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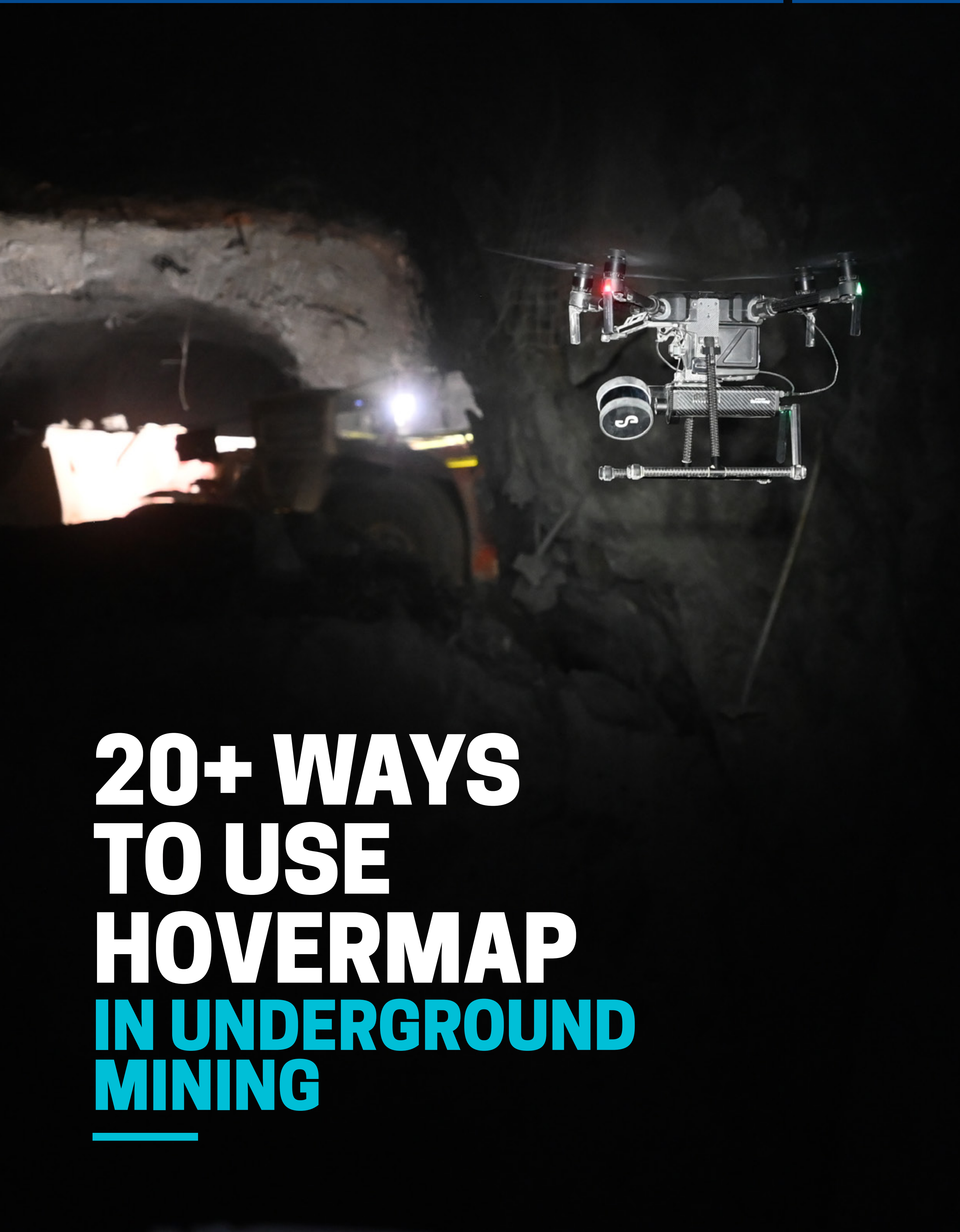
USE CASE



20+ WAYS TO USE HOVERMAP IN UNDERGROUND MINING

20+ WAYS TO USE HOVERMAP IN UNDERGROUND MINING

Hovermap is a SLAM-based LiDAR mapping system. It enables data capture of critical underground mine excavations and captures new insights to optimize mine development and operations.

When mounted to a drone, Hovermap enables autonomous flight (AL2) beyond line-of-sight and communication range, in hazardous, GPS-denied environments. Operators can capture high quality data from inaccessible underground voids and use it to inform their decision-making, while personnel remain safe under controlled ground.

With AL2, Hovermap pilots can fly an entire mission, from take-off to landing, using a tablet. Data is processed on-board, providing the operator with a 3D map of the environment in real time. Waypoints are set with a simple tap on the map and Hovermap takes care of the rest, safely navigating the drone to achieve the mission.

INFORMED DECISION-MAKING

Accurate data collected from previously inaccessible areas, such as stopes, ore passes and vent raises, allows mine managers to make data driven decisions that optimize planning and production across the lifecycle of a mine.

IMPROVED SAFETY

Personnel are not exposed to hazards during data capture and inspections.

CERTAINTY AND SAVINGS

Personnel can scan drifts, stopes and raises in minutes and obtain the information they need to move forward, thereby reducing impact on production.

SAVINGS ON EQUIPMENT AND CONSULTANCY SERVICES

Hovermap's versatility and user friendly design make it suitable for multiple applications within the mine, and easy for personnel to use.

Discover 20+ of Hovermap's many data capture applications in underground mining.

For information on Hovermap's use cases for mining go to www.emesent.io

USE CASES

Workplace safety is a priority for all underground mines. The implementation of autonomous systems helps eliminate, substitute or separate personnel from hazardous environments. Autonomous data capture delivers accurate and timely information. Rapid access to data-rich information results in better decisions and, ultimately, a more efficient mine.

This paper outlines the multiple ways in which Hovermap's autonomous mobile scanning technology can be used in underground mines.

Development

Stable excavations are an integral component of a safe and productive workplace. To achieve and maintain them, much effort and expense must be devoted to monitoring and assessing development. Hovermap LiDAR scanning, coupled with beyond line-of-sight flight, provides a fast, safe data capture method which delivers high quality data to better inform development decision-making.

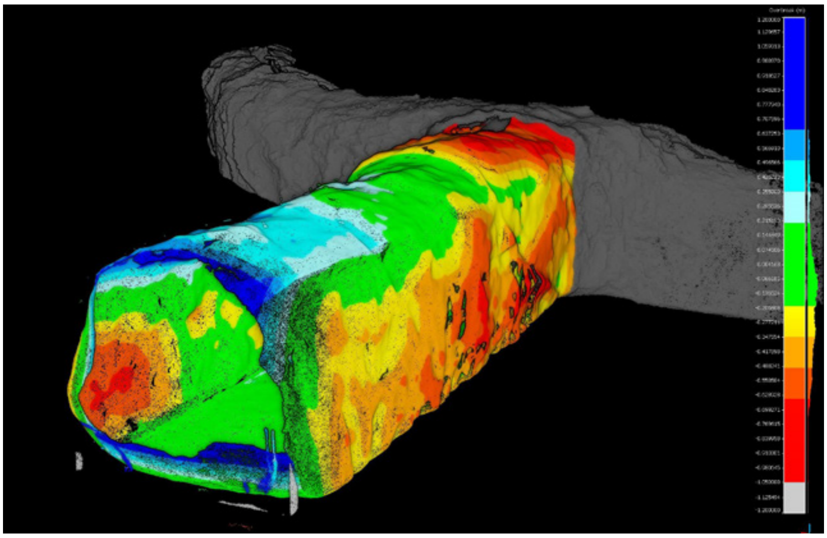
"Hovermap has been an unprecedented success in our eyes. This game-changing piece of technology allows us to make much more informed decisions about our underground voids. The teams on site have been totally blown away by the level of detail they now have access to, and consider it an essential piece of equipment."

