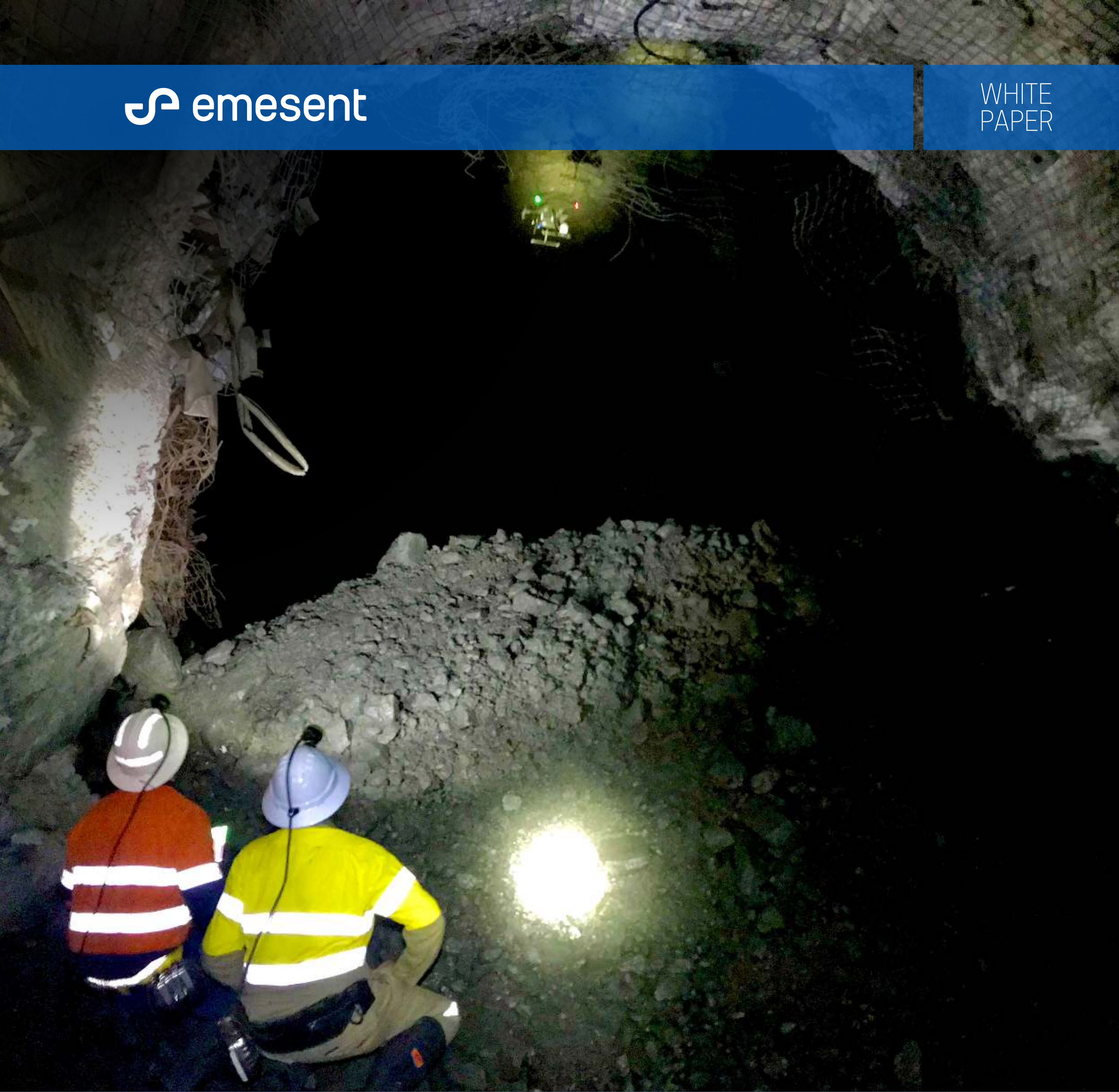
WHITE PAPER



SAFE, FAST & EASY MAPPING

OF HAZARDOUS AREAS IN UNDERGROUND HARD ROCK MINES

SAFE, FAST & EASY MAPPING
OF UNDERGROUND HARD ROCK MINES

Deep and high-stress conditions make mining inherently high-risk environments for personnel, equipment, and infrastructure. Laser scanners are used to capture data in underground areas so that mining and geotechnical engineers can understand the effect of mining-induced and tectonic stresses on the rock mass and maintain safe and efficient operations.

