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AUTONOMOUS DRONES UNDERGROUND

CHALLENGES AND BENEFITS

DR. STEFAN HRABAR
CEO & CO-FOUNDER
EMESENT

AUTONOMOUS FLIGHT IN CHALLENGING CONDITIONS

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AUTONOMOUS FLIGHT IN CHALLENGING CONDITIONS

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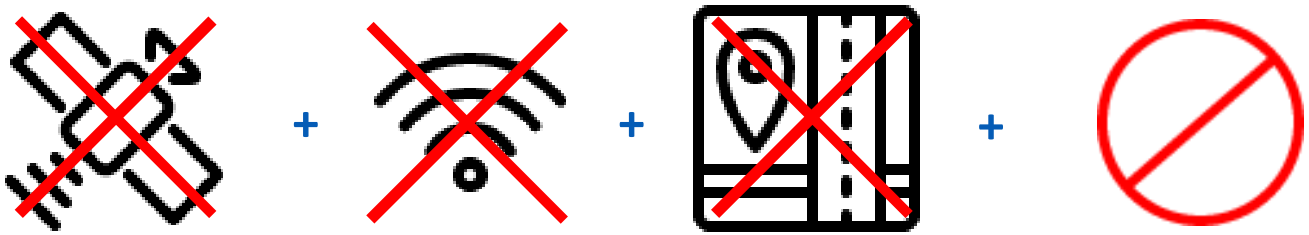
PROBLEM – COLLECTION AND ANALYSIS OF DATA

IN GPS-DENIED AND CHALLENGING ENVIRONMENTS

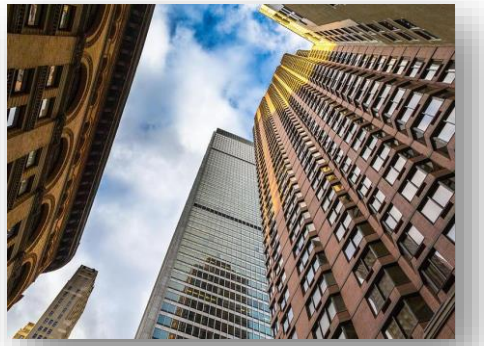


MINING

RAIL & ROAD

INDOORS

SEARCH & RESCUE



URBAN

THE UNDERGROUND DATA COLLECTION CHALLENGE

- As mines become deeper, they are subject to more seismicity and other hazards so require more monitoring
- Paradoxically, monitoring becomes more challenging and hazardous at depth
- Increased drive to remove humans from hazardous areas while still requiring increased levels of data collection for monitoring
- Autonomous underground data collection can offer a solution

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DRONES UNDERGROUND - CHALLENGES

- Technical
  - no GPS, no comms, BVLOS
- Environment
  - Dust, water, wire, mesh
- Operational / Integration
  - Drone pilot skills
  - Integration with current workflows
  - Data volume / management
- Return on Investment / Business Case
  - Need to justify the expense and show value
- Regulations
  - CASA (if also used above ground)
  - Standard Operating Procedures

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  - Data volume / management

Autonomy / data processing

- Return on Investment / Business Case
  - Need to justify the expense and show value
- Regulations
  - CASA (if also used above ground)
  - Standard Operating Procedures

Case studies / early adopters leading to mainstream use

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HOVERMAP : LIDAR MAPPING + AUTONOMY

