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UNDERGROUND MEASUREMENTS OF HARD-TO-REACH SPACES WITH A SPECIAL INSPECTION SYSTEM

WOJCIECH STOLARSKI

GEOTRONICS
DYSTRYBUCJA

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Trimble®

TRANSFORMING THE WAY THE WORLD WORKS

VRSNET.PL

GEOTRONICS R&D

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A COMPLETE SOLUTION: LIDAR MAPPING + AUTONOMY

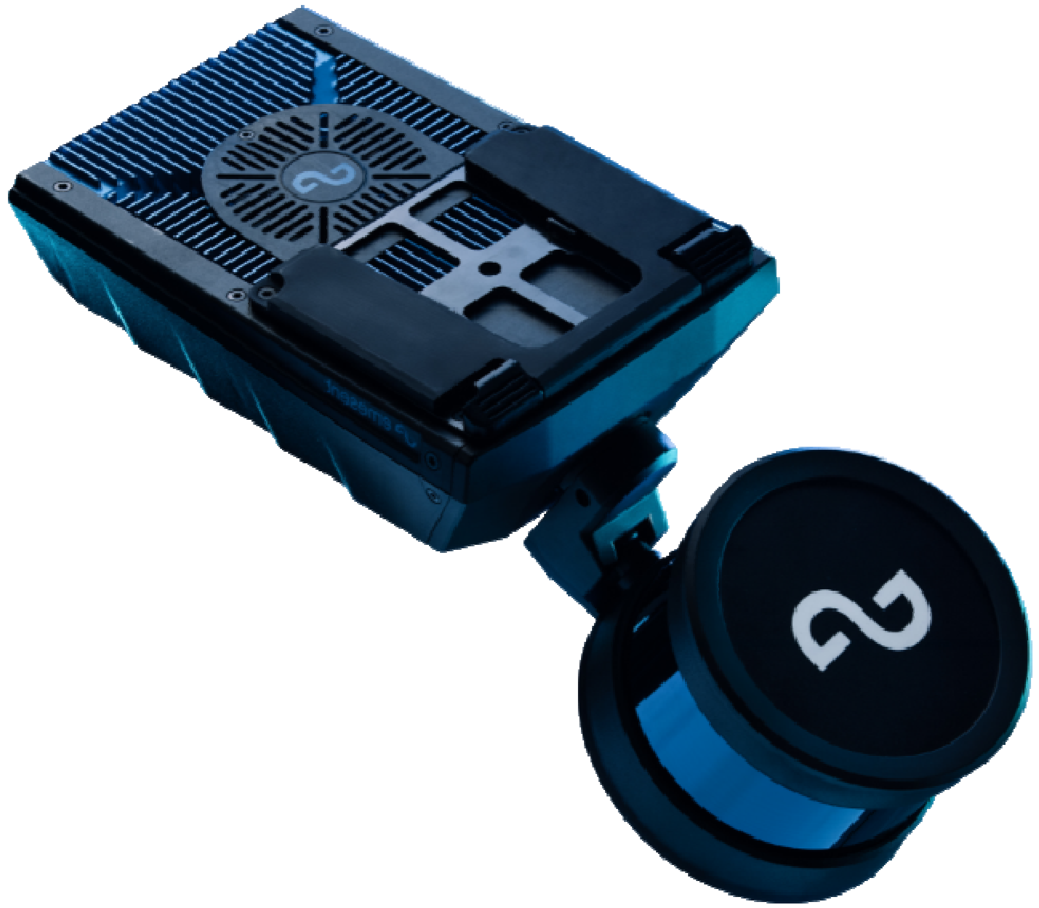
Provides advanced autonomy and mapping when drone-mounted, or can be used as a standalone mobile mapping system

SLAM[1] LIDAR MAPPING

GPS-DENIED FLIGHT

COLLISION AVOIDANCE

ADVANCED AUTONOMY



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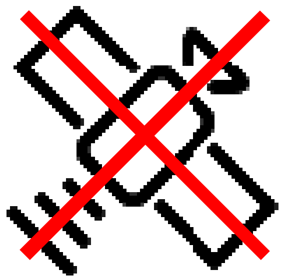
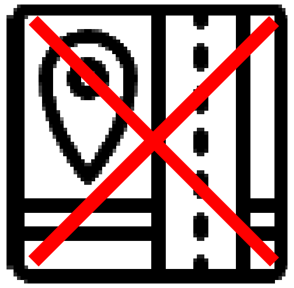
1. SIMULTANEOUS LOCALIZATION AND MAPPING