Matt Jones
Senior Surveyor, Evolution Mining, Mungari Operations

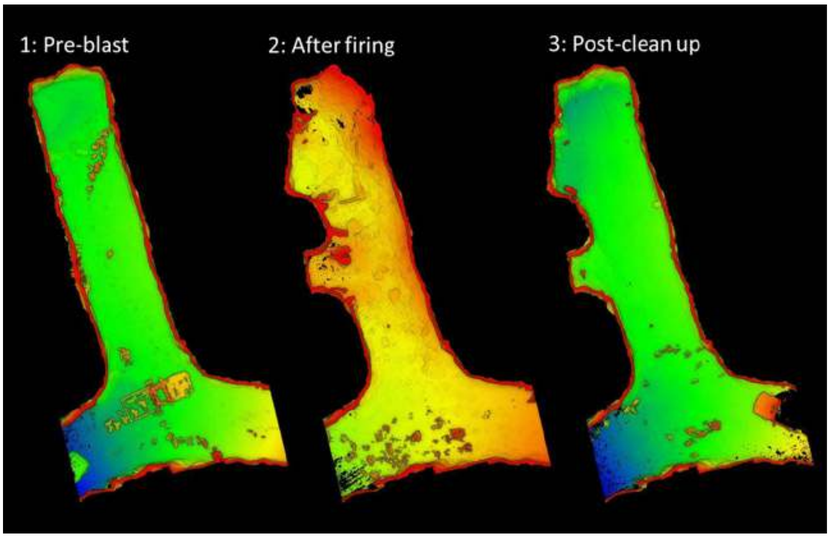
1 DEVELOPMENT OVER-BREAK

Hovermap's drone or vehicle-based mobile LiDAR scans enable data to be collected rapidly in development areas, without interrupting other activity or risking the safety of personnel.

Comparing the as-built to the as-design provides a detailed over-under-break analysis and identifies areas within and outside tolerances.



This image shows the results from calculating the difference between the as-design and the as-built using Hovermap data. Warm colors represent over-break; cool colors represent underbreak.



Hovermap was used to scan this development drive before and after the firing of two wall strippings. The second scan captured the distribution of material and the post-clean up scan captured the drive shape, prior to support.

2 DEVELOPMENT PICKUPS AND CUT VOLUMES

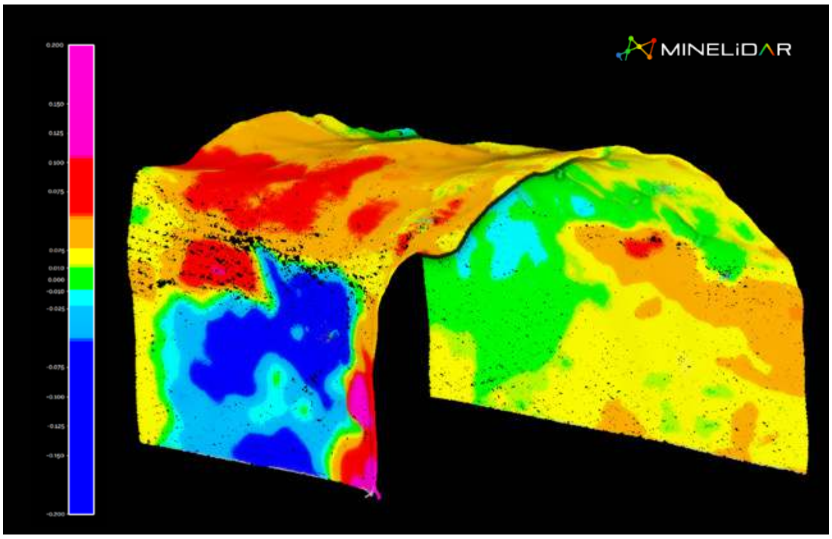
A heading can be scanned within minutes, using Hovermap. Operators are able to capture data shortly after firing, before other development activities commence. Detailed point cloud data provides development shapes that enable development pickups. Hovermap data can also be used for more detailed analytics, such as calculating moved material volumes, bulking factors and reconciliation.

Comparing pre- and post-blast scans can determine the in situ rock volume, the post-blast bulked volume and the bulking factor.

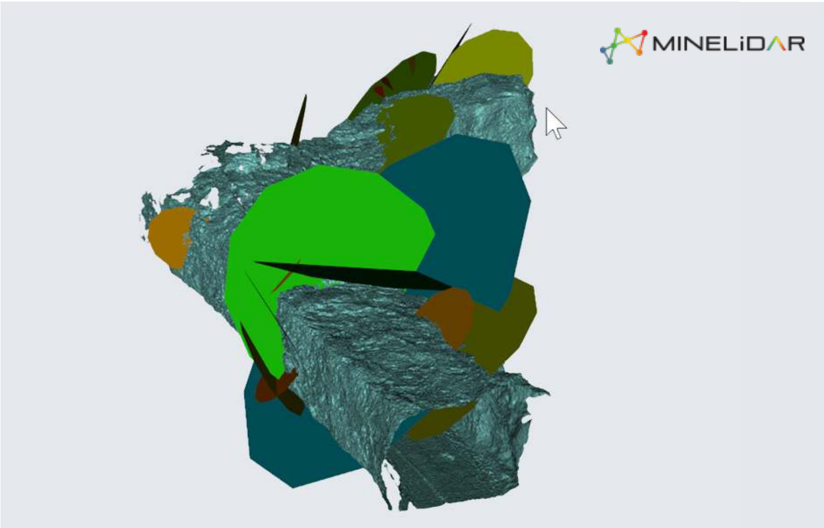
3 CONVERGENCE MONITORING

To maintain a safe working environment in any underground operation, accurate monitoring of ground support is essential. Hovermap scans, captured by walking, vehicle or flight, provide insights that are superior to those obtained from broad scale observational mapping or traditional extensometer readings.

Hovermap accuracy is sufficient to identify changes exceeding 5 mm. Rapid scanning methods enable data collection to occur at regular intervals. This leads to improved recognition of convergence trends and closure rates. As a result, residual capacity can be estimated more accurately and rehabilitation schedules optimized accordingly.



Production drifts greater than 200 m in length were scanned in a few minutes, using Hovermap attached to a vehicle. Multiple scans, captured at regular intervals, were merged to identify areas of closure (warm colors), and expansion (cold colors).



High-resolution LiDAR point clouds captured by Hovermap enable structural features in the development heading to be picked. Further analysis and plotting can help identify lode-wide discontinuities.

4 STRUCTURE DETECTION

Hovermap's high resolution point clouds are compatible with automated structural recognition programs, such as Maptek PointStudio, Sirovision and CloudCompare, the popular open source point cloud analytics software.

In this example, the identified structures have sufficient scale to control the drive profile.