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

SLAM LIDAR MAPPING

GPS-DENIED FLIGHT

COLLISION AVOIDANCE

ADVANCED AUTONOMY

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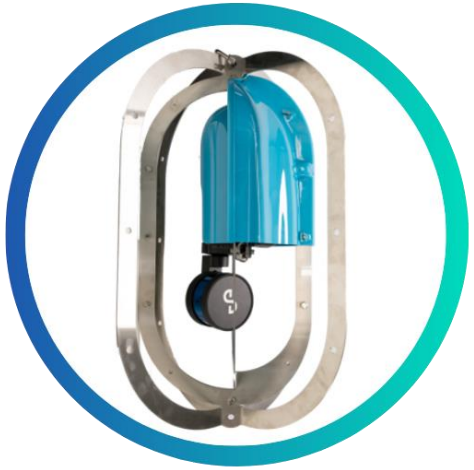
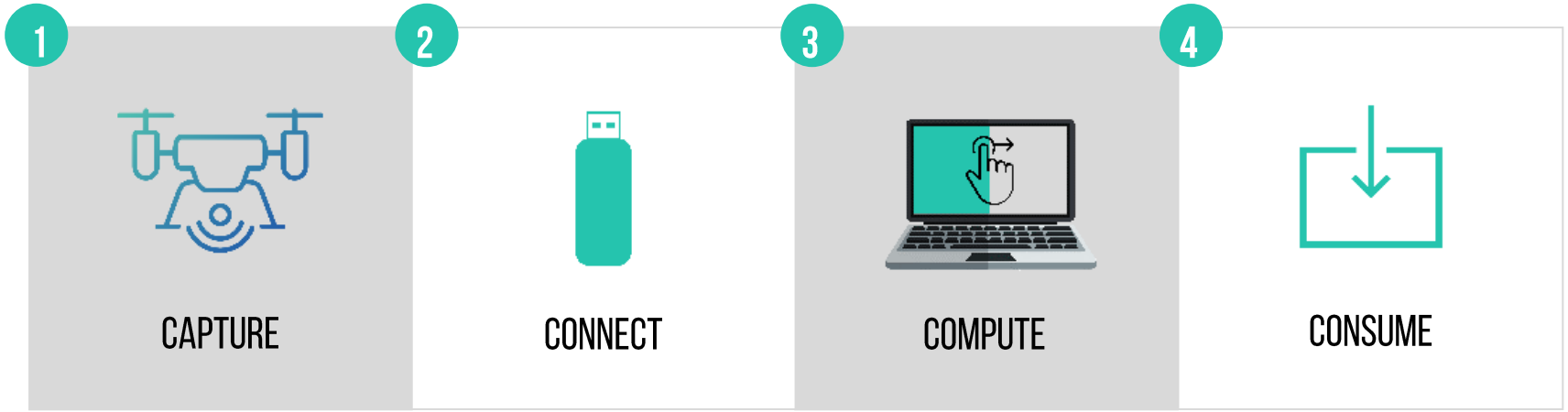
DANGER
NO UNAUTHORISED ENTRY
DANGER
DRILLING ABOUT TO BREAK THROUGH

ON AND OFF-DRONE USE



DATA CAPTURE AND PROCESSING WORKFLOW



Fly/Walk/Drive

Download via USB

Process data
2 times flight time

High resolution data
.las, .laz, .ply, .dxf

Deswik

MAPTEK

MICROMINE

DATAMINE

EMESENT LEVELS OF AUTONOMY

AUTONOMY LEVEL 0
MAPPING ONLY MODE

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

AUTONOMY LEVEL 1
PILOT ASSIST MODE

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

AUTONOMY LEVEL 2
WAYPOINT MODES

- 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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AUTONOMY LEVEL 1 – PILOT ASSIST MODE

- 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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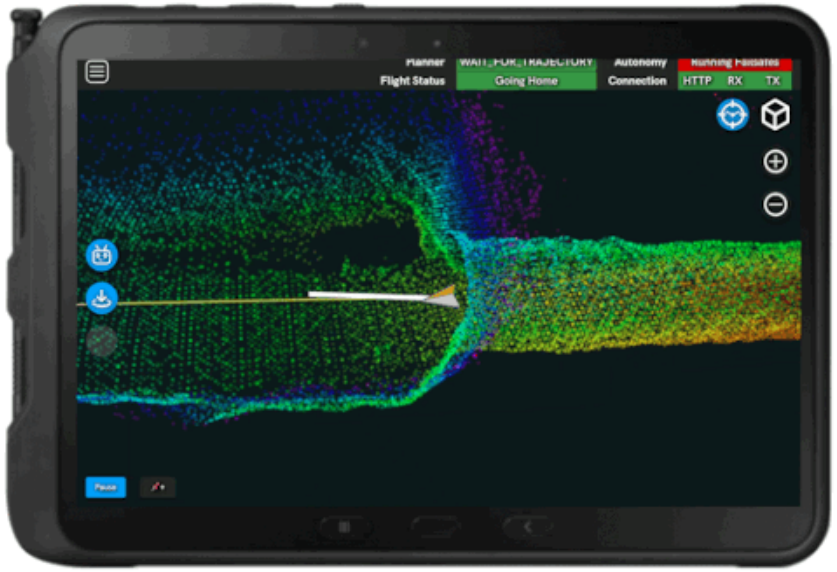
AUTONOMY LEVEL 2 - AUTONOMOUS BVLOS FLIGHT



Built on the mission proven AL1 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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SMART RETURN TO HOME AND FAILSAFES

- Return to home (RTH) via shortest known route
- Low Battery RTH
- Critical Battery Landing
- WiFi or RC communications loss RTH
- Heavy Dust Back-Track
- Poor Waypoint Placement