PROBLEM – COLLECTION OF DATA

IN GPS-DENIED AND CHALLENGING ENVIRONMENTS


No GPS


No Comms


No Maps


No Access


MINING


RAIL & ROAD


INDOORS


SEARCH & RESCUE

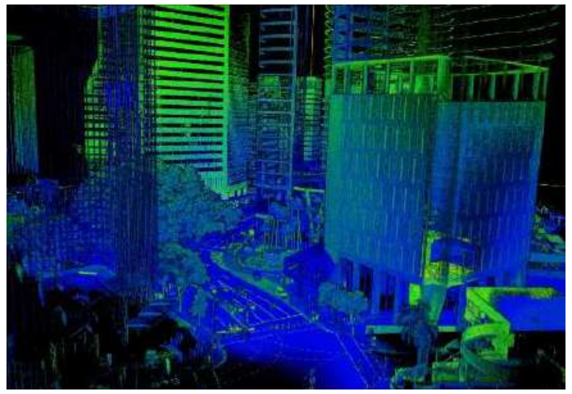

URBAN

COMMERCIAL APPLICATIONS

UNDERGROUND MINING

UNDERGROUND TRANSPORT

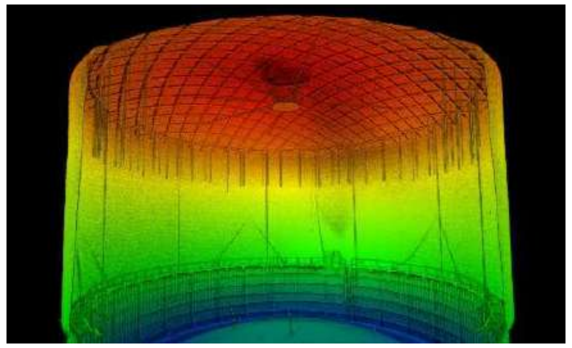
URBAN MAPPING



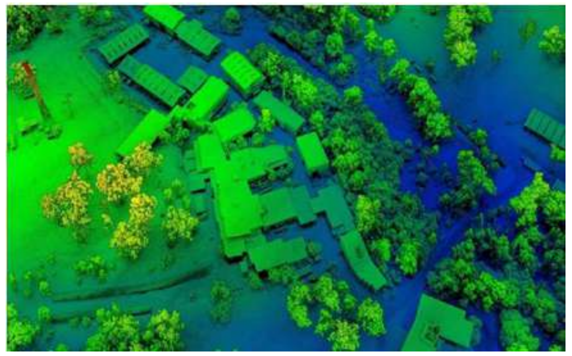
DEFENSE

BRIDGE INSPECTION

OIL & GAS



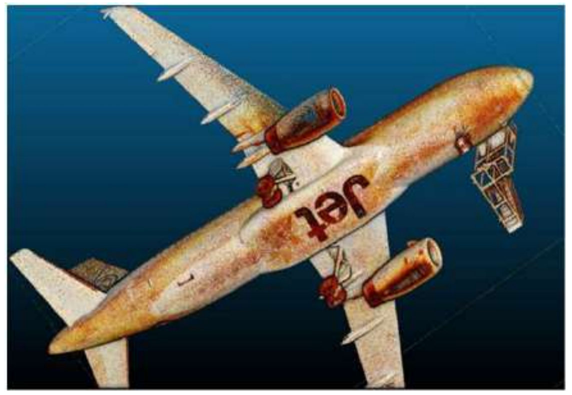
TERRAIN MAPPING



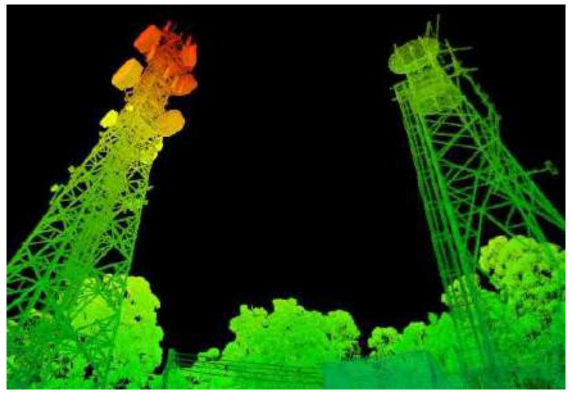
FORESTRY

INDOORS

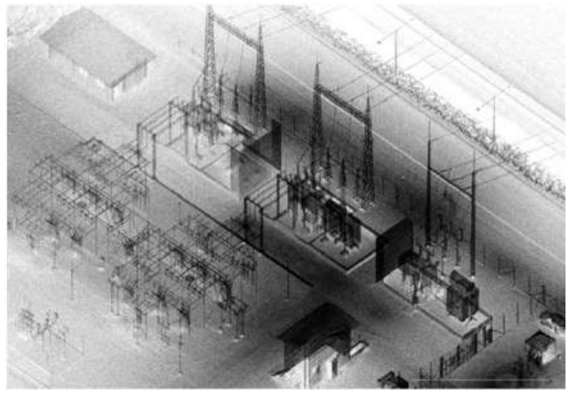
COMPLEX ASSET DIGITIZATION



TELECOMMUNICATIONS TOWERS

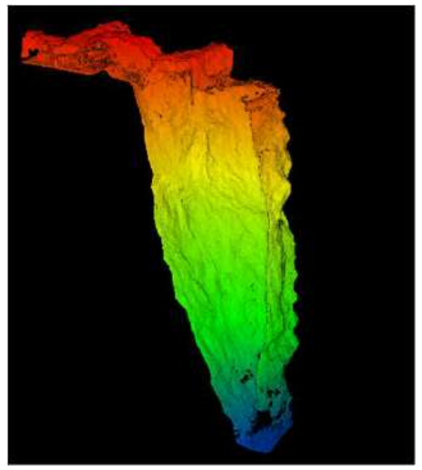


INDUSTRIAL INFRASTRUCTURE

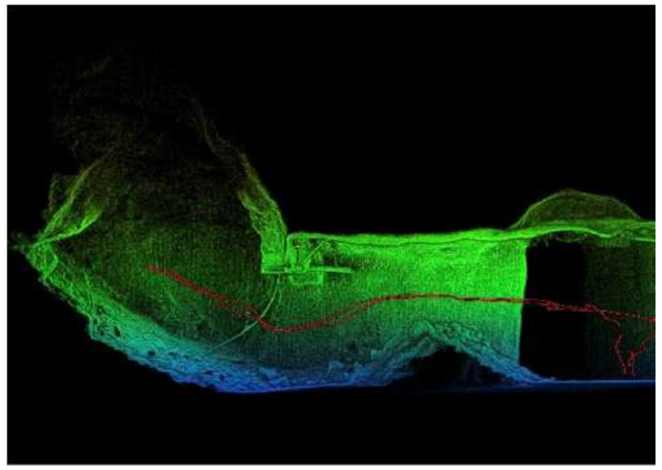


UNDERGROUND MINING USE CASES

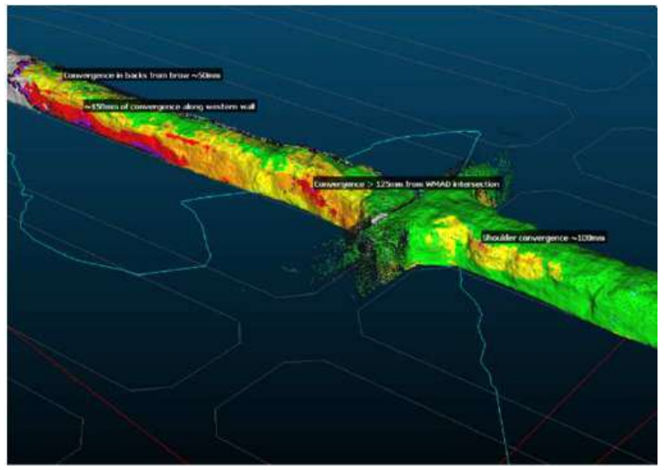
STOPES



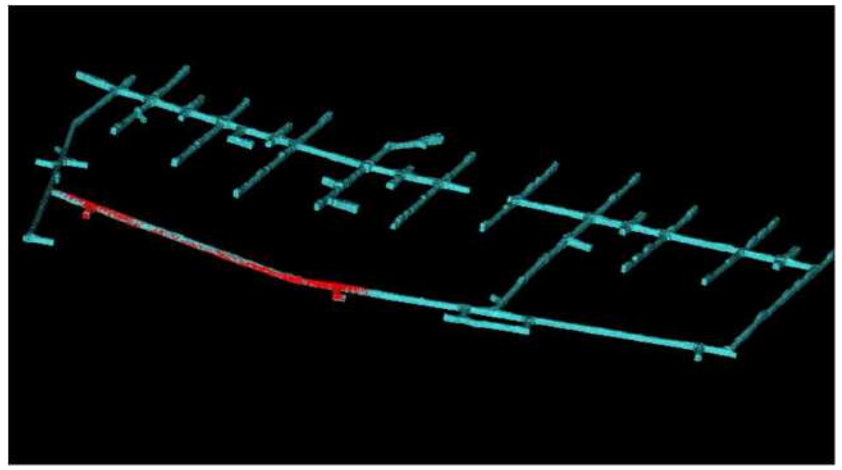
DRAW POINTS



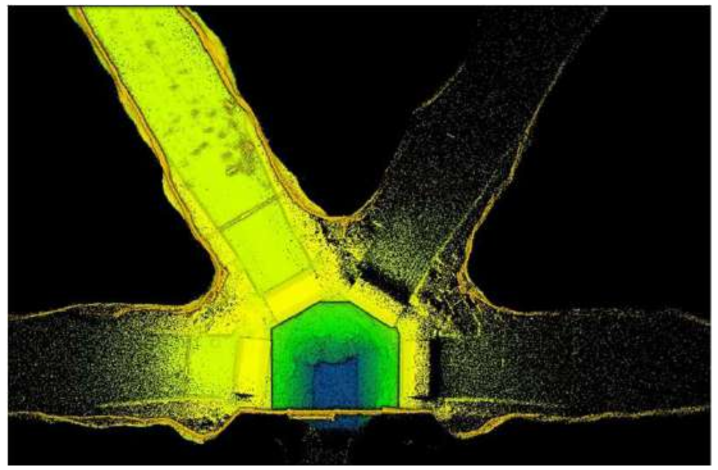
CONVERGENCE MONITORING



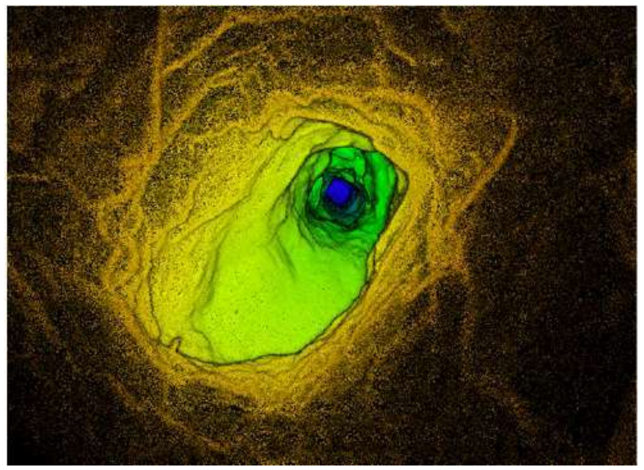
OLD WORKINGS



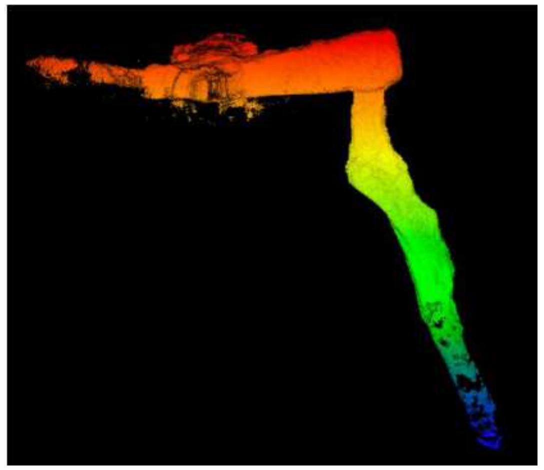
TIPPLE INSPECTION



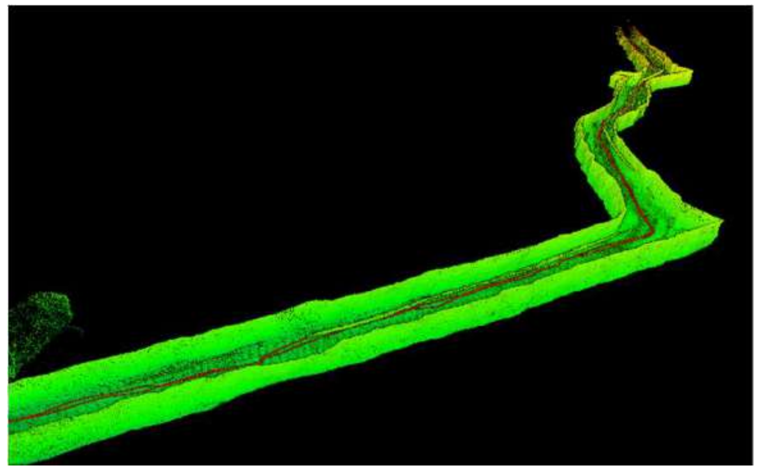
VENT SHAFTS



ORE PASSES



DRIFT/DRIVE MONITORING



KEY FEATURES

SPECIFICATIONS

Velodyne Puck LITE LiDAR

- Single Return Mode: up to 300,000 points/sec
- Dual Return Mode: up to 600,000 points/sec
- 0.40 to 100m range
- Dual return
- Intensity

360° x 290° Field of View

512Gb Storage (8h)

Wi-Fi

14 to 54 V input

1.6kg (3.63 lb)

AUTOMATED WITH Velodyne Lidar

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SLAM-BASED MAPPING

- World’s best SLAM solution
- High resolution, accurate data
- Georeference to survey control points or scan-to-scan registration
- Output in .laz, .las, .dxf, .ply and .E57

Per-point attributes

- Intensity
- Range
- Time
- Return number
- Ring number
- RGB / True color (optional hardware)

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AUTONOMY

Virtual Elliptical Shield (VESH360)

- Dynamically adjusts to drone speed and direction
- Size adjustable during flight

GPS-denied Flight

- Position hold, velocity control
- Waypoint navigation

Compatible with DJI M210v1, M300, Acecore Zoe

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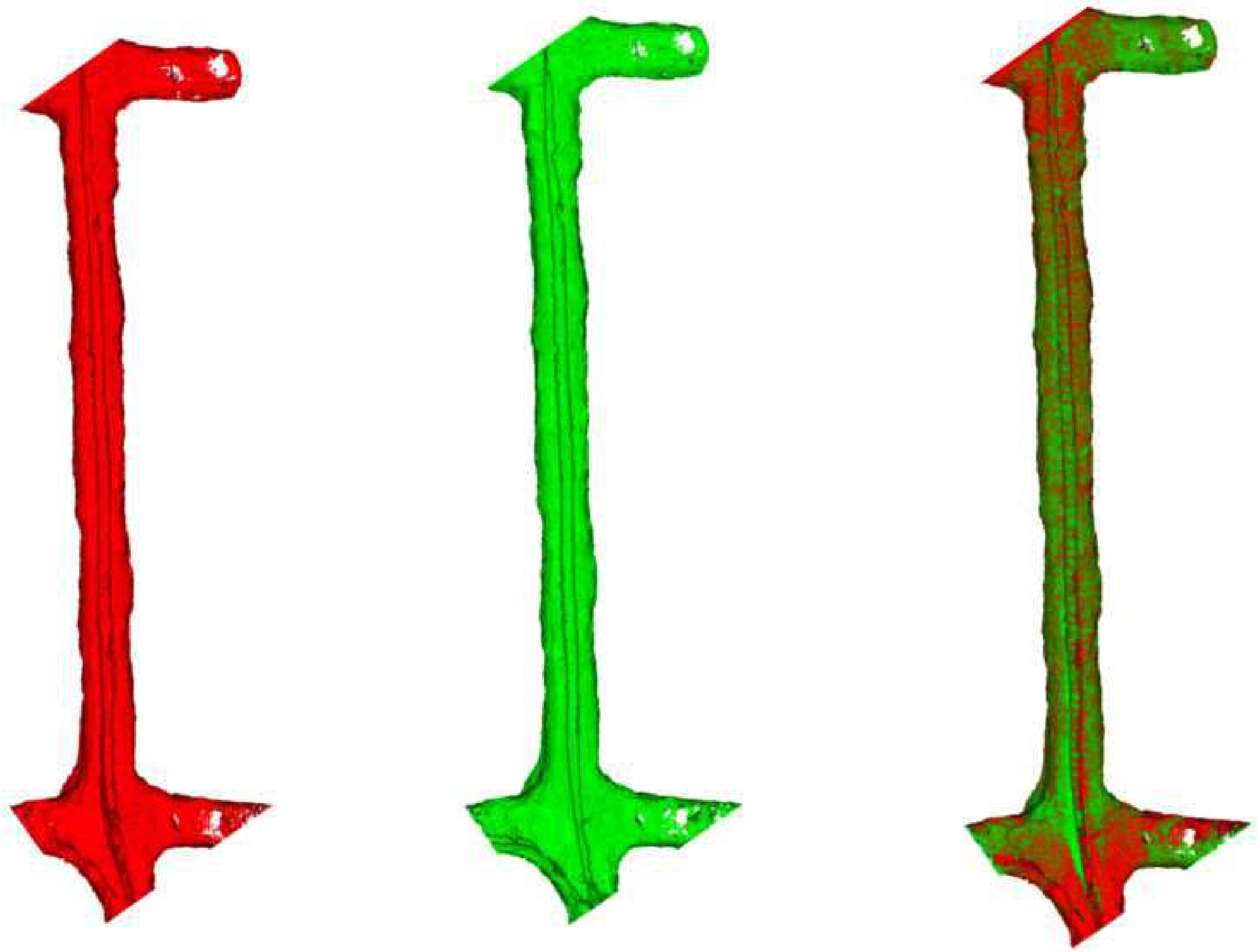
ACCURACY

- 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



Repeatability test for Change detection

- 95% of points within +13 to -16 mm
- 99% within +/-20 mm

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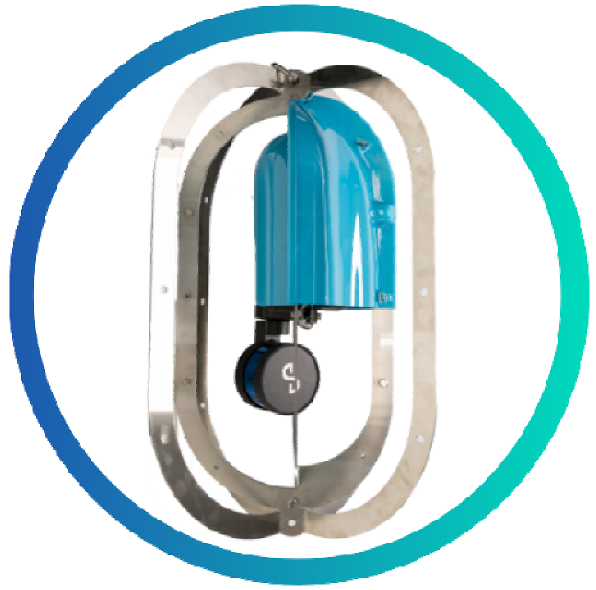
ONE SYSTEM, MULTIPLE USES

Faster return on investment

- Ease of use – quickly deploy to site on vehicle, backpack, robot, tether, cage, CMS adaptor
- Combine multiple scans (indoors & outdoors)
- Easy technology adoption – minimal training required and simple workflows



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BACKPACK

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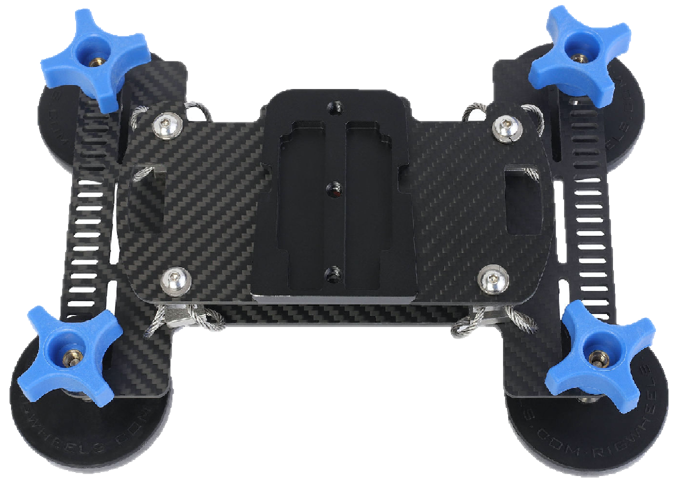
ATTACHMENT ACCESSORIES



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READY TO FLY IN 60 SECONDS

- Quick release attachment
- Connect power and signal
- Push button to start
- Fly and scan
- No waiting for GPS signal
- No GPS/INS calibration flight
- Use all flight segments

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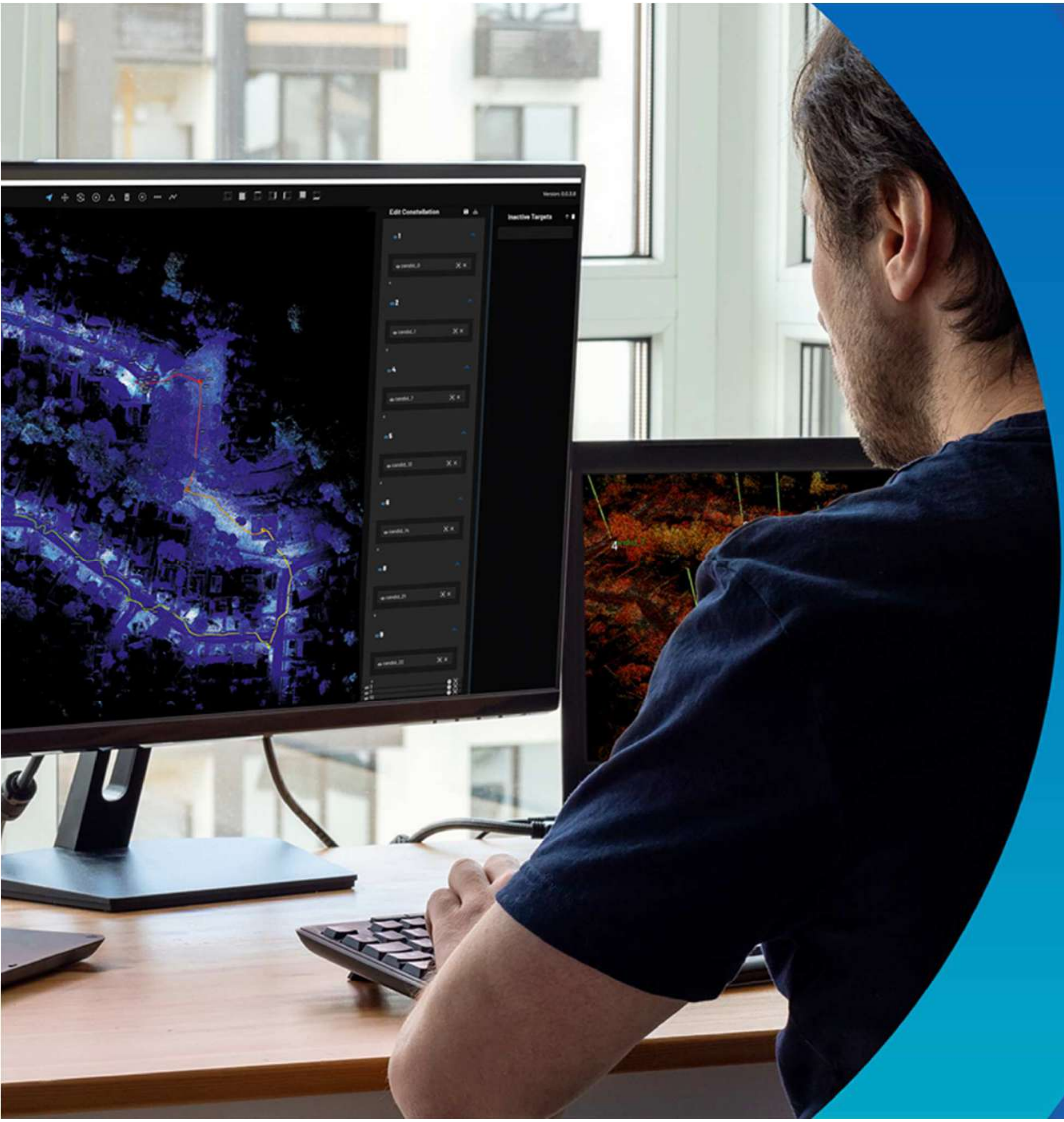
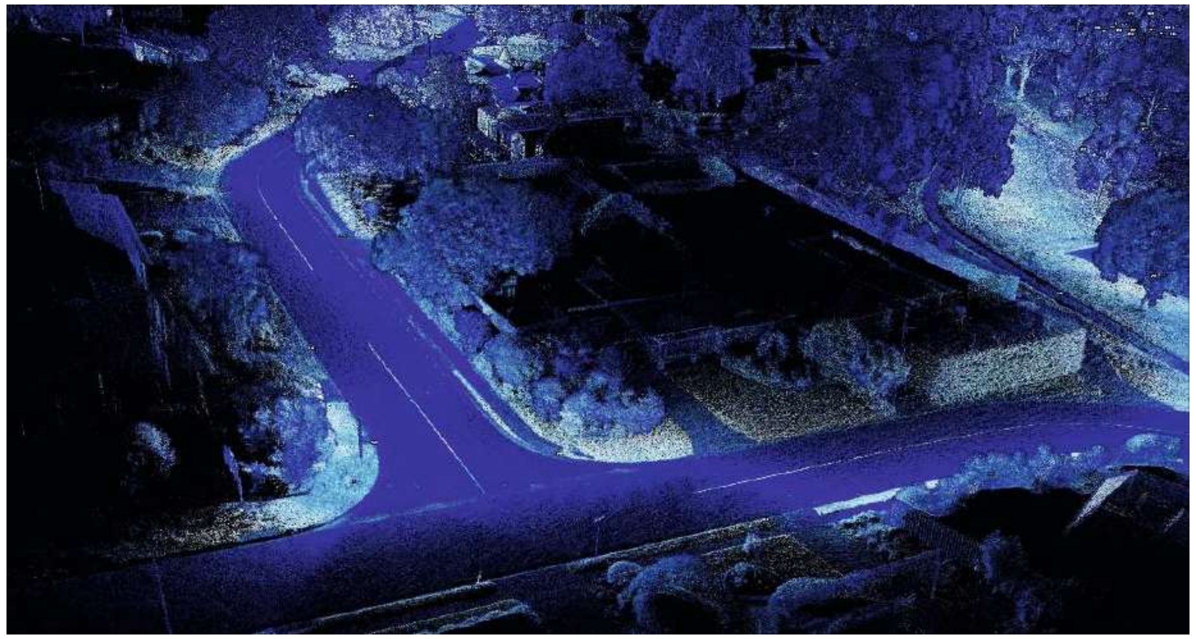