However, the data collection process can be hazardous. Mapping areas using a traditional cavity monitoring system (CMS) is time-consuming and increases safety risks for personnel, who have to control a boom-mounted sensor in exposed unsupported ground. For example, mapping one stope may take hours, requiring personnel to perform multiple scans from separate entrances, including the hazardous drawpoint at the bottom. The time and safety risks may have a material impact on production.

Hovermap reduces these risks by keeping personnel at a safe distance and minimizing the time taken to map any hazardous or inaccessible area. Drone-mounted, Hovermap enables autonomous-flight and collision avoidance capability to produce shadowless, high resolution scans of any underground area. Mining or geotechnical engineers can quickly and safely inspect stopes, drives or drifts with minimal disruption to production.

"We've done side-by-side comparisons between Hovermap and a boom-mounted CMS in terms of setup and scan time as well as the data quality. Hovermap was a clear winner, with the scanning flight completed before the CMS boom was even set up, and the data was far superior in terms of coverage, point density and point density uniformity. We've mapped stopes in 5 minutes that had previously taken hours with a CMS, requiring scans from multiple entry points."

Matt McKinnon, Founder and CEO
Unmanned Aerial Services Inc.

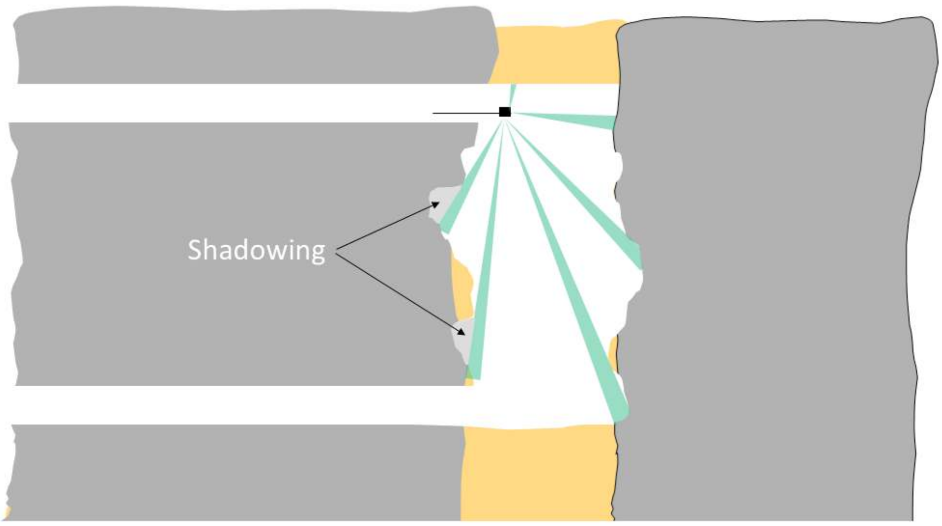
TRADITIONAL CMS SCANNING — TIME-CONSUMING AND HAZARDOUS

Inspections of inaccessible areas, orepasses, stopes, drawpoints, require specialized systems, such as a cavity monitoring system (CMS). Consisting of a light detection and ranging (LiDAR) scanner attached to a boom, a CMS has provided the best means of scanning and mapping for geotechnical analysis. But CMS scanning is time-consuming and often requires multiple scans that can slow production and/or monthly reporting.

Typically, mapping a stope requires a CMS sensor, mounted on a boom, to be extended into the stope by hand as far as possible and requires the surveyor to work in close proximity to drawpoints or at a stope brow. Through this, the surveyor is exposed to the risk of sudden rock fall, riling hazards, as well as unknown undercutting.