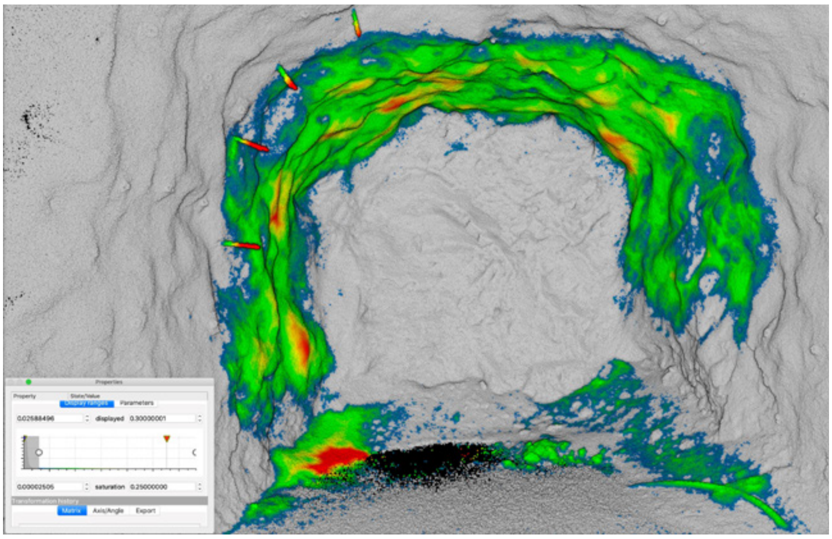
More comprehensive characterization of the rock mass would include window mapping to identify other potential contributing factors.

5 SHOTCRETE THICKNESS

Hovermap can be used to record the void, structures and ground support, prior to shotcrete application. This data can provide a baseline for future analysis and audits.

Conducting a second scan of the surface after shotcrete has been applied allows engineers to determine whether the application is within specification and matches the invoiced volume. This second scan can also be used as a baseline for detecting damage or movement in the shotcrete after development activities commence.

By contrast, traditional methods, which rely on drilling and measuring widely-spaced depth holes, are time-consuming and inaccurate.

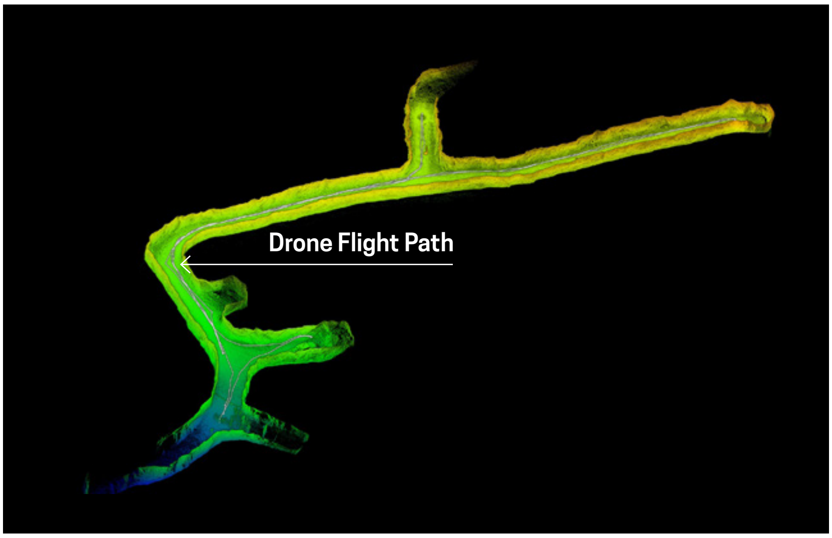


Pre and post-shotcrete Hovermap scans record conditions, while a comparison heat map visually highlights whether the application is within specification. In this thickness heatmap, warm colors represent areas of overspray and cold represent underspray.

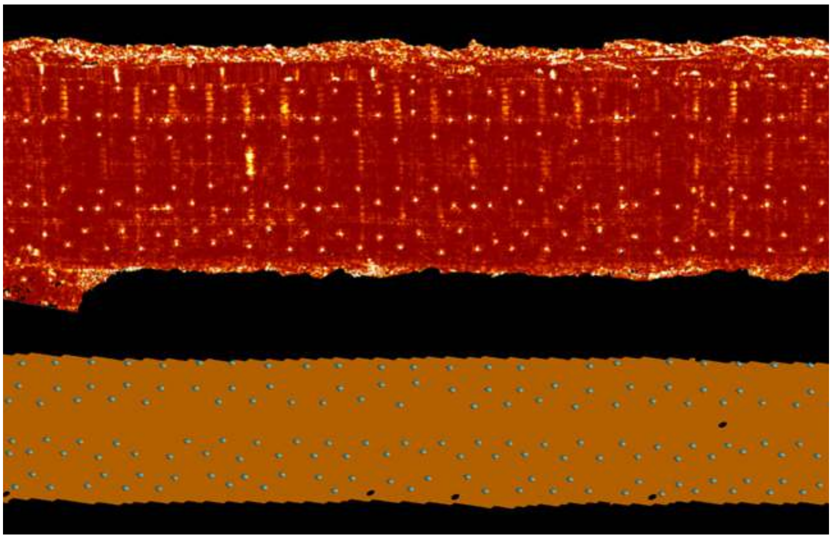
6 HEADING RE-ENTRY

Hovermap's autonomous, beyond line-of-sight flight allows it to safely enter and scan areas of high geotechnical risk, such as failed headings.

Personnel can use the captured data to assess the conditions and develop job hazard analyses and safe re-entry plans.



Hovermap is able to fly into and scan high risk areas, such as failed headings. The resultant data provides the basis for detailed condition and structural assessments, and re-entry plans.



(top) Hovermap point cloud of a drift roof identifies rock bolt locations, (bottom) additional processing produces a graphical representation of bolt locations.

7 GROUND SUPPORT INTELLIGENCE

Ground support is necessary to prevent rock falls and enable mines to operate safely. Using Hovermap, personnel can collect data that allows them to visualize and report on rock bolt installations, quickly and safely.

Scans provide a permanent record of the location, type and spacing of installed ground support. They can provide insight into whether the ground support is acting as a system, or as individual elements, and can be used to inform the response to geotechnical incidents on site.

8 ACCESS FALLS-OF-GROUND

After a significant geotechnical event, assessing the area and developing a rehabilitation plan to make it safe to re-enter is a priority for mine owners.

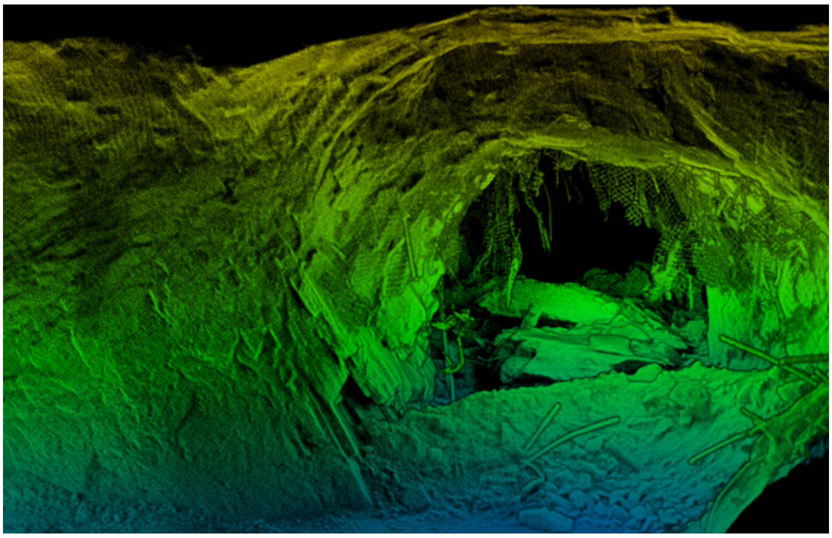
Hovermap can be deployed to scan the area, without putting personnel at risk. Captured data can be used to produce visualizations, calculate the volume and surface area of the collapse, and determine whether adequate pillars remain. It can also form a baseline for deformation analysis, predicting future falls-of-ground and convergence activity.