AUTOMATED GROUND CONTROL

SURVEY GRADE POINT CLOUDS

SURVEY GRADE ACCURACY FOR HOVERMAP POINT CLOUDS

- Improved local and global accuracy
- Automated georeferencing
- Extend the capabilities of SLAM, eg long, linear assets and large or feature-poor environments
- Reduce manual error
- Streamline your workflow



Roadway Scan Accuracy Results

Survey length: 900 m (0.56 mi)
Ground control targets: 10
Survey check points: 81
Mean distance from survey to Hovermap scan results: 11 mm (7/16")

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LEVELS OF AUTONOMY

MAPPING MODE
AUTONOMY LEVEL 0

- Mount Hovermap to any vehicle or platform that can carry it
- Use the drone in-built autopilot to operate it

PILOT ASSIST MODE
AUTONOMY LEVEL 1

- Omnidirectional collision avoidance
- GPS-denied position hold
- Overrides pilot commands to keep drone safe
- Enables safe line of sight flight

AUTONOMOUS WAYPOINT MODE
AUTONOMY LEVEL 2

- Set waypoints in an existing map for routine pre-programmed flight
- Tap-to-fly interactive waypoint mode in live stream map
- Includes collision avoidance
- Enables beyond line of sight flight

FUTURE DEVELOPMENTS

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MAPPING FEATURES

	MAPPING	PILOT ASSIST	AUTONOMOUS WAYPOINT
World's Best SLAM mapping	✓	✓	✓
All in one hardware	✓	✓	✓
Companion processing software	✓	✓	✓
RGB colorization software	✓	✓	✓
Optimized point cloud merging	✓	✓	✓
20+ adjustable processing parameters	✓	✓	✓
Automated Ground Control software	✓	✓	✓
Customer support + knowledge base	✓	✓	✓
Vehicle, backpack usage	✓	✓	✓
Drone enabled	✓	✓	✓
Real-time point cloud	✓	✓	✓
Observer mode	OPTIONAL	✓	✓
Drone camera		✓	✓

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AUTONOMY FEATURES

	PILOT ASSIST	AUTONOMOUS WAYPOINT
GPS-denied flight	✓	✓
Omnidirectional collision avoidance	✓	✓
Barometric pressure chance tolerance	✓	✓
Magnetic interference tolerance	✓	✓
Live stream onboard drone camera	✓	✓
Obstacle proximity map	✓	✓
Smart battery Return-to-Home	✓	✓
Operate beyond line of site		✓
Operate beyond communication range		✓
Tap-To-Fly		✓
Smart waypoint based flight		✓
Guided exploration		✓
Intelligent path planning		✓
Communications loss return to home		✓

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PILOT ASSIST MODE

AUTONOMY LEVEL 1


Detecting the Invisible
Hovermap perceives and avoids 1mm wires

PILOT ASSIST MODE - AUTONOMY LEVEL 1

- Omnidirectional LiDAR-based collision avoidance
- GPS-denied position hold and velocity control
- Mixes pilot commands to keep aircraft safe
- Enables safe line of sight flight
- Beta release 2018, commercial launch Jan 2019
- Thousands of hours of use by customers in challenging environments

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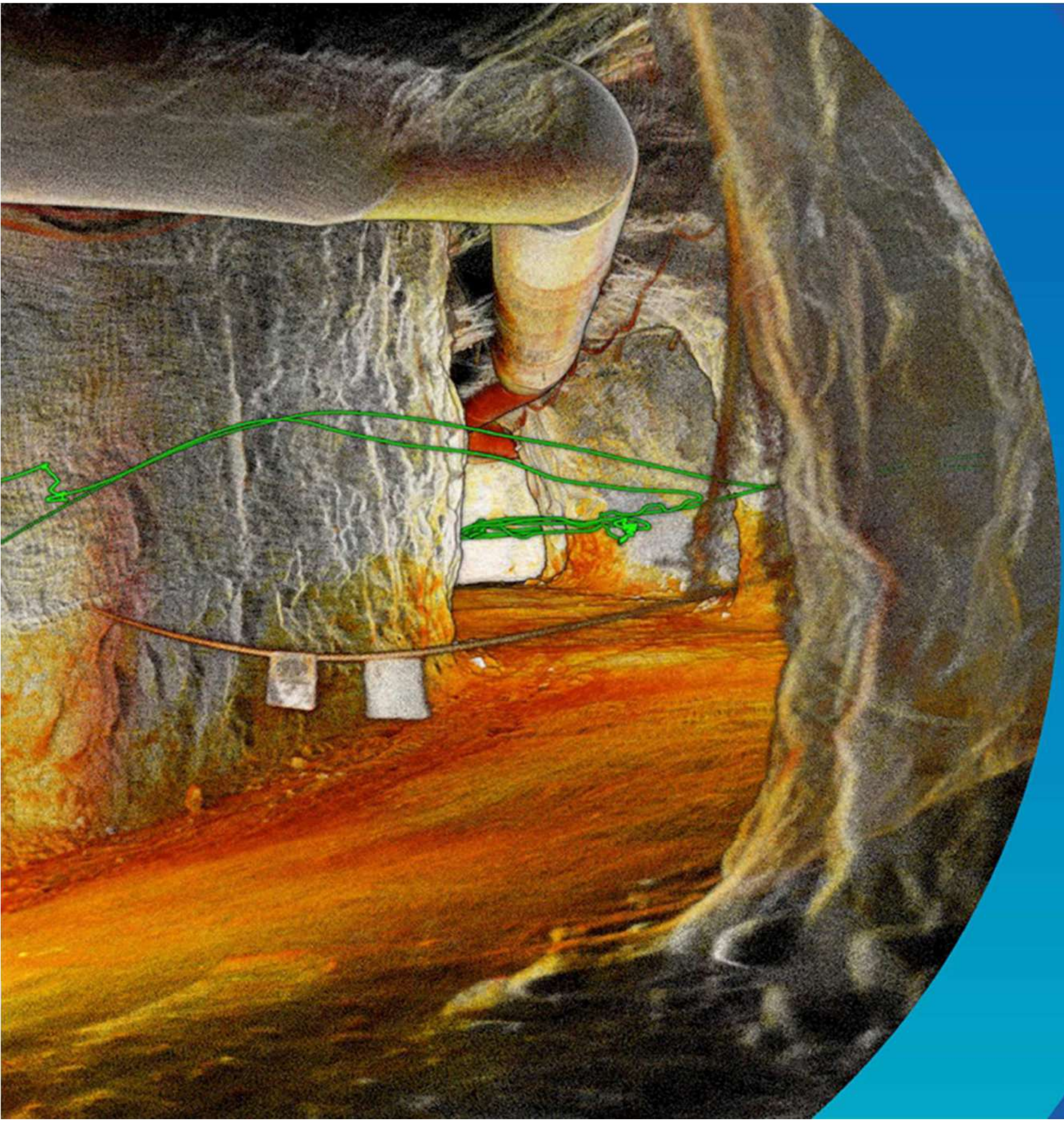
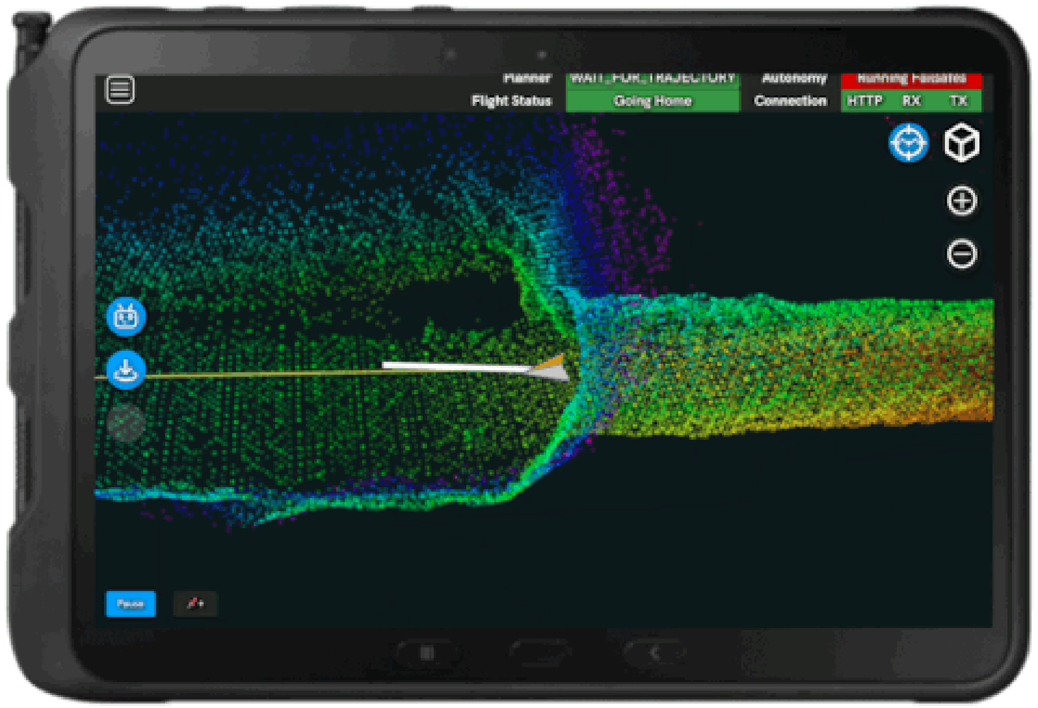
HOVERMAP TABLET APP – PILOT ASSIST



AUTONOMOUS WAYPOINT MODE

AUTONOMY LEVEL 2

AUTONOMOUS WAYPOINT MODE – BVLOS SELF NAVIGATION



Built on the mission proven Pilot Assist Mode and
10+ years of R&D

Autonomous BVLOS GPS-Denied Flight

Tap-To-Fly Smart Waypoints Guided Exploration

Live Streaming Map

Advanced Failsafes

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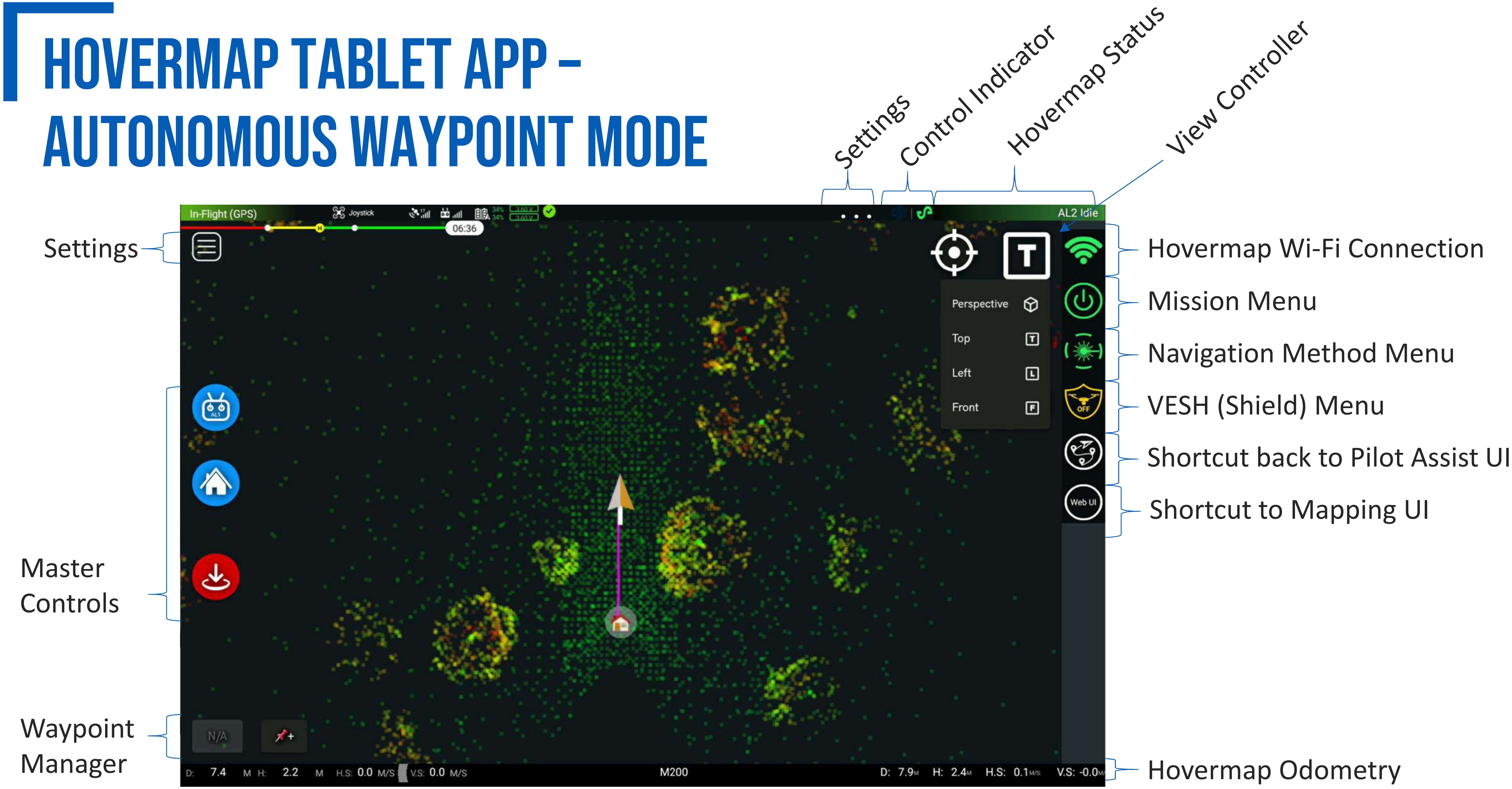
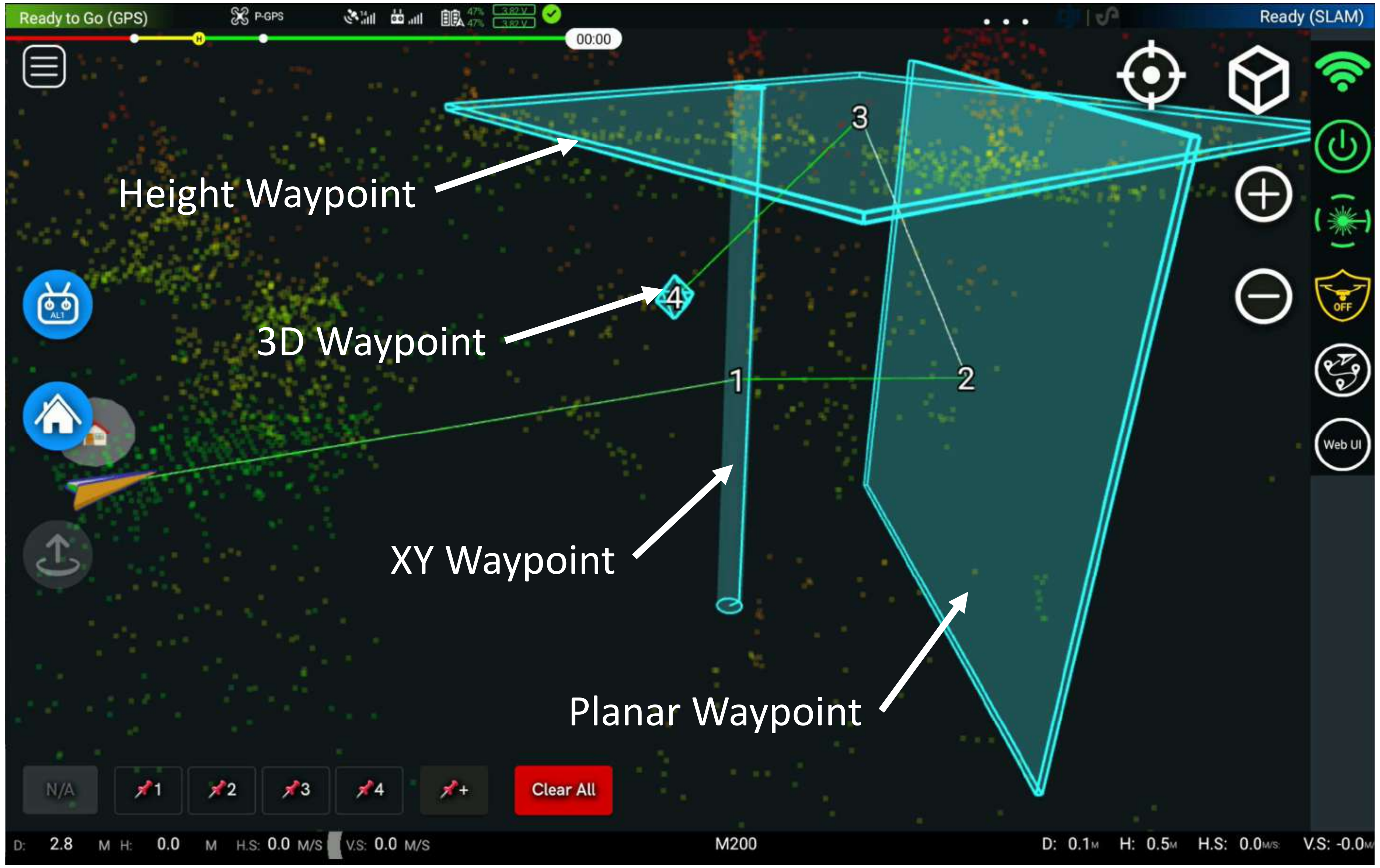
HOVERMAP TABLET APP – AUTONOMOUS WAYPOINT MODE