Upon completion, the surveyor must then retrieve the device, exposing them a second time to the initial hazards.

For full coverage of large stopes, traditional CMS methods require scans from multiple entrances. Each scan takes in the order of 30 minutes to an hour to setup and complete, not including travel time between scan locations. Added to this are the hours required for post-processing, which can increase the timeframe for useable output to days.



SHADOWS AND VARIABLE POINT DENSITY

Point cloud results from CMS imaging typically contain variable point density and coverage, with some areas in shadow, potentially reducing the value of data, whether for geotechnical, volumetrics or reconciliation analyses.

Substituting a CMS with a drone-mounted LiDAR scanner such as Hovermap reduces or eliminates the requirement for surveyors to work near open cavities or unsupported ground, and improves data quality and coverage.

MAP HAZARDOUS AREAS IN MINUTES WITH HOVERMAP

Hovermap is a versatile mobile mapping solution able to operate in GPS-denied and hazardous environments. When mounted to a drone, Hovermap can fly a mission and within minutes capture high resolution LiDAR point clouds and imagery. These data sets provide mining and geotechnical engineers with rock mass, structural and volumetric data of unparalleled quality, improving decision-making in mine safety and design with minimal impact to production schedules.

In addition, Hovermap's advanced collision avoidance and flight autonomy technology enables beyond-visual-line-of-sight (BVLOS) flight and mapping of underground and other GPS-denied areas. Hovermap combines a rotating LiDAR sensor, which captures a near 360° x 360° spherical field of view, with simultaneous localization and mapping (SLAM) algorithms for mapping, navigation, collision avoidance and position hold capabilities without a GNSS positioning system.

Typical flight duration ranges from 2-5 minutes, depending on the target volume, distance to access and the required point density of the results. Even large stopes (100 m or 330 ft) are mapped in about five minutes. For safety, flight speeds are regulated by Hovermap 1 – 2 m/sec (3 – 6 ft/sec).

The SLAM data is first utilized in-flight to provide autonomous navigation, collision-avoidance, position-hold flight capability and regulate flight speed. Post-processing outputs provide high resolution point clouds, with multiple attributes, that can be registered to the mine coordinate system in *.las, *.laz (1.2 or 1.4) *.dxf or *.ply formats that are ready for visualization and analysis.

Weighing only 1.8 kg (4 lb.), Hovermap is easily deployed, and able to switch between drone-mounted, handheld, vehicles, and other data capture techniques.

ENHANCED STOPE ANALYTICS

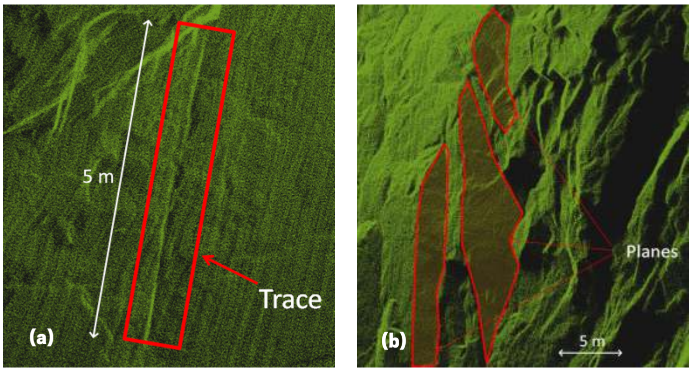
The reconciliation and analysis of a stope relies heavily on the quality of the data produced by the stope scan.

With CMS, the quality of the scan is typically limited by the location of a static scanner, the size and shape of the cavity. The resulting data often contains shadowing and can vary greatly in point cloud density, from thousands to single points per square meter. Shadowing and poor density can occlude significant overbreak, affecting stope volumetric calculations, analysis of rock mass failures and safety.