Hovermap is ideally suited to the exploration and mapping of areas affected by a fall-of-ground. In 2019, when LKAB's Kiruna Mine experienced a seismic event, Emesent partner AMKVO mapped kilometers of damaged drifts in just a few days.

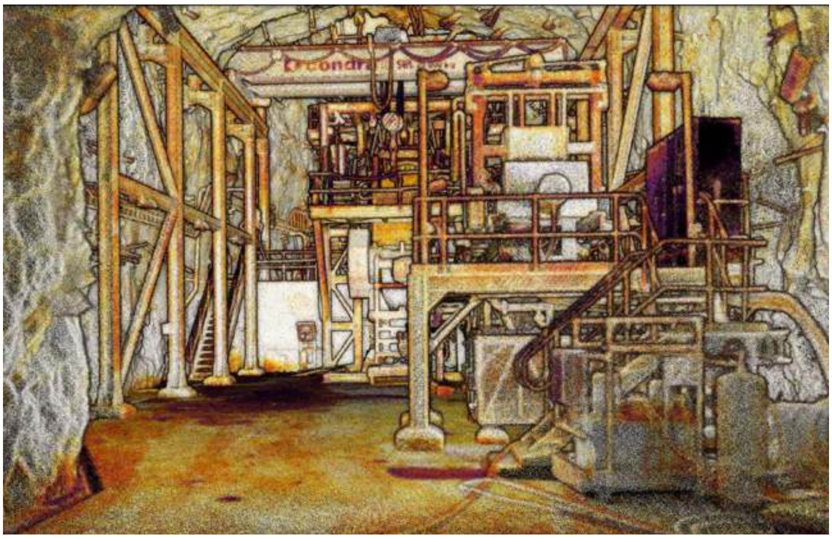
9 EXPLORATION OF OLD WORKINGS

Abandoned mines are now being reassessed for recommencement, due to price increases in some commodities. Typically, these old mines have substandard ground support, which has further deteriorated over time.

Sending in Hovermap to capture data reduces the unknowns, by allowing engineers to complete a comprehensive risk assessment safely. They can assess the rock mass and structural conditions to identify and mitigate hazards, before personnel enter the area.



Hovermap's exploration of abandoned workings captures data for engineers to assess the risks and plan for re-entry.



This underground crushing plant scan was captured in a single Hovermap flight.

10 INFRASTRUCTURE AS-BUILTS

Hovermap can capture built environment in a flight or walking scan. Accurate and detailed as-built point clouds can be transformed into CAD plans of complex 3D structures quickly and easily.

Comparing consecutive scans allows engineers to detect whether changes have occurred between scans.

"The ease of use and operation means a wide variety of people can utilize the system, from a basic operator needing to look at a new decline face that has recently been shot, to a geologist mapping a new stope. It's really going to help get that improved information to make better decisions, faster."

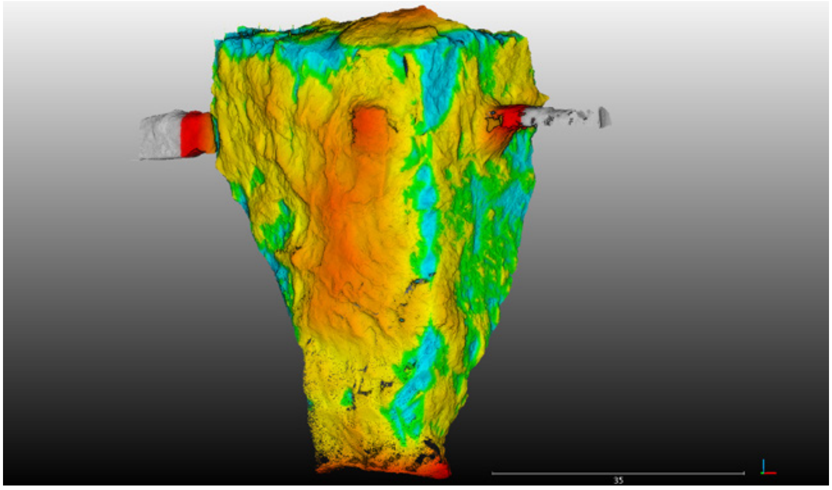
Andrew Rouse
CEO, Digital Terrain

Stope Analysis and Reconciliation

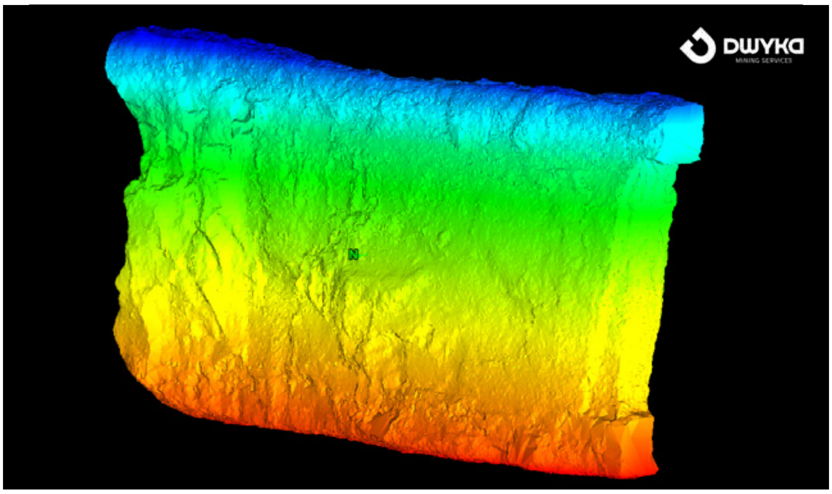
Hovermap's drone-based high quality LiDAR scanning of stopes and beyond line-of-sight flight capability provide geotechnical, geology, drill and blast and survey teams with unprecedented insight into stope conditions.

11 STOPE SHAPE

Hovermap can deliver high resolution stope shape point clouds with uniform point density and minimal shadowing. Accurate stope data can improve mine efficiency by allowing drill and blast engineers to see how their initial drill pattern has performed. Subsequent patterns can be refined, to maximize ore body extraction, and improve material flow.



Hovermap mesh data of a stope final shape compared to design. Analysis of this data can identify structural features, and over and under-break. Hot colors show where the stope is larger than design dimensions and cold colors show where it is smaller. (Source: BHP, Evan Jones, Emesent webinar.)



A single Hovermap flight delivered comprehensive coverage of this 30 m stope. Point clouds with uniform point density and minimal shadowing produce an accurate mesh and allow greater confidence in the final stope volume and shape.