SMART WAYPOINTS



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FUTURE OF AUTONOMY

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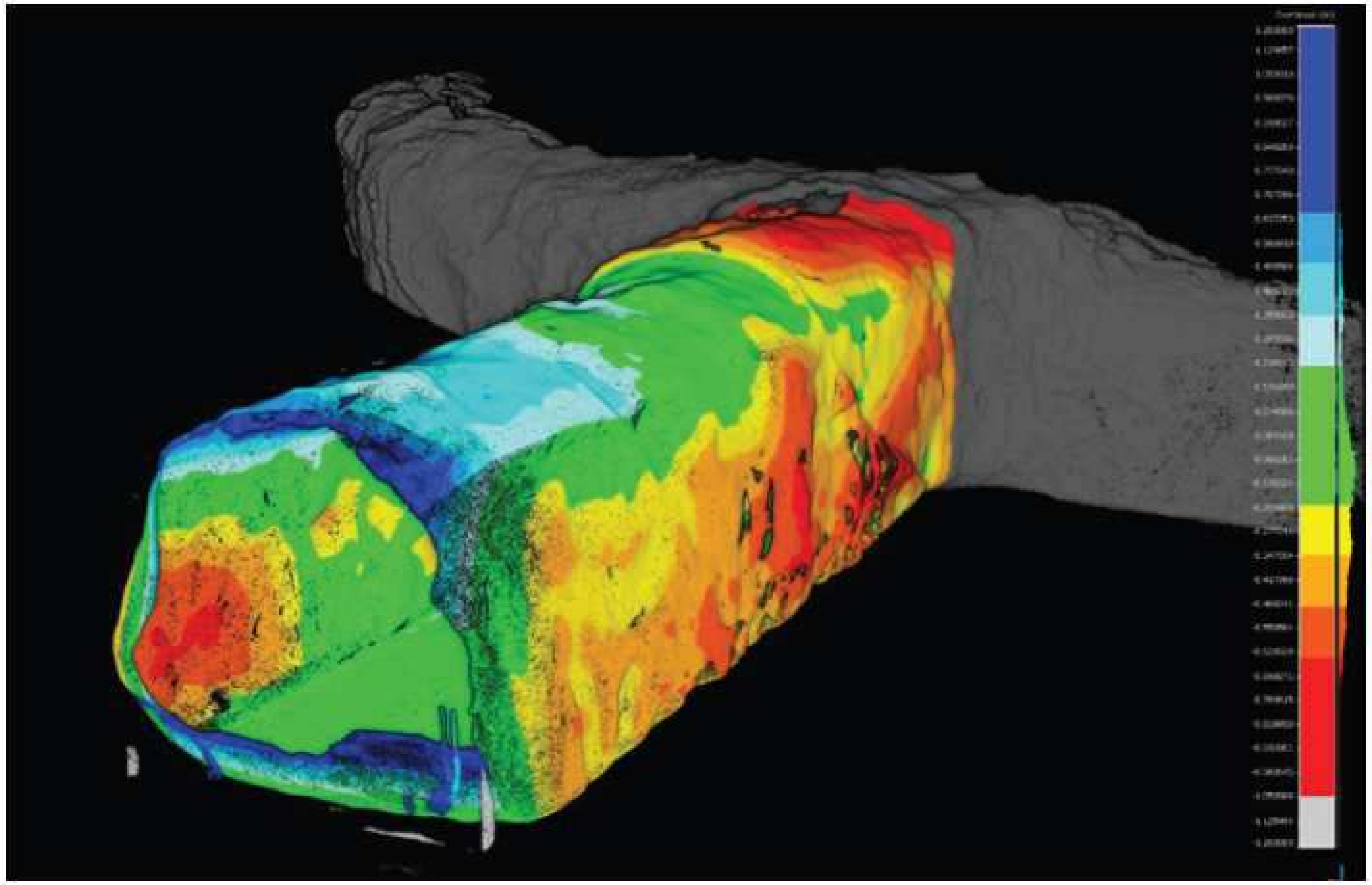
MINING APPLICATIONS

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.

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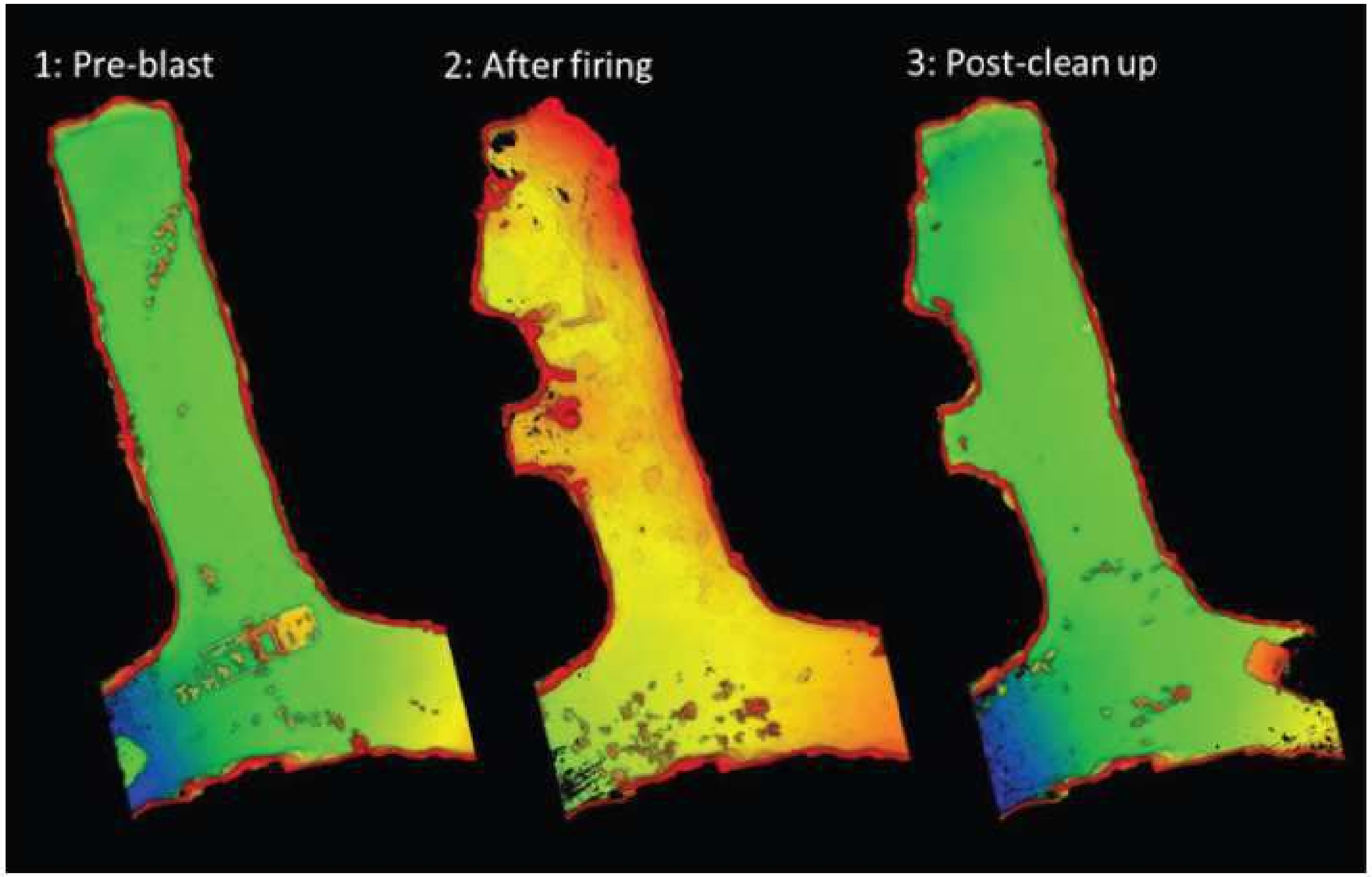
MINING APPLICATIONS



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.

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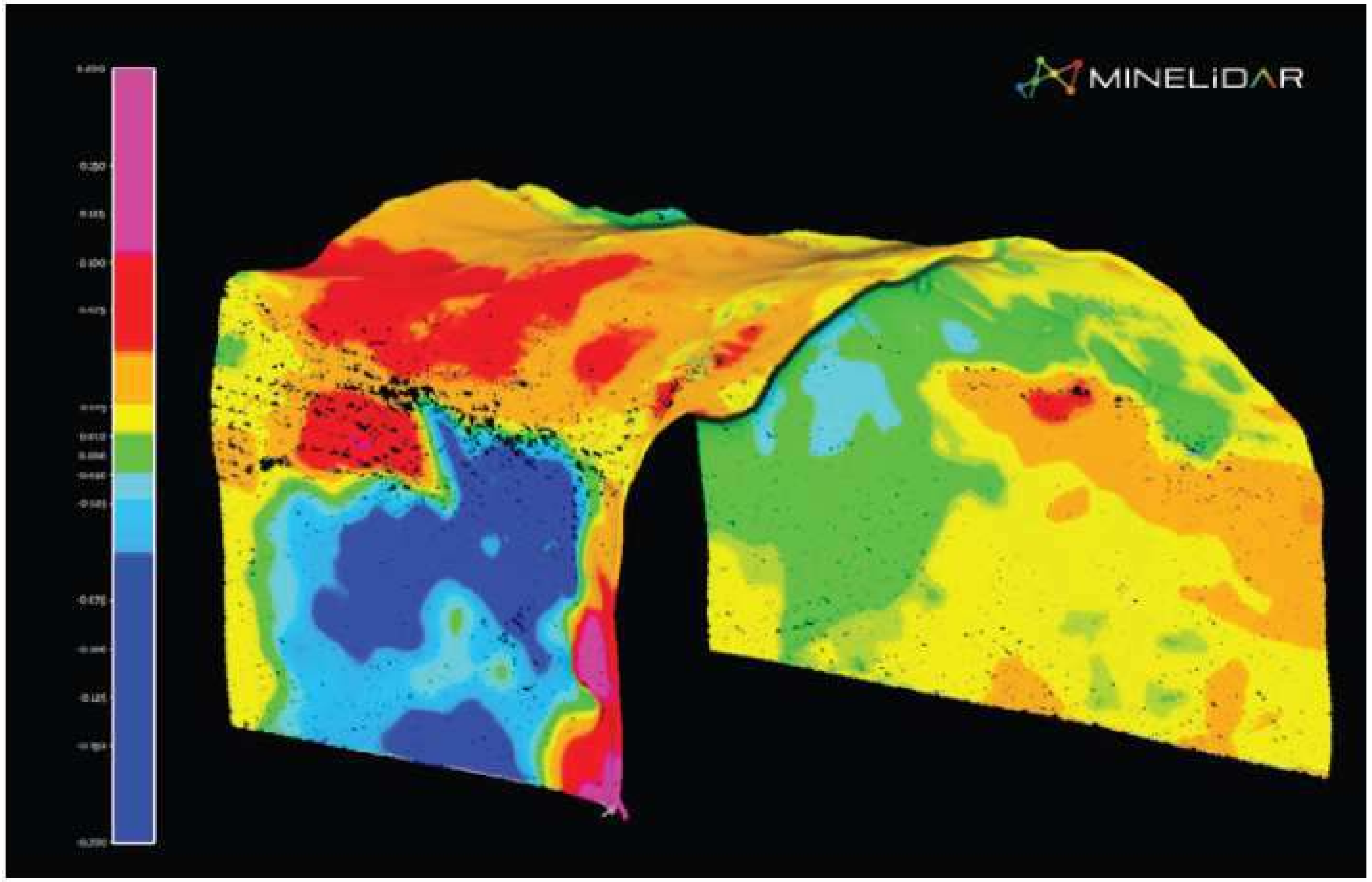
MINING APPLICATIONS

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)