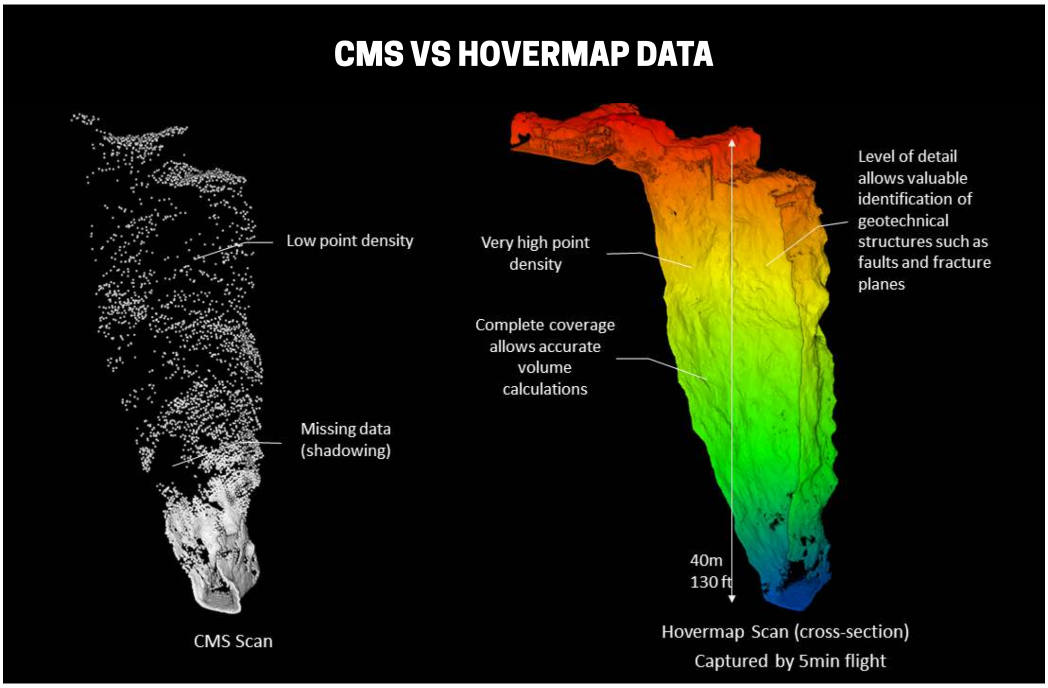
In comparison, Hovermap flies beyond the brow, down into the stope, to capture data consistently in the range of ten thousand points per square meter (or better) and shadowing is greatly reduced.

High resolution point clouds deliver several benefits. For example, analytics conducted on high resolution data can give engineers greater confidence in the final stope volume for reconciliation of production tonnes or for backfill (where applicable).

Over- and under-break can be calculated with greater certainty, and there is better opportunity for interpretation of the mechanism by which it occurred. Furthermore, discontinuity traces and structural planes within a stope can be identified by geotechnical engineers, which was not previously possible given CMS coverage and quality limitations.



Example point cloud density from Hovermap provides sufficient detail for the recognition of (a) structural discontinuity traces and (b) planes.



The level of detail, and accuracy, of the final stope shape captured by Hovermap far exceeds that of traditional CMS. Color scale is a height ramp to provide contrast.