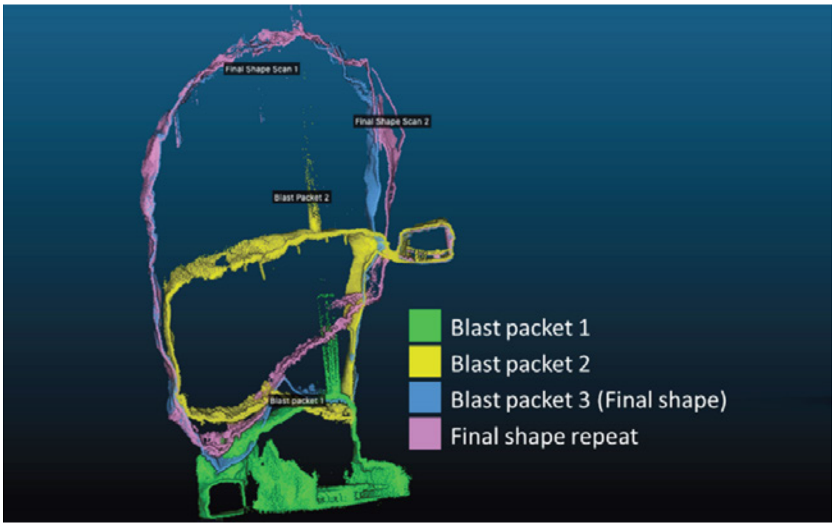
12 STOPE VOLUME

Hovermap's high quality point cloud data can enable geologists to analyze the final stope more accurately. Data can be used to reconcile production tonnes, quantify over and under-break and inform depletion modelling. Having access to accurate data makes it possible to quantify the expected grade of the stope with greater confidence and ensure material has gone to the correct ROM stockpile. In collaboration with the mill metallurgy, geologists can ensure target grades are blended and variability in EOM reconciliation is reduced.

13 BLAST PERFORMANCE

Using Hovermap to scan a stope at regular intervals during the extraction process can help to build a richer understanding of blast performance. Comparing scans over time makes it possible to identify emerging issues, such as fragmentation and over-break, that may affect the mucking rate or impact adjacent stopes.

Having access to this library of data allows engineers to compare extraction progress with the schedule and adjust downstream activities accordingly, thereby averting the complications and cost of equipment stand down.



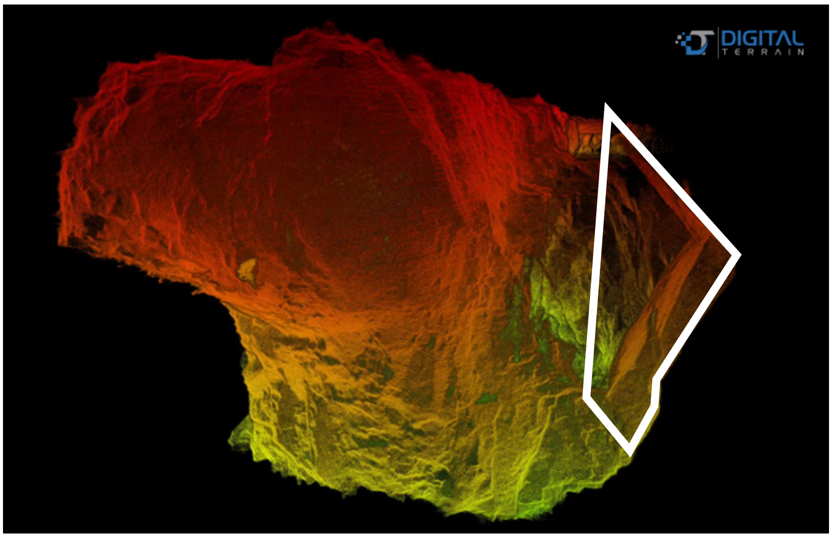
Multiple Hovermap scans were used to record blast progress in a stope at BHP's Olympic Dam mine[1]. Scans were geo-referenced and merged to produce the accurate model of the blast performance and stope shape shown here.

[1] Baylis, C., Kewe, D. & Jones, E. (2020). Mobile drone LiDAR structural data collection and analysis. In J Wesseloo (ed.) Proceedings of the Second International Conference on Underground Mining Technology, pp. 325-334. Australian Centre for Geomechanics.

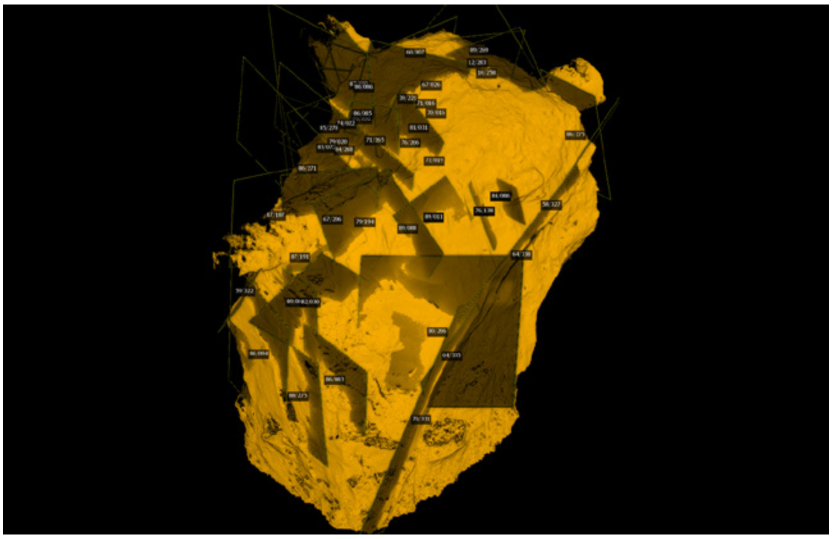
14 OVER AND UNDER-BREAK

The value extracted from a stope is one of the key metrics for an underground operation. Using Hovermap to scan stopes regularly can help to maximize this value.

Because of the precision and density of Hovermap point clouds, geotechnical engineers can conduct detailed back analysis on failures, identify the geotechnical mechanisms responsible for over and under-break with a high degree of confidence, and adjust their method to minimize the likelihood of re-occurrence.



Using legacy CMS technology, geotechs had no visibility of the over-break in this stope. In a three minute flight, Hovermap captured data that revealed the current shape of the stope, the over-break (block on the right) and the discontinuities.



BHP's Olympic Dam mine stope analysis process involves picking geological structures from Hovermap scans. High-resolution final stope scans are imported into the mine's co-ordinate system before the geotechnical team picks the structures that control the final stope shape. (Source: BHP, Evan Jones, Emesent webinar.)

15 STRUCTURE DETECTION

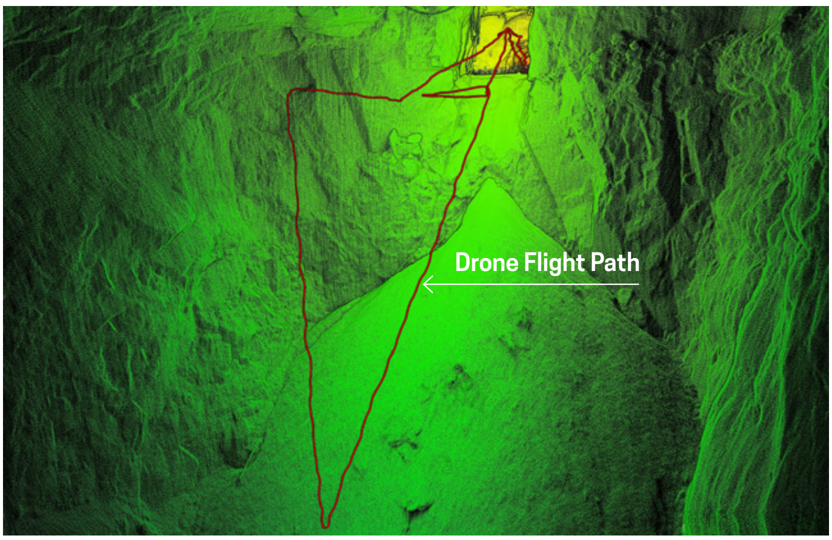
Hovermap's accurate, high-resolution point cloud data can allow geotechnical engineers to identify structural traces and planes with greater confidence. Structural characteristics, such as dip and azimuth, persistence, roughness, and spacing of features can be extracted and used for rock mass characterization and design purposes.