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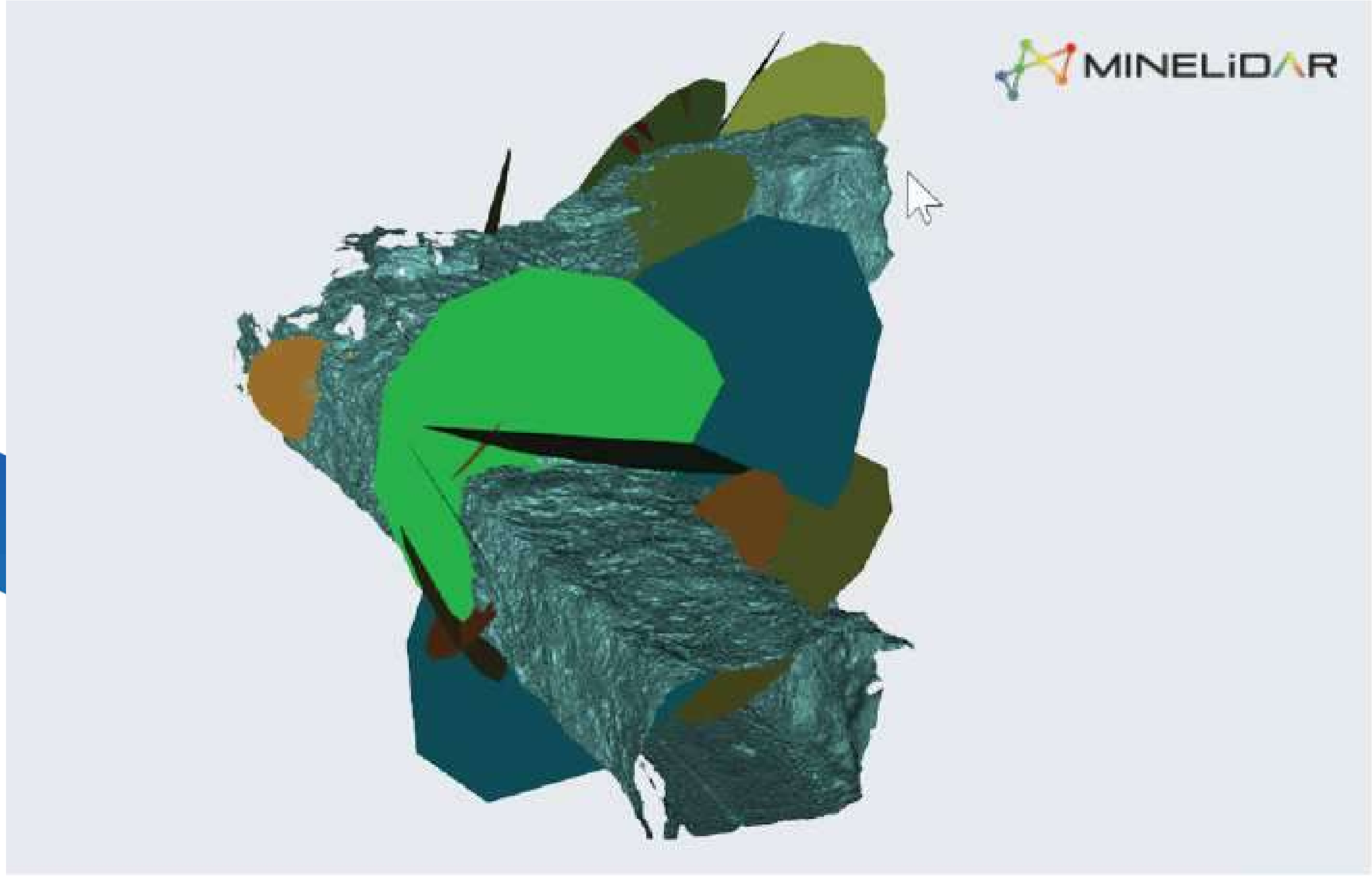
MINING APPLICATIONS



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.

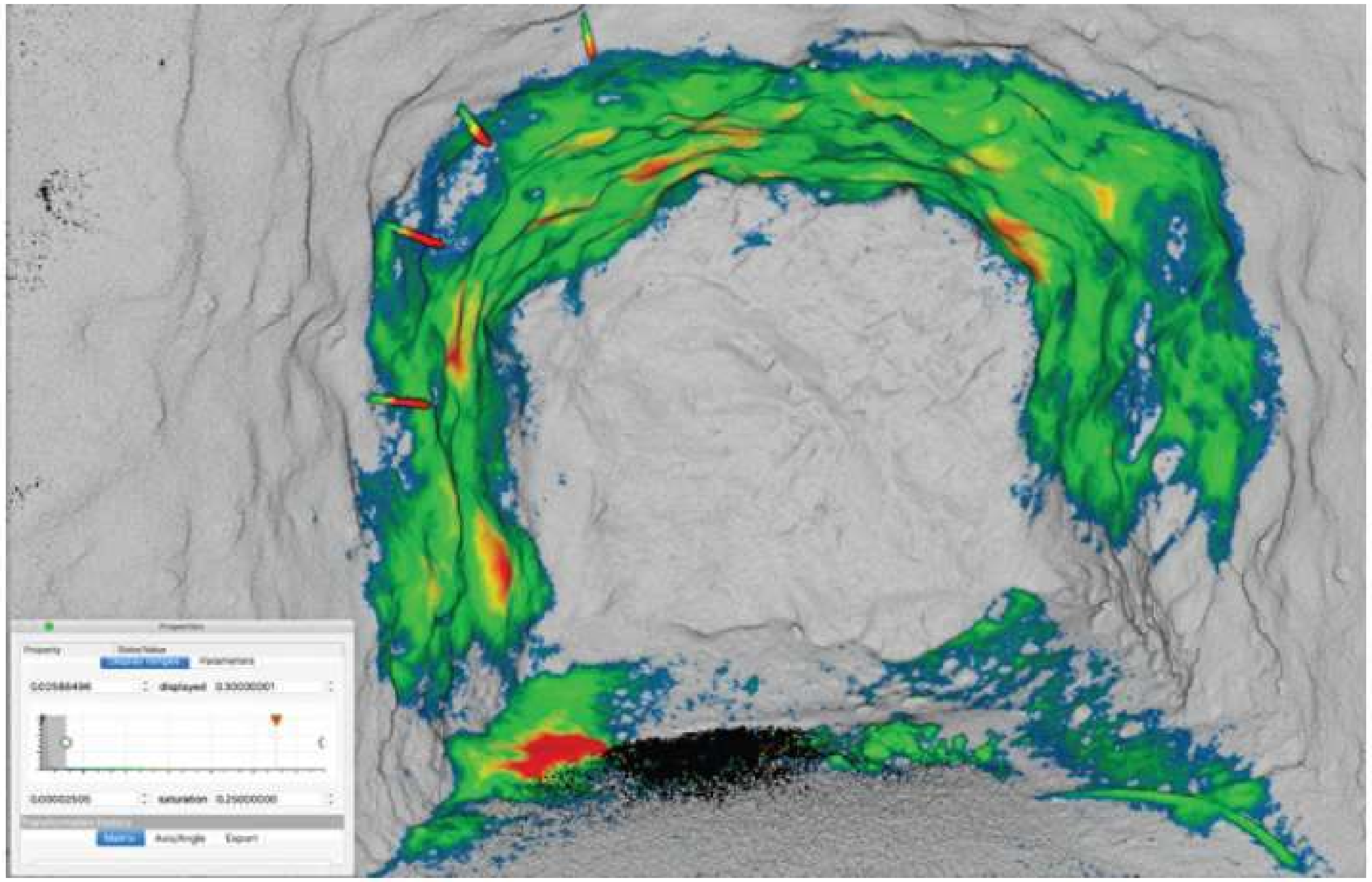
MINING APPLICATIONS

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.

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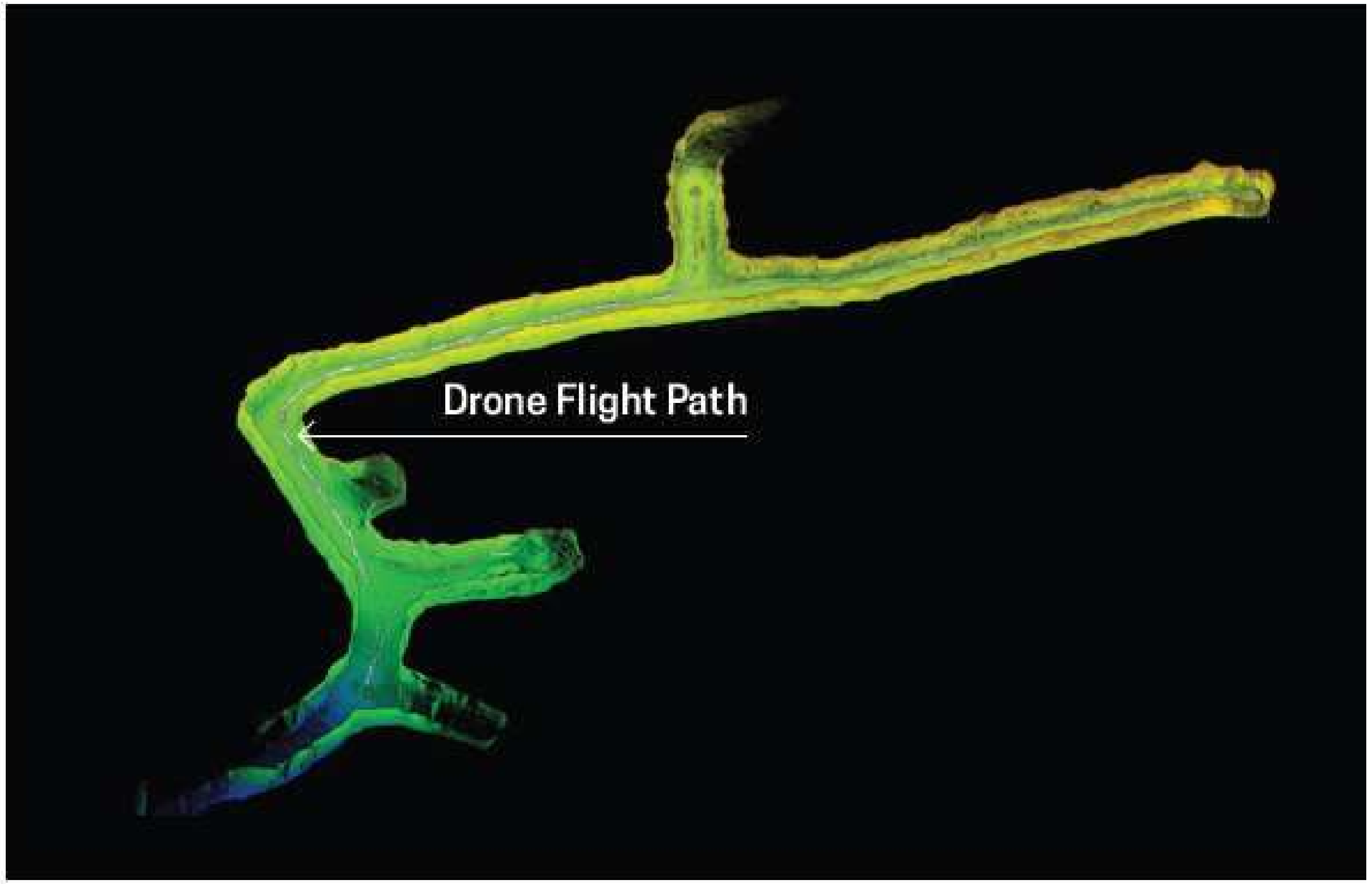
MINING APPLICATIONS

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.

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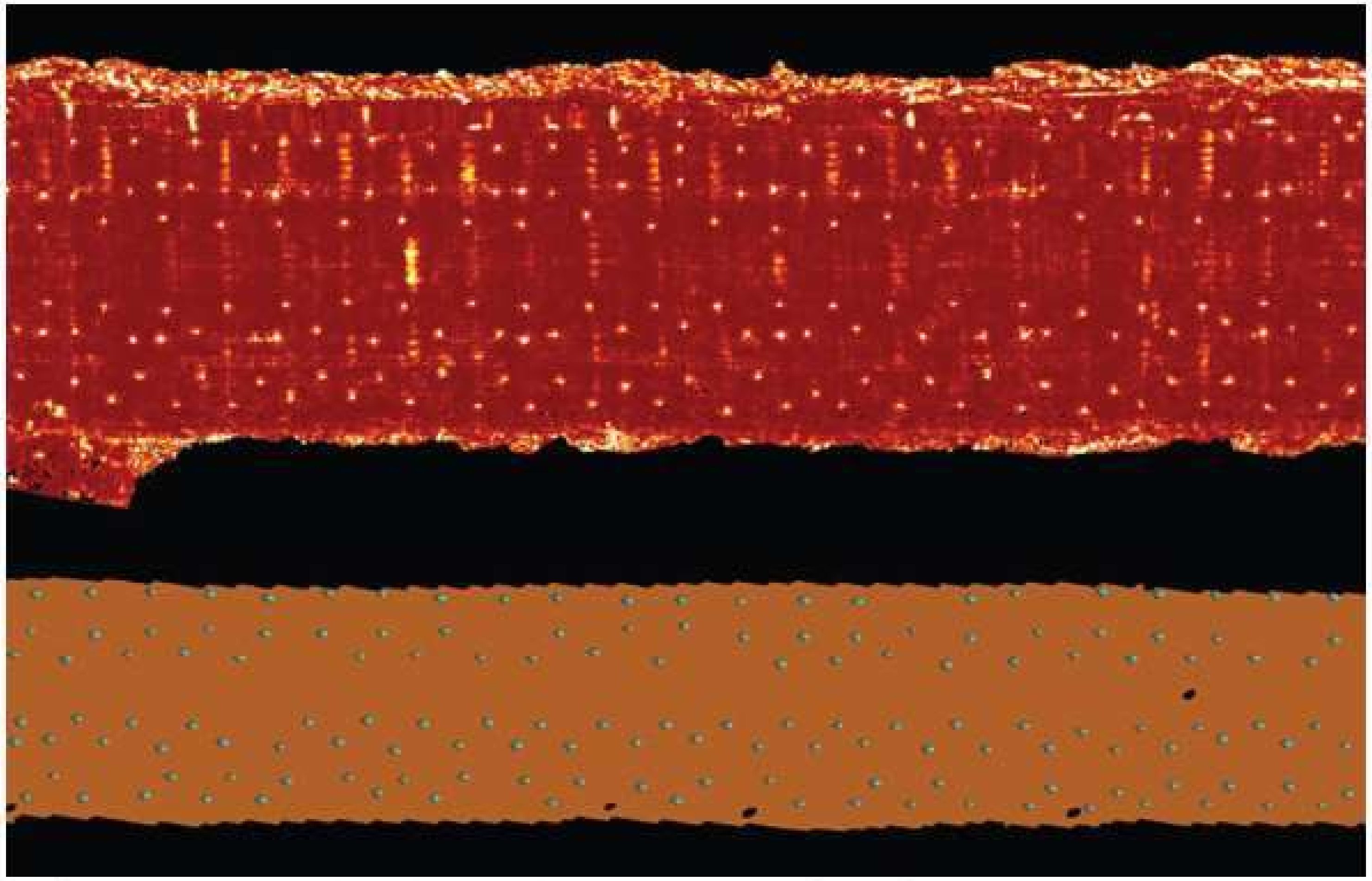
MINING APPLICATIONS



(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.