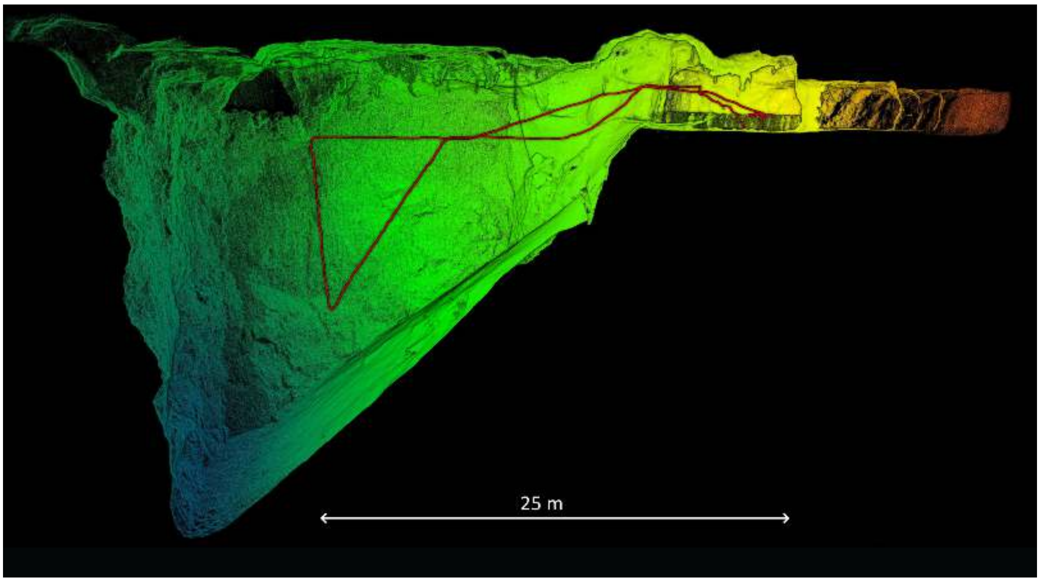
ACCURATE BACKFILL MONITORING

Mining operations backfill stopes to meet a variety of requirements; however, in high stress mining environments, where a high extraction ratio is planned, backfilling controls the possible unravelling/dilution, and provides global stability, similar to a pillar controlling hanging wall and footwall closure.

Monitoring of backfill material used for engineering purposes, therefore, requires a high degree of detail to confirm the correct placement of the material within the stope. This helps to ensure the design has been correctly followed and facilitates calculation of the correct batch volume. An example of a stope scanned by Hovermap in the process of backfilling is shown below.

Following stope backfill, whether it is unconsolidated rockfill to reduce the haulage of waste material or pastefill, understanding the remaining volume assists production scheduling on how best to direct the materials and calculate the remaining volume to fill.

With Hovermap's rapid acquisition of data, engineers have access to accurate information on backfill placement, heights and remaining stope volumes.

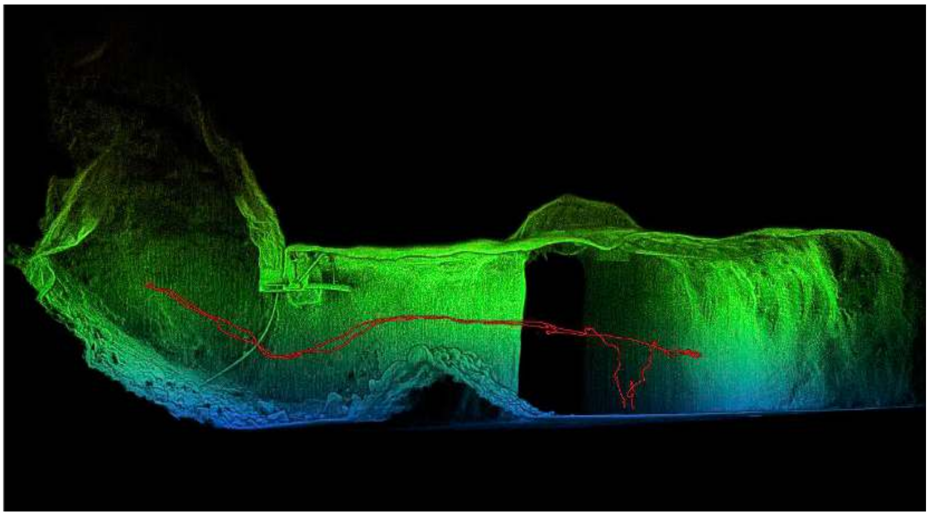


Profile image of Hovermap dataset showing backfill height.

HANG-UP INSPECTIONS

Drawpoint hang-ups in both stoping mines and caving mines pose a serious safety hazard to the personnel attempting to clear them, and cause unplanned delays to production.