Stoping relies on the stability of large un-supported walls so identifying structural features that may affect current and future stoping performance can improve stope economics.

Traditional scanning methods have not allowed this level of detailed analysis.

16 BACKFILL HEIGHT / VOLUME

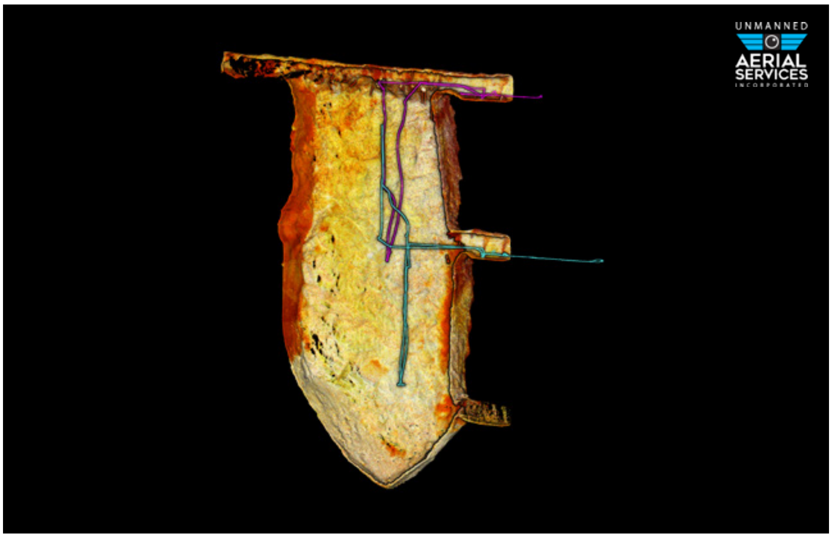
Hovermap scans can be used to monitor backfill heights and ensure backfill types are installed correctly. Rather than relying on bucket counts, schedulers are able to obtain an accurate measure of remaining stope volumes and can direct material accordingly.



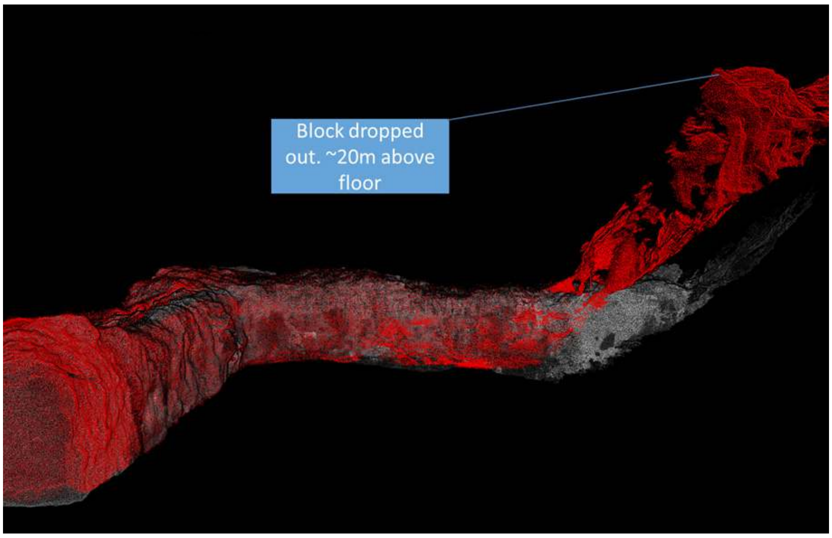
Using Hovermap to scan a stope during backfill can provide accurate fill volumes and a quantifiable measurement of cement and backfill type usage.

17 STOPE DIMENSIONS

Hovermap scans can enable surveyors to maintain highly accurate void models. This is a statutory requirement for underground mines in many jurisdictions. Traditional CMS void modelling methods typically result in gaps in the data and this may expose surveyors to legal risk, in the event of an incident. Moreover, having accurate, high resolution spatial models of stopes limits the need for other technical teams to conduct their own inspections.



Hovermap can scan a stope from the crown, mid-level or drawpoint entrance, capturing shadowless point clouds of uniform point density. These quality data sets provide greater confidence in the final stope mesh and dimensions.



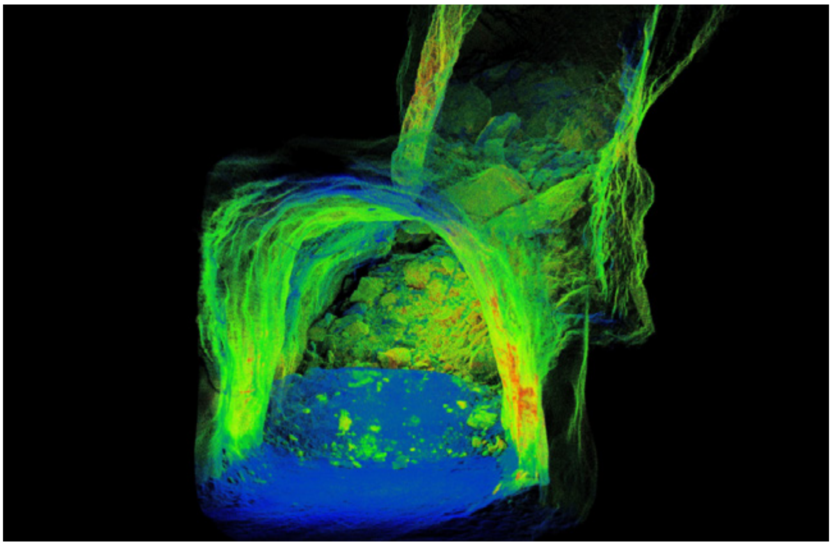
Two Hovermap scans of a drawpoint at the BHP Olympic Dam mine, taken a week apart and merged, record brow movement as a result of bogging. The original scan is gray, while the later red scan shows a very large block has dropped from the back. (Source: BHP, Evan Jones, Emesent webinar.)

18 BROW DEFORMATION

In the event of brow failure, Hovermap scans can be used to create a comprehensive picture of the affected area and extract detailed measurements of the damage. Engineers can use this intelligence to determine whether the area should be rehabilitated or abandoned. Traditional CMS methods cannot provide this level of clarity and obtaining the scans can put operators and equipment at risk.

19 DRAWPOINT INSPECTION

Hovermap scans can provide engineers with superior insight into oversize material and hang-ups at drawpoints, in stoping and caving mines. These phenomena pose a safety hazard to personnel and to the equipment used to clear them. Flown or attached to a loader, Hovermap's LiDAR range and wide field of view capture can enable it to deliver scans which provide a better perspective of the blockage than those obtained via traditional CMS methods.