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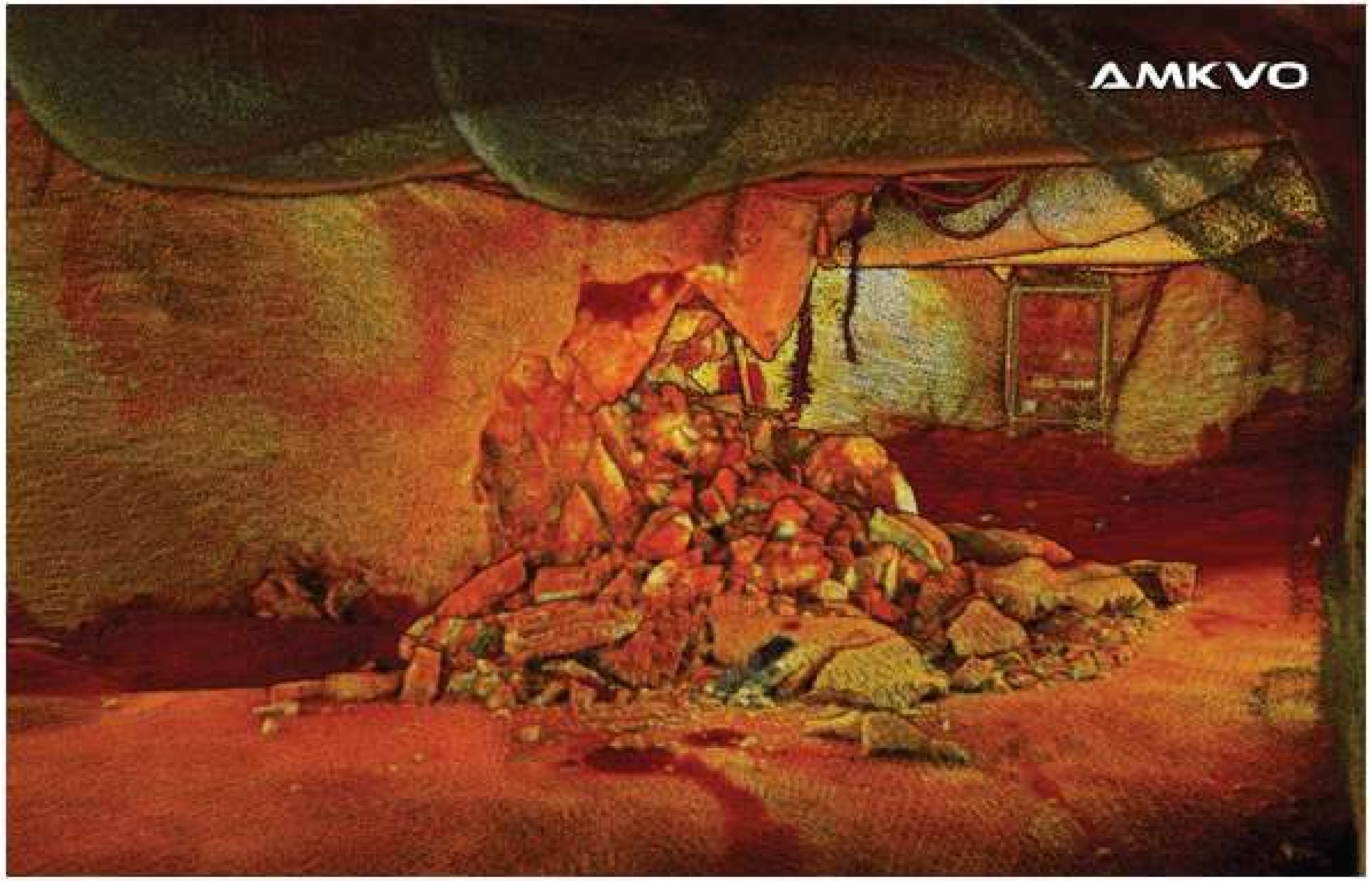
MINING APPLICATIONS

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.

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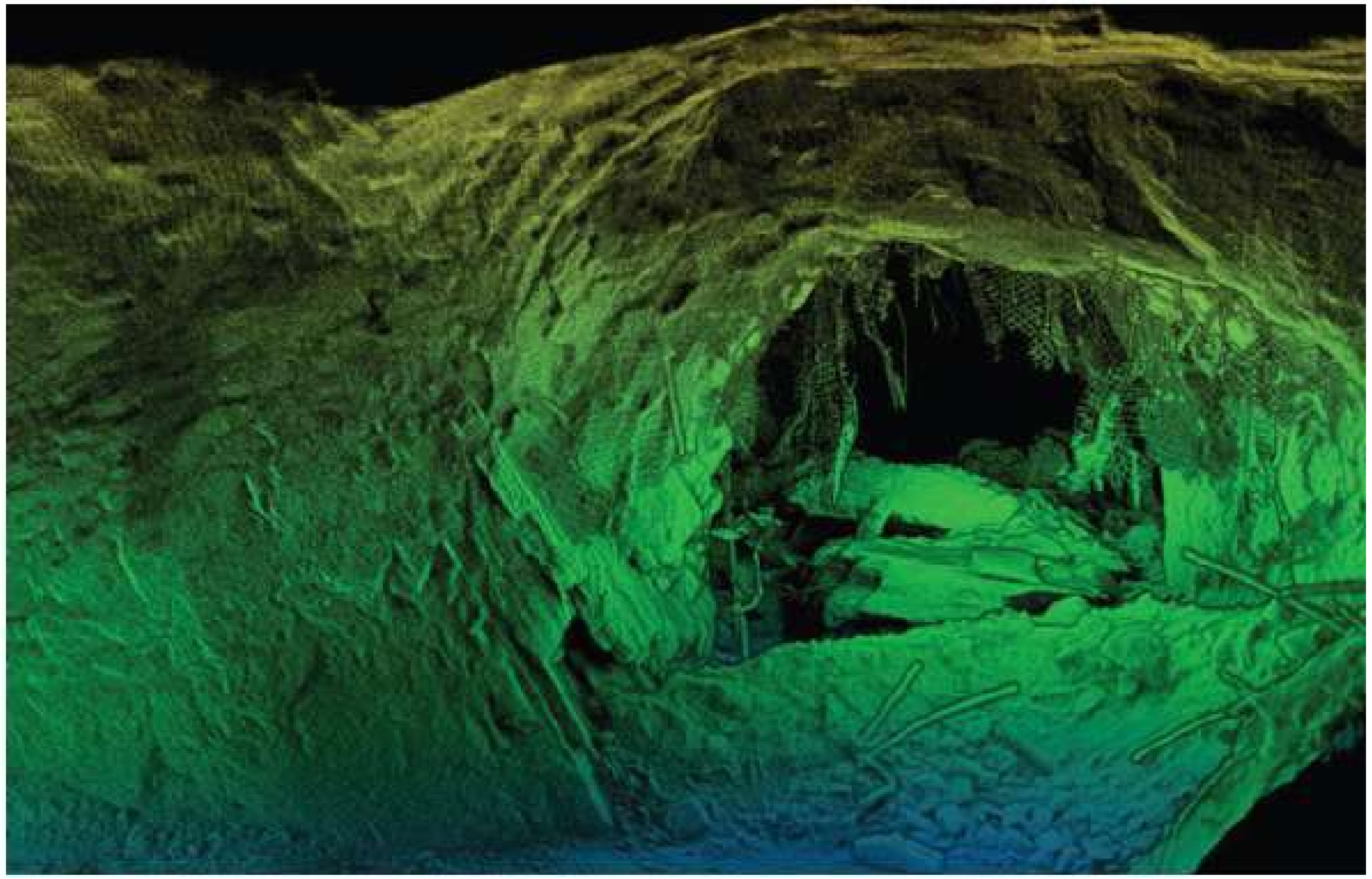
MINING APPLICATIONS

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.

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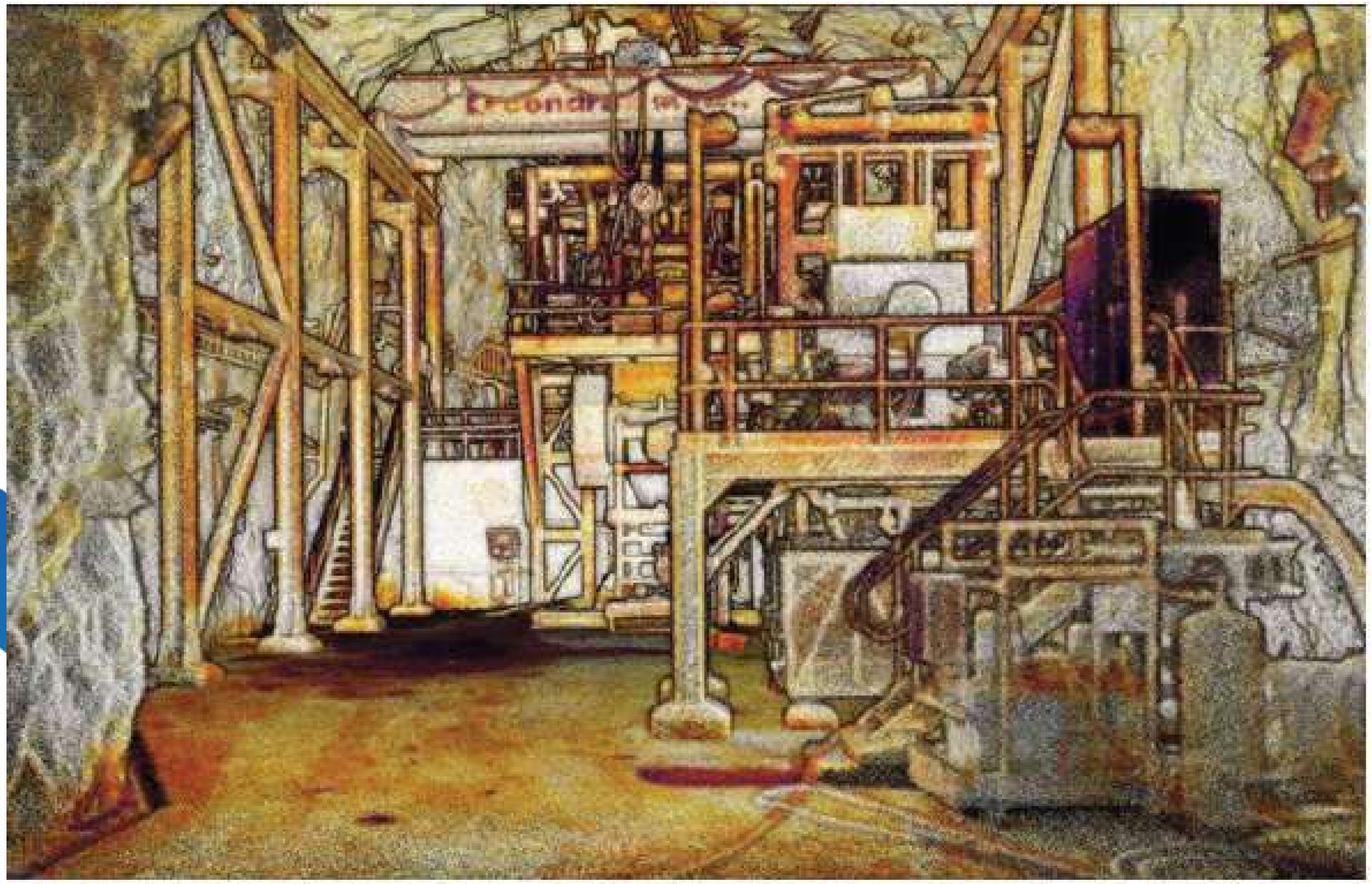
MINING APPLICATIONS



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.

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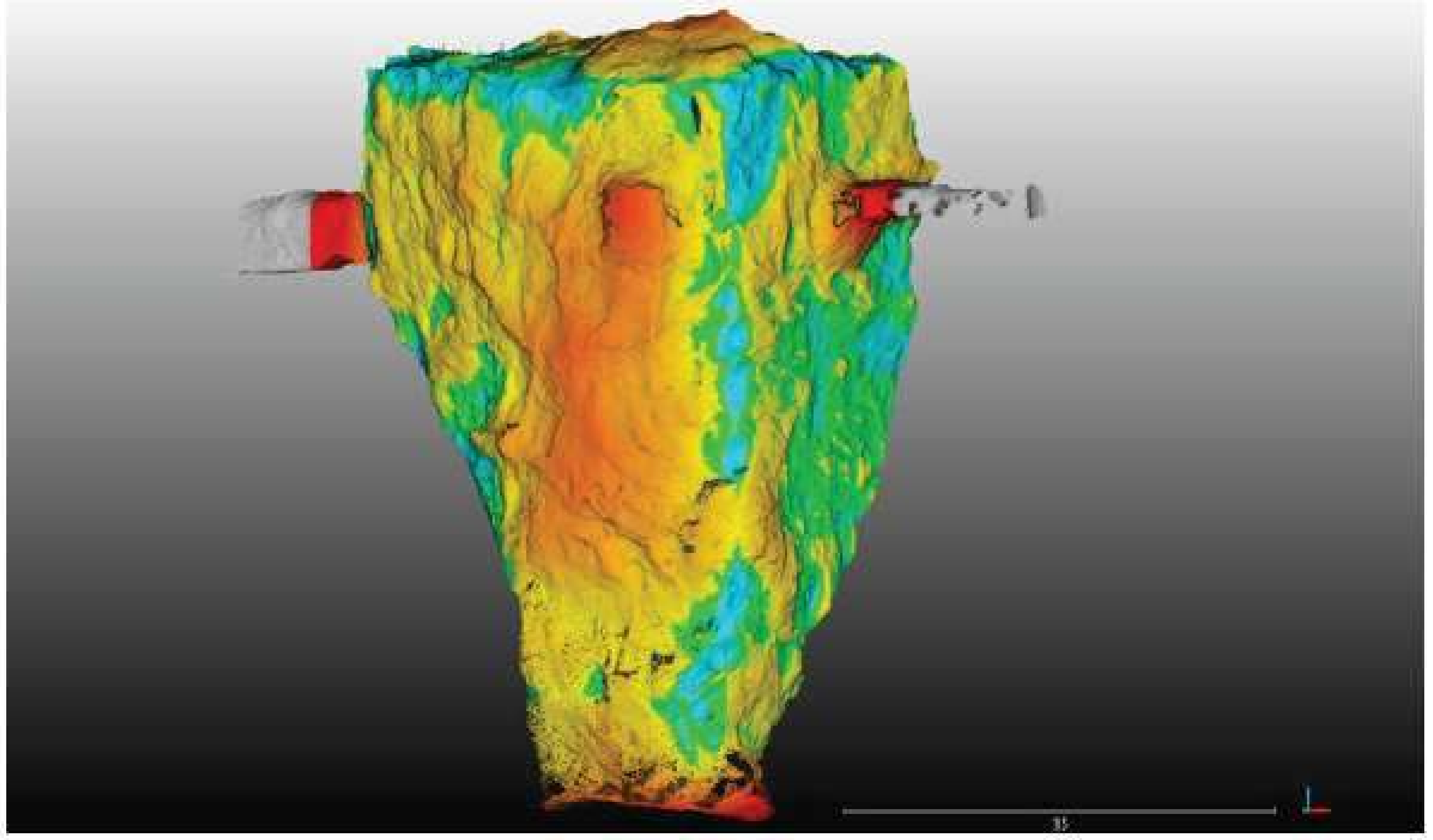
[redacted]

MINING APPLICATIONS

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.)