Common clearing methods include blasting and hosing with water to dislodge the material blocking the drawpoint. Capturing data with Hovermap, however, gives miners a clear view of the blockage and facilitates a targeted management approach



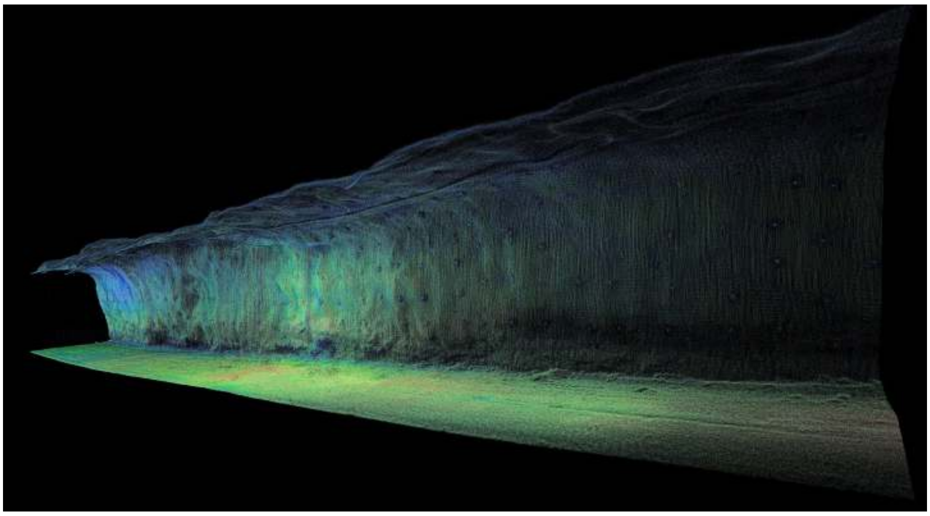
In this example of a block cave hang-up, the drone pilot flew Hovermap from the extraction drift, away from the drawpoint, minimizing the safety risk from potential movement. The flight went to just past the brow beam, and within minutes of the drone landing, miners had a clear view of the blockage and were able to formulate a safe, rapid approach to remove the material.

An example of a scan showing a drawpoint hang-up with the red line indicating the drone's flight path.

GROUND SUPPORT ANALYSIS AND DEFORMATION MONITORING

Much of the risk exposure for personnel is throughout development drives and, as such, miners place a high priority on ground support installation and monitoring damage, stability, and convergence. Data captured with Hovermap, whether by flying, driving or handheld, enables engineers to recognize convergence trends and detect areas of change exceeding 10mm.

Change detection using Hovermap data provides greater insights than traditional broad scale observational mapping through capturing the 'whole scene' including rock bolts, mesh support, ventilation and other services along the drive.



Closure rate trends can be identified from periodic scans, which in-turn provide guidance for residual capacity and the scheduling for rehabilitation. The measured displacements provide quantitative data that informs administrative controls, such as Trigger, Action, Response plans (TARPs), while visualizing the point cloud by its intensity attribute (strength of the LiDAR return) can assist in identifying features and improve methods of QA/QC and management.

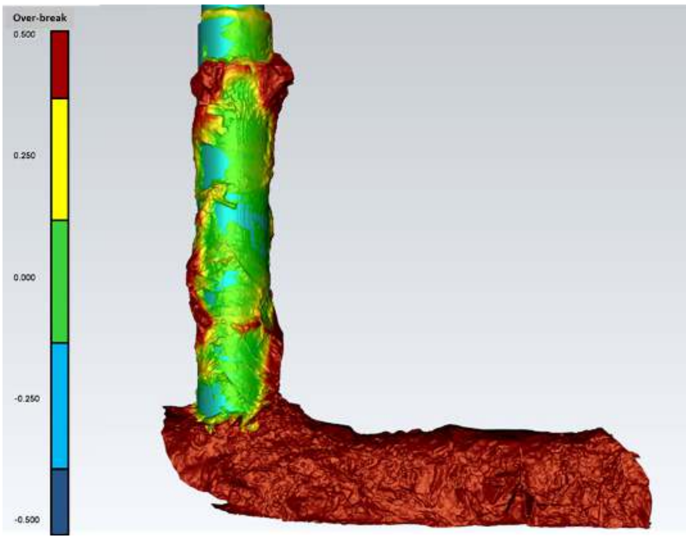
Example cross section view of a drive colored by point intensity facilitating the identification and location of features within the scene including rock bolts, mesh support and services.