This stope drawpoint was scanned from the adjacent extraction drive, with the Hovermap pilot safely removed from any potential rockfall. A short flight to the bund captured enough detail to reveal the oversize material causing the hang-up.

Vertical Infrastructure

Orepasses and vent raises are essential but expensive infrastructure in underground mines. To maintain safe and efficient operations, mining and geotechnical engineers need to understand the effect of mining-induced and tectonic stresses on orepasses and vent raises. The traditional data collection process, involving C-ALS scanners and the drilling of inspection holes, produces incomplete, low resolution scans of raises. It is time-consuming and expensive and very often not undertaken until significant failure has occurred.

By contrast, LiDAR scanning using Hovermap is cost effective, typically accounting for less than 1% of the raise bore/orepass excavation cost[2]. It is also extremely efficient. For example, a 100 m (110 yd) raise can be scanned by Hovermap in around 20 minutes.

Hovermap is most commonly lowered on a tether to capture complete, high resolution scans of raises in excess of 1,000 m. Personnel are able to remain removed from hazards around vertical shafts.

20 VENT RAISE INSPECTION

Ventilation is a critical component of any underground mine. Hovermap can scan vents easily and economically: by flight when the diameter of the vent is greater than four meters, and mounted in a protective cage and lowered on a tether when it is less than four meters.

Using Hovermap, engineers can quickly create as-builts of ventilation systems, for comparison with the original construction specifications. Stress induced damage can be easily identified and this intelligence can enhance geologists' understanding of the deformation.

Stress-induced damage can be easily identified in Hovermap data. Buckling and stress-induced spalling perpendicular to the principal stress direction can be observed in this vent raise.

Hovermap can scan orepasses that are hundreds of meters in length and produce accurate point clouds that allow engineers to visualize their condition. After noting the fall-out (dog-earing) and water inflow in this orepass at a Petra Diamonds mine in South Africa, engineers opted to abandon it, rather than incur significant remediation expenses.

21 OREPASS INSPECTION

Maintaining the structural integrity of orepasses helps mine operators meet production targets. Regular inspections enable engineers to detect changes, deformation and blockages promptly, and to ensure no undercut is present at the tip head location. Lowered in a cage, Hovermap can scan orepasses hundreds of meters in length, quickly and easily, and produce accurate condition data that can be used to inform remediation decisions.

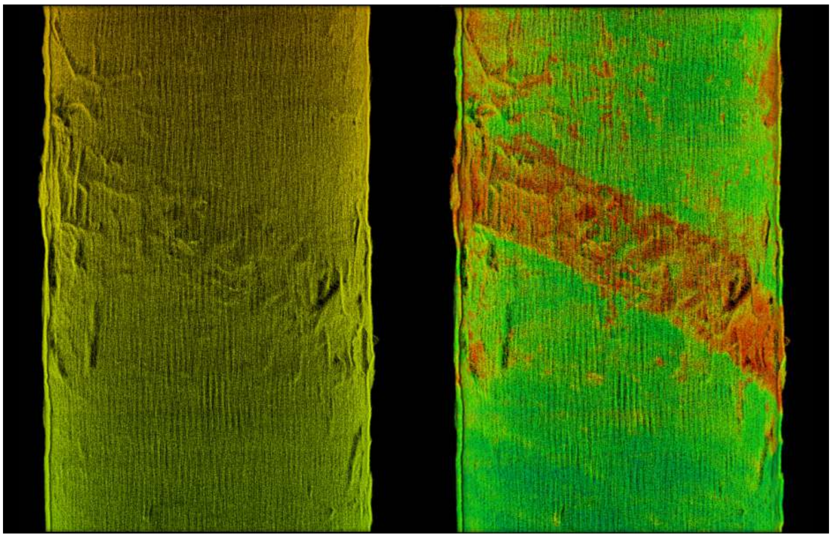
[2] Peter Evans, MINELiDAR.

22 GEOLOGICAL FEATURE IDENTIFICATION

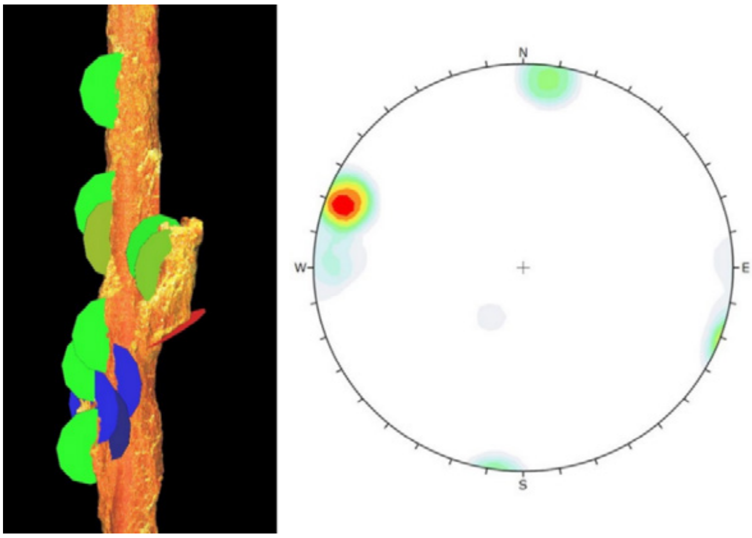
In underground mines, geological features, such as fractures, faults, lithology changes, mining stress and tectonic stress, can contribute to changes in rock mass behavior. Monitoring deformation and failure in raises, and determining whether remediation is required or cost effective, is a perennial challenge.

Analyzing Hovermap LiDAR data can assist geologists to infer a wide range of geological features and improve their characterization of the rock mass.

This enhanced intelligence can be used to inform management responses.



Hovermap's LiDAR attribute intensity can help to identify geological features that could represent a change of lithological unit, such as intrusive sills. In this scan, red indicates a lower intensity return. The increased rock damage in the area may necessitate further geotechnical investigation, to determine the cause of the feature, whether it requires remediation, and how future raises will perform when intersecting it.



Analysis of a data set, captured with Hovermap lowered in a protective cage and visualized above as planes and in a stereonet, shows the structures responsible for generating fallout in an orepass.

23 STRUCTURAL ANALYSIS OF RAISES

Local, mine or regional-wide structures can have a significant impact on raise performance. Lowered in a protective cage, Hovermap can be used to capture high resolution, multi-attribute data, to inform structural analyses of vertical raises and other underground voids. Identifying the structures, using Maptek PointStudio, Sirovision or CloudCompare, that have caused an existing failure can help geotechs assess the potential for more significant failure, and inform back analysis to improve future designs.