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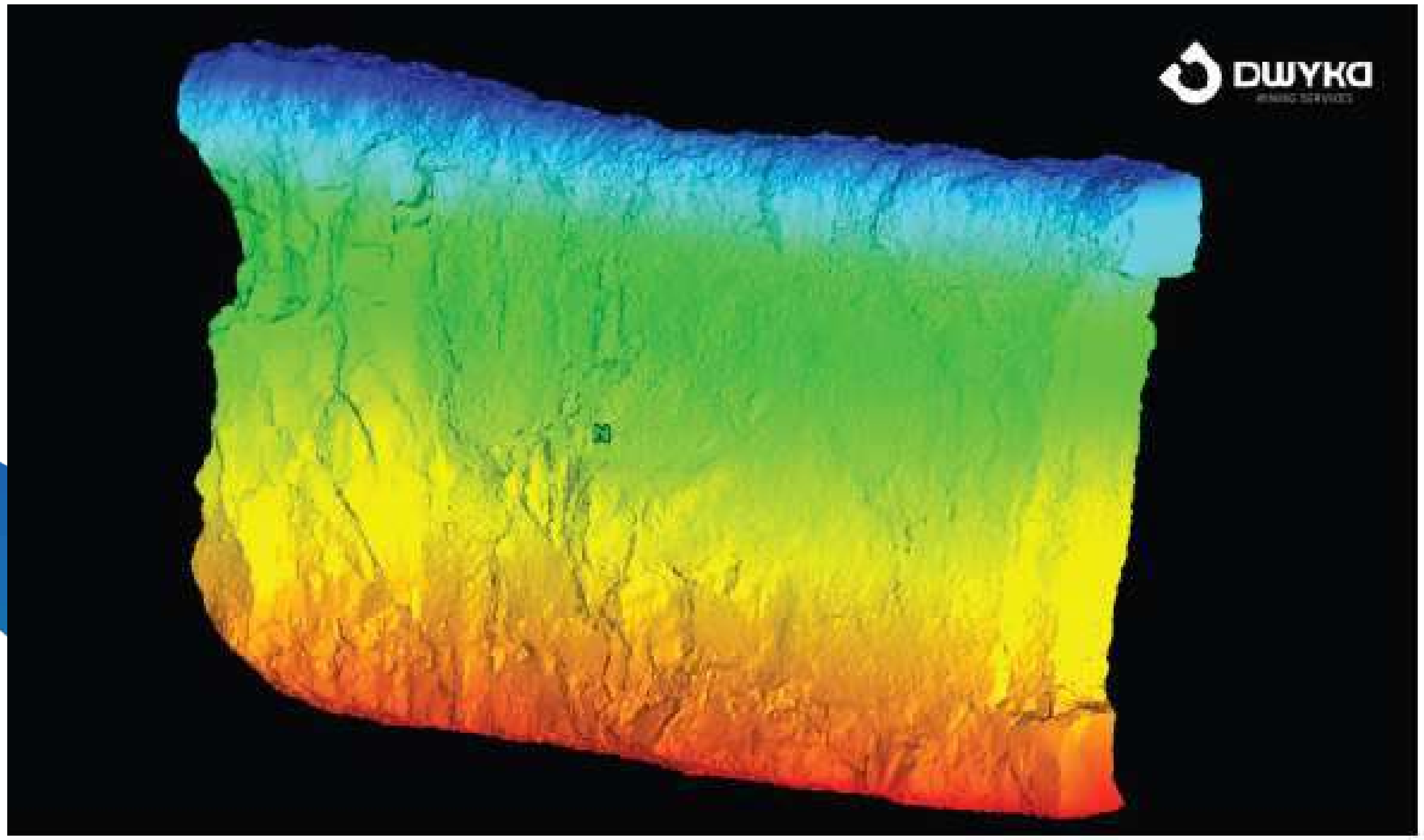
MINING APPLICATIONS



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.

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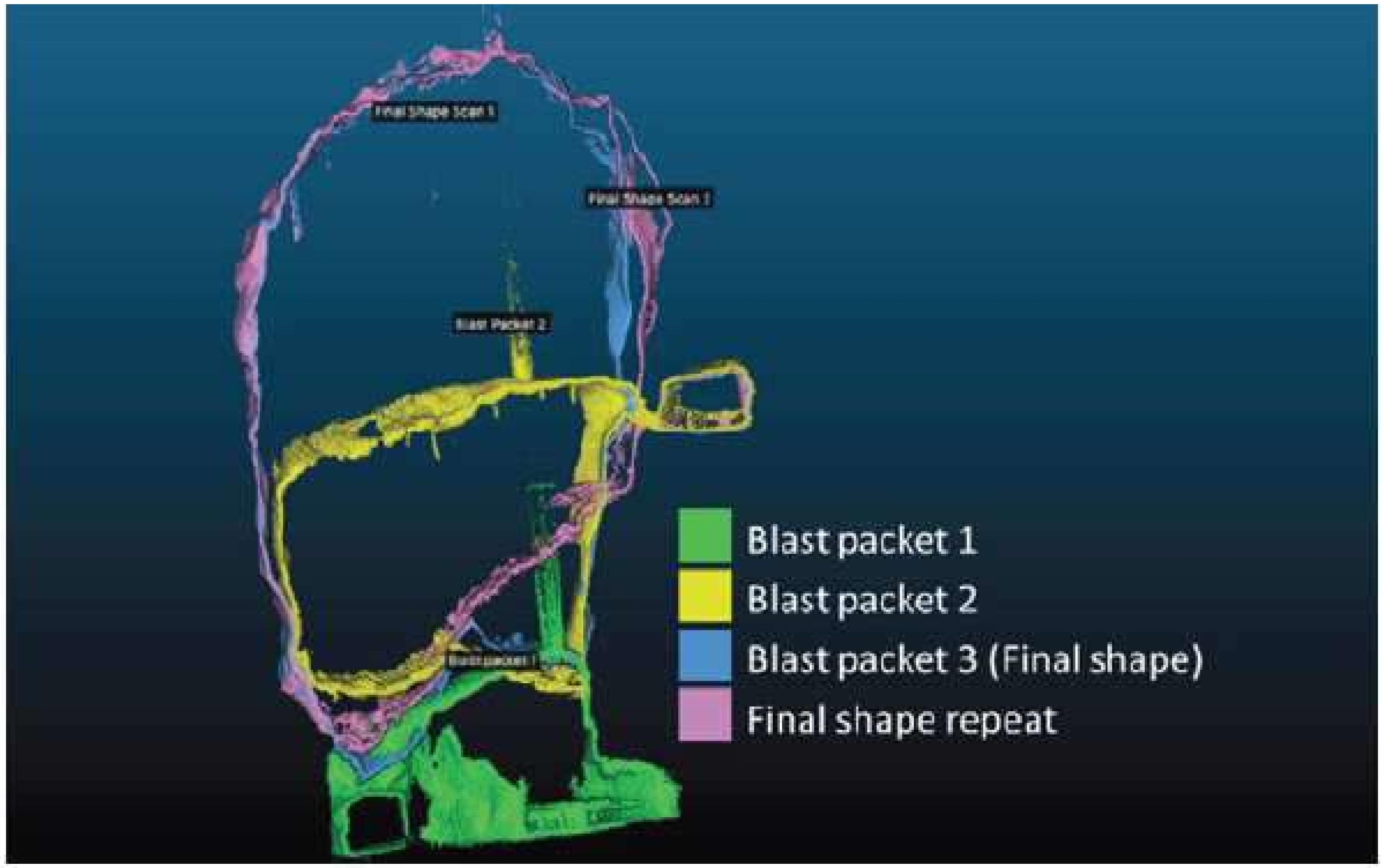
MINING APPLICATIONS

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.

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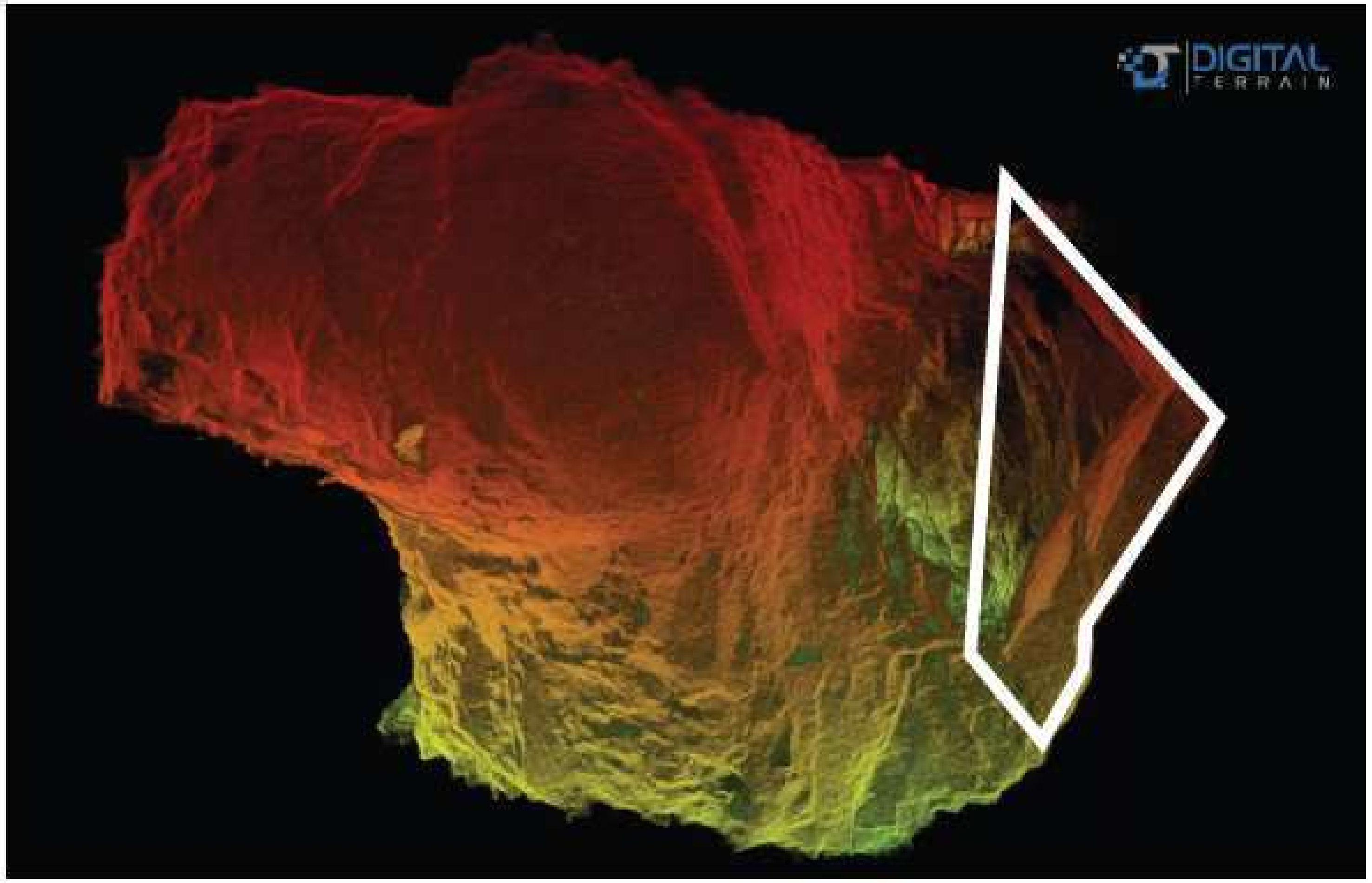
14 OVER AND UNDER-BREAK

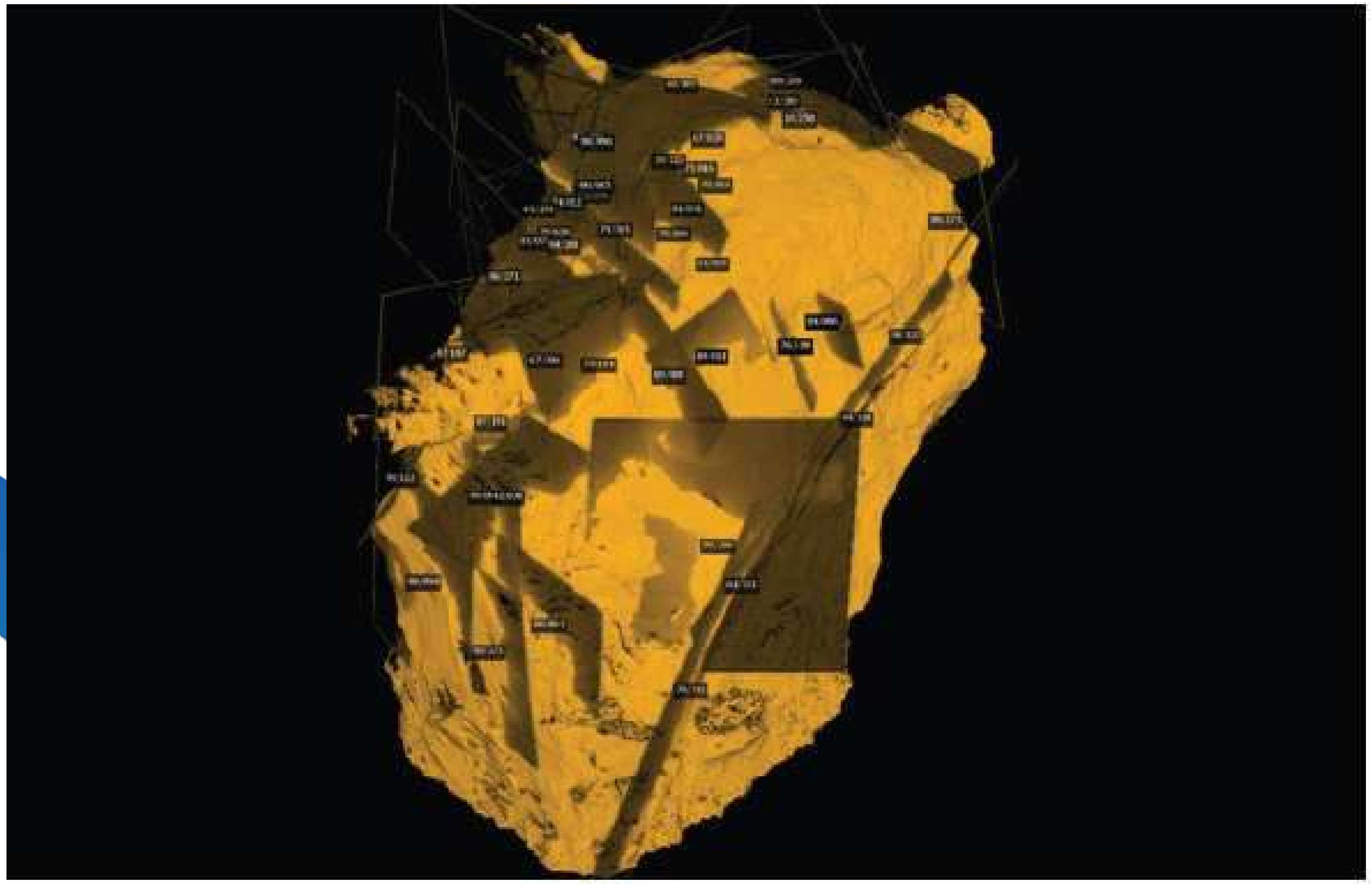
The value extracted from a stope is one of the key metrics for an underground operation. Using Hovermap to scan stopes regularly can help to maximize this value.

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.

MINING APPLICATIONS



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.