VERTICAL INFRASTRUCTURE SCANNING

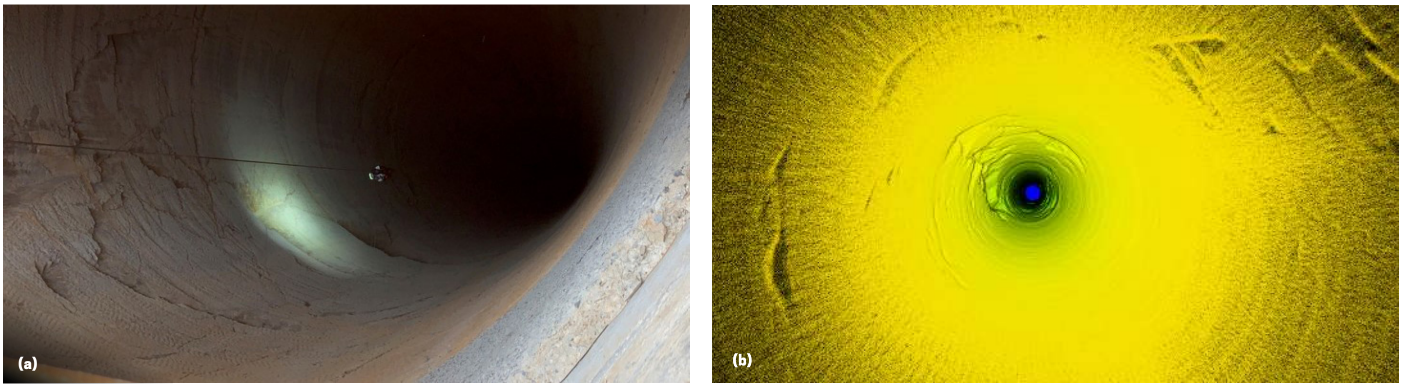
Vertical infrastructure (i.e. vent raises, orepasses, finger passes and shafts) have, traditionally, been difficult and costly to survey and monitor. The exposure to falling objects excludes inspection techniques that risk the safety of personnel, and alternatives, such as borehole CMS, are often costly, hazardous, time-consuming and can put these areas out of production for extended periods.

Nevertheless, inspections remain a high priority as many vertical excavations are unsupported and susceptible to self-mining, either as a response to a change in stress conditions, a loss of confinement or from the wear by material continuously dropping through (e.g. orepasses).

Hovermap provides a low-cost, rapid data acquisition method for monitoring and management of these excavations. Where there is sufficient width, Hovermap can fly to capture data. Other options are to attach the Hovermap unit to a tether, lowered in a cage and/or mounted to a motorized buggy (which is attached to a tether), with the cage or buggy being well suited for orepass inspections. The resulting data can be used for the detection of discontinuities, over-break, blockages or wear within orepasses and raises.



Example of overbreak analysis from a Hovermap shaft scan. The data illustrating both the location and severity of observed issues.



a) Lowering Hovermap down a raisebore shaft, 5m diameter, 500m depth, by cable and the (b) resulting point cloud obtained.