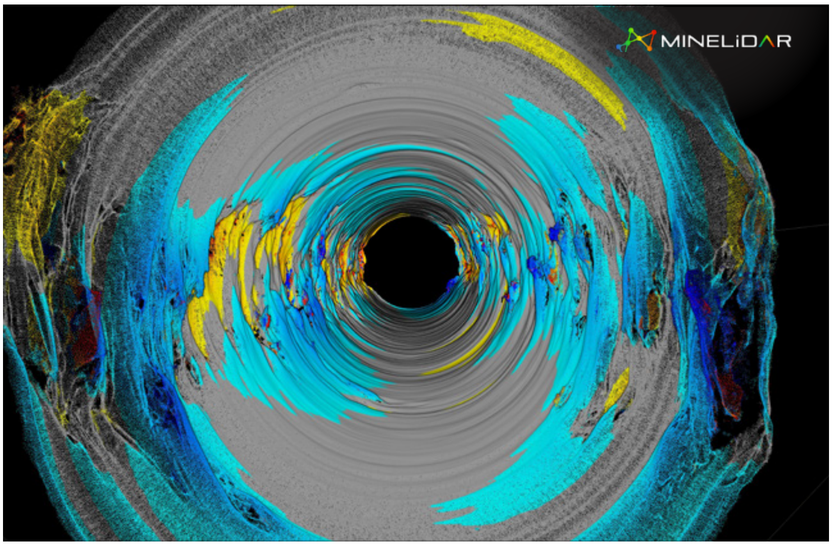
> "We lowered Hovermap down ore passes, flew the drone into drawpoints and even scanned our shaft and ramps by fixing the scanner to one of our vehicles. The visualization delivered exceeded all our expectations. The data captured in one ore pass saved us significant time and effort by confirming it was irreparable. That saved us millions."

Alex Holder
Group Strategic Business & Innovation Manager, Petra Diamonds Ltd

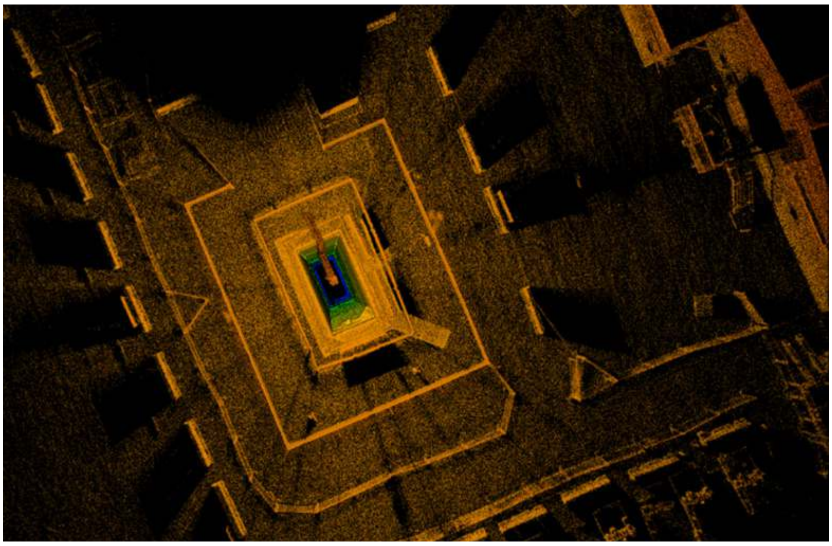
24 RAISEBORE INSPECTION

A raise must be inspected once reaming has occurred, to prepare for shotcrete lining, create a baseline for further inspections and to ensure it has been constructed to specification. Lowered in a protective cage, Hovermap can be used to capture data to produce as-builts and condition reports quickly and economically.

By contrast, inspecting a raisebore using traditional CMS scanning methods is difficult and expensive.



Created using Hovermap data, this plot of a raise design vs actual shows stress damage is already present in the shaft. The stress-induced distortion has caused a reduction in raise diameter adjacent to areas of fall out. Hot colors show where the excavation is 50 mm (2 in) larger than design dimensions and cold colors show where it is 50 mm smaller.



Attached to the end of a crane winch and lowered down 40 m, Hovermap was used to scan this retired shaft at BHP's Olympic Dam mine. Data was then compared to a scan completed two years earlier. (Source: BHP, Evan Jones, webinar)

25 DECOMMISSIONED INFRASTRUCTURE INSPECTION

Old vertical infrastructure frequently lacks technical drawings or as-builts. Lowered in a protective cage, Hovermap can be used to conduct condition inspections safely. The data captured can be used by engineers to identify hazards and inform remedial planning.

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HOVERMAP

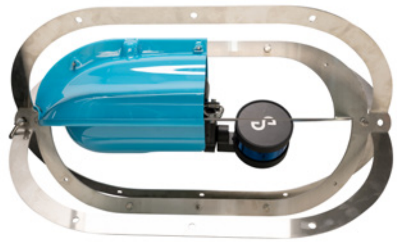
Hovermap, a versatile LiDAR scanning solution, makes mapping of inaccessible areas safe, easy and fast.

Designed as a drone payload, Hovermap combines advanced collision avoidance and autonomous flight technologies to safely and quickly map hazardous, inaccessible, GPS-denied environments.

Easily mounted on drone, vehicle, winch or a backpack, Hovermap capture is adaptable for any development, production or infrastructure environment.

» Versatile: fly, drive, walk, winch—multi-application mapping
» GPS-denied flight—unaffected by GPS loss
» SLAM based mapping—precision mobile LiDAR scans without GPS
» Collision avoidance—detects and avoids obstacles as small as 1 mm wires
» Tap-to-Fly autonomy—autonomous flight beyond line-of-sight and communication range
» 360° field of view—shadowless, uniform-density point cloud data

Designed to operate in hazardous, underground environments.



The Hovermap cage easily attaches to a winch, providing a complete shaft scanning solution. The stainless steel frame is specially designed to slide smoothly, avoid snags and deliver uncompromised scan quality in vertical shafts and raises.

MAPPING SPECIFICATIONS

SLAM mapping	Simultaneous Localization and Mapping (SLAM) based LiDAR mapping +/- 0.03% drift
LiDAR range	0.40 to 100 m
LiDAR accuracy	+/- 30 mm
Mapping accuracy	+/- 20 mm in general environments +/- 15 mm in typical underground and indoor environments +/- 5 mm for close range scanning
Angular field of view	360° x 360°
LiDAR data acquisition	Up to 300,000 points/sec
Maximum data capture travelling speed	Vehicle: 40 km/h; flight: 5 m/s above ground, 2 m/s underground or confined spaces
Start / stop scanning while in motion	Yes
Outputs	Full resolution point clouds, decimated point clouds, trajectory
Point cloud file format	.las, .laz, .ply, .dxf
Point cloud attributes	Intensity, range, time, return number and ring number
Processing parameters	Pre-set profiles with 20+ adjustable parameters
File size	300 MB/min
USB3	High speed data offload
Storage	480 Gigabytes – approximately 12 hours of sensor data
Operating temperature	0-50°C (32 - 122°F)

PHYSICAL SPECIFICATIONS

Weight	1.8 kg (4 lb.)
Input voltage	12 - 50V, powered from a battery or auxiliary power input
Deployment	Drone/UAV, robot, vehicle, backpack, tether, bike
Supported Drones	M210; M300
Quick release mount	Yes

AUTONOMY SPECIFICATIONS

Flight modes	Autonomy Level 1: Non-GPS flight, position hold and assisted flight Autonomy Level 2: Non-GPS waypoint flight
AL2 waypoint types	2D, 3D, planar, height
AL2 navigation modes	Guided exploration, local and global path planning
Autopilot compatibility	DJI A3
Omnidirectional collision avoidance	360° x 360°; range 0.4 – 40 m; size of an obstacle > 2 mm wire

Included accessories	Handle Universal carbon fiber mounting plate with appropriate drone mount
Optional accessories	Colorization camera Vehicle mounts: suction grip, magnetic, bull bar Protective cage Hard case backpack

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Version 1