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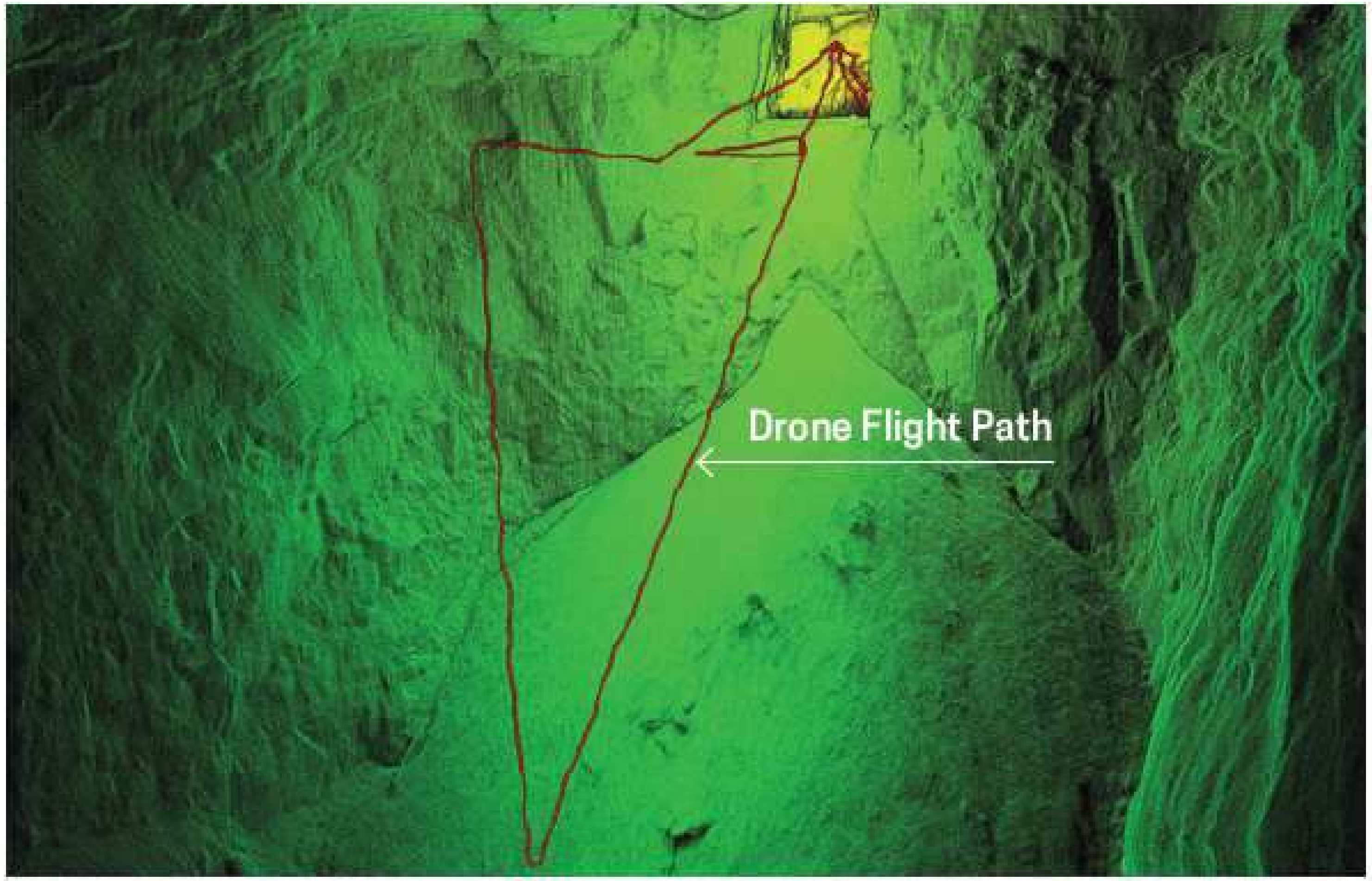
16 BACKFILL HEIGHT / VOLUME

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.

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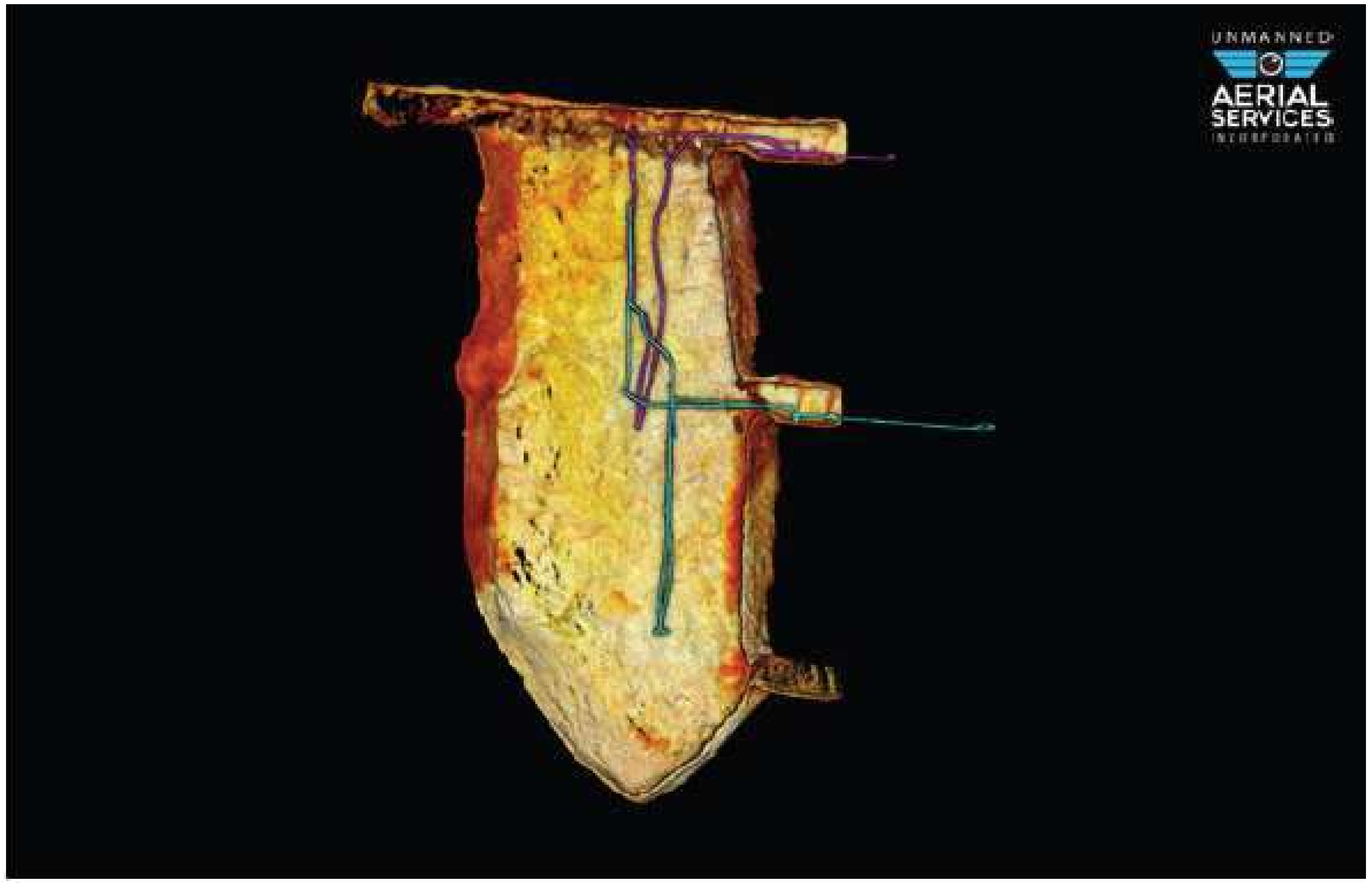
17 STOPE DIMENSIONS

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.

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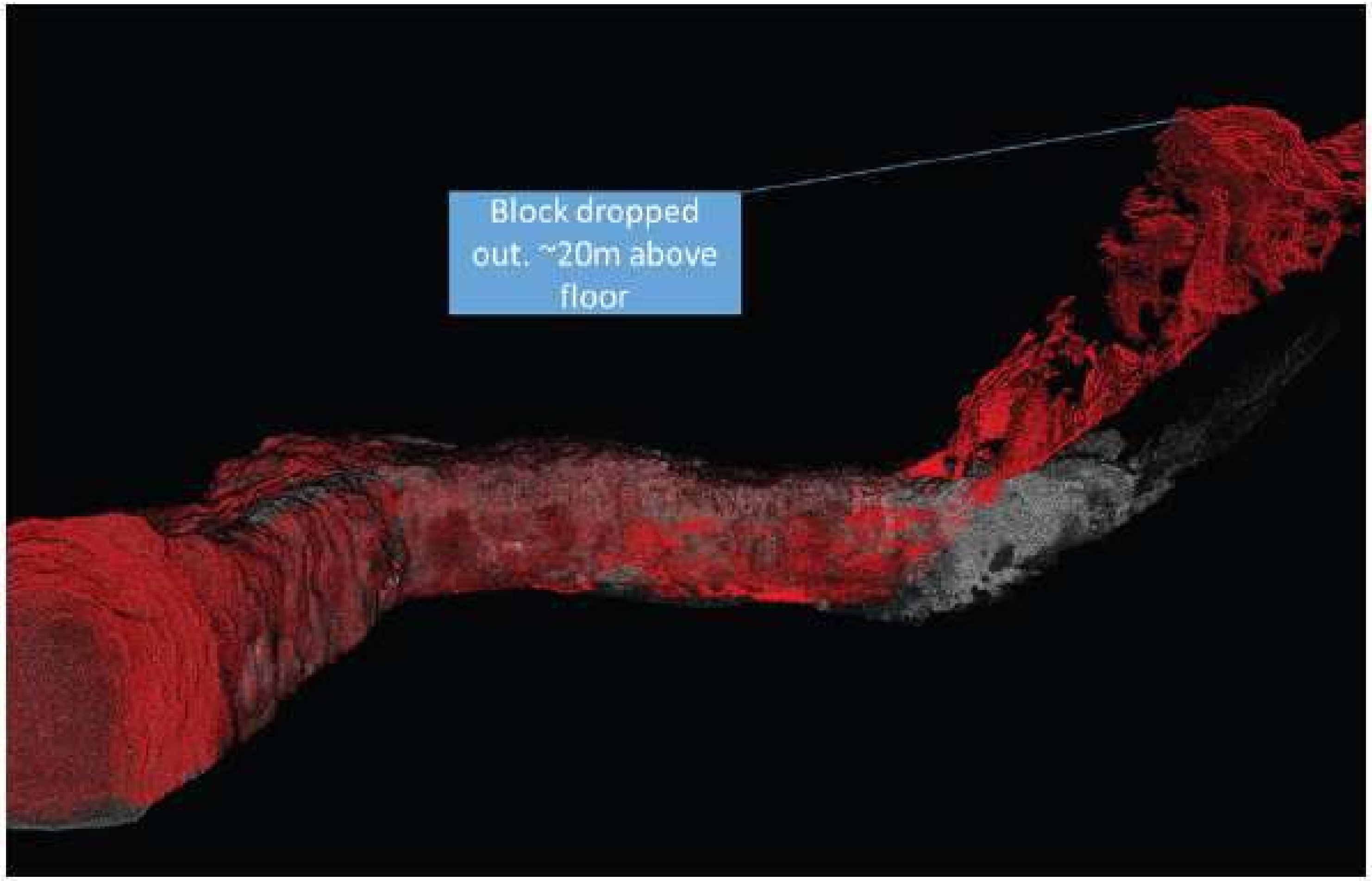

Two Hovermap scans of a drawpoint at the BHP Olympic Dam mine, taken a week apart and merged, record brow movement as a result of bogging. The original scan is gray, while the later red scan shows a very large block has dropped from the back. (Source: BHP, Evan Jones, Emesent webinar.)

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.

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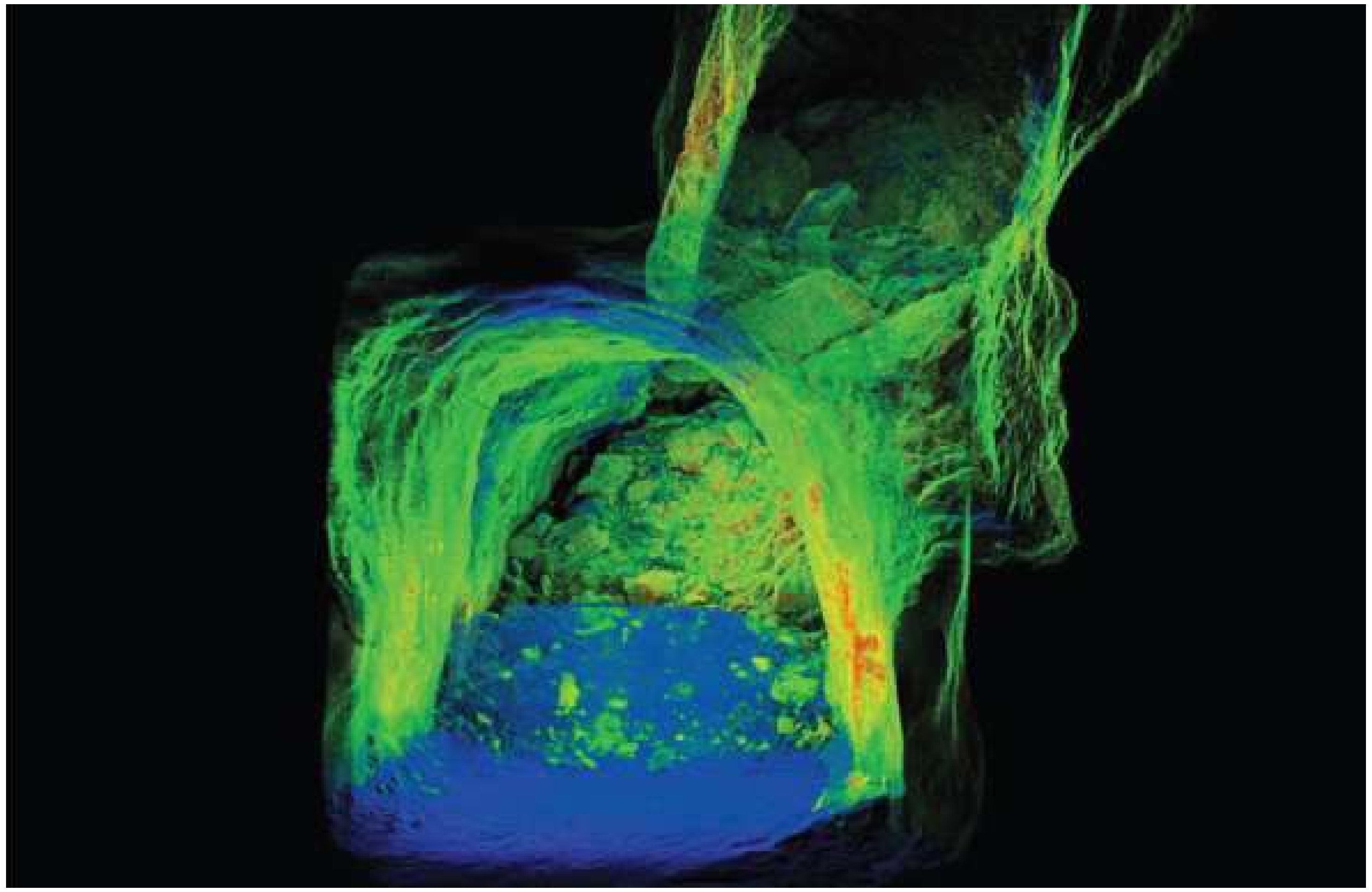
19 DRAWPOINT INSPECTION

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.

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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.

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Hovermap Data Capture
for the Digital Mine