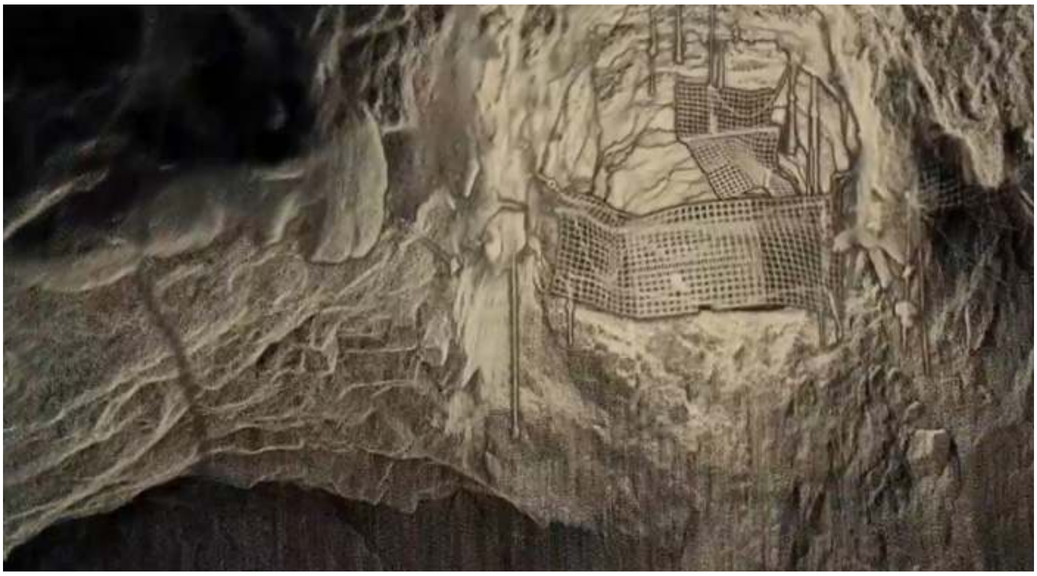
3D DIGITAL TWINS OF INFRASTRUCTURE

Producing digital twins has relied on the use of traditional terrestrial LiDAR scanners to map under- and above-ground infrastructure. Typically, this method produces high quality data, however, this approach can be very time-consuming, and is unable to access hazardous areas. This can result in data that is compromised with shadows (areas that are not visible to the scanner) and/or is variable in point density, which can affect the integrity and precision of the resulting products.

Using a mobile LiDAR scanner, such as Hovermap, enables rapid data acquisition along with a more complete (fewer shadows) point cloud that is both accurate and of more uniform density. Regardless of whether the data capture is by drone, handheld, vehicle, or tether, Hovermap point clouds can be registered to the mine coordinate system using standard survey control points and automatically merged at areas of overlap to form complete digital twins of the mapped infrastructure.

Example inspection and as-built capture of a 'buffer' facility at a mine in South Africa.

OLD WORKINGS



Old workings, untouched for years, are high risk environments for personnel and equipment. Using Hovermap's autonomous flight capability, mine surveyors are able to assess and digitize entire networks of historical workings, while personnel remain safe in controlled areas.

Scan of old workings from an underground mine in Canada. Image credit: Unmanned Aerial Services.

MAPPING APPLICATIONS IN UNDERGROUND MINES

Globally, mines continue to seek new approaches to improve workplace safety. Elimination, substitution and separation from hazardous environments are the primary safety controls, and all three can be achieved by implementing autonomous solutions, such as Hovermap, across a wide range of applications.

Stope analysis and reconciliation	Development	Infrastructure inspection
Volumes and dimensions	Heading pickups and dimensions	Vent raises
Over/under break	Over/under break	Ore passes
Structure detection	Cut volumes	Old workings
In situ stock volumes	Convergence monitoring	Digital twins
In situ fragmentation PSD	Structure detection	
Backfill heights	Ground support QA/QC	
Backfill volumes	Stockpile volumes	
Change detection or self-mining	Shotcrete thickness	
Brow break-back	Heading re-entry	
Bund heights/locations	Access past falls-of-ground	
Drawpoint hang-ups	Drive progression	
Tipple and drawpoint inspection		

MAPPING THE INACCESSIBLE

Data collection using a versatile LiDAR mapping solution, such as Hovermap, improves safety, efficiency and productivity in underground mines.

This article highlights only a few of the applications where mining and geotechnical engineers, surveyors and geologists can improve operational insights when they have access to accurate, high quality data. Compared with existing CMS and terrestrial laser scanners, Hovermap captures data in minutes (rather than hours) with added value though its diversity of deployment whilst minimizing the exposure of personnel to hazardous areas.

For more information: contact Emesent at **info@emesent.io** emesent

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