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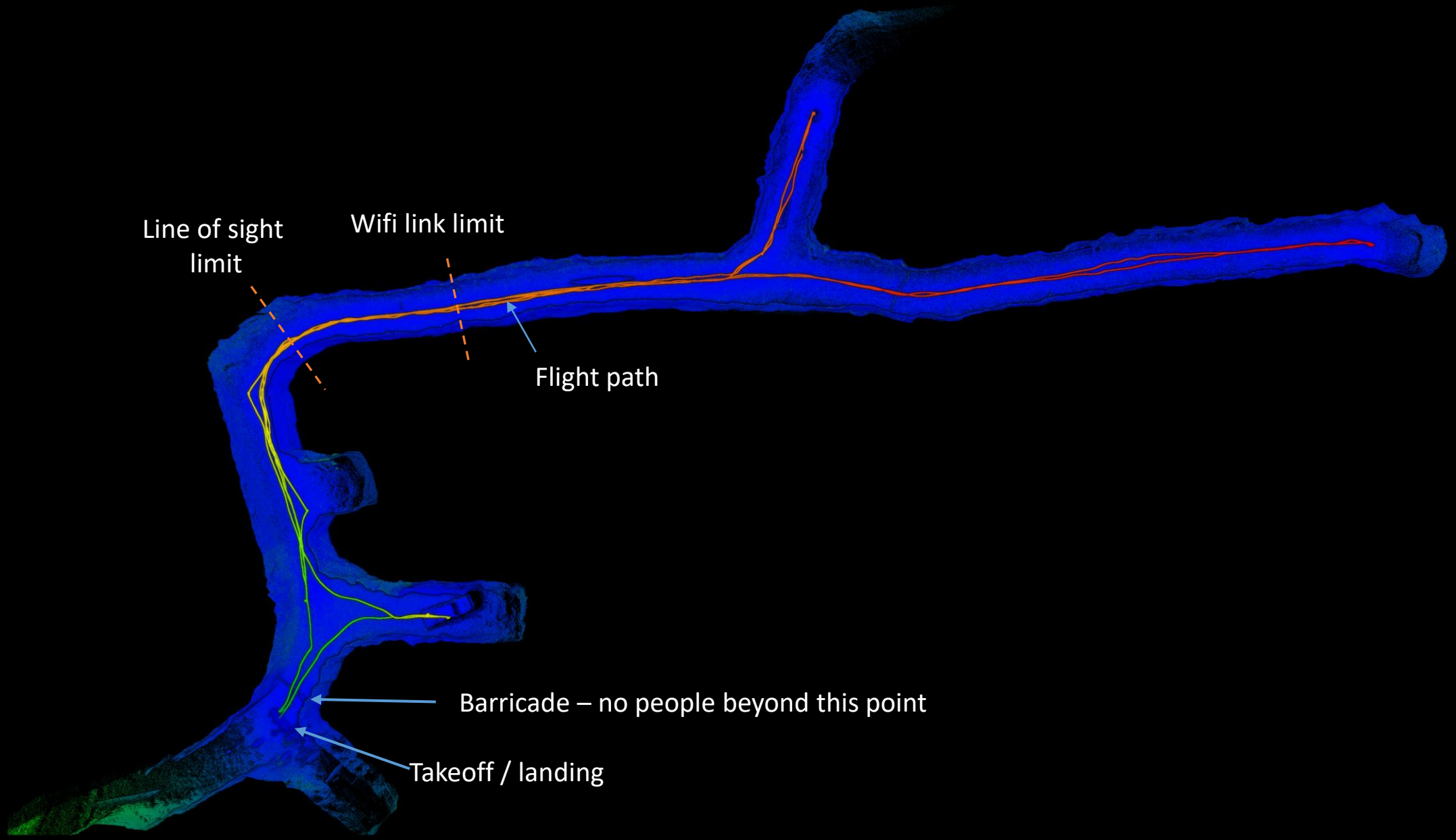
AL2 BVLOS FLIGHT EXAMPLE – DRIVE MAPPING



BVLOS FLIGHT EXAMPLE

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POINT CLOUD FROM BVLOS FLIGHT

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LKAB KIRUNA MINE SCANS AFTER SEISMIC EVENT

"This is a safe and efficient way to work. No one carrying out inspection work will be exposed to any kind of risk.

It is also a very effective means of investigating difficult-to-access areas, ore passes and areas affected by rockbursts.

For example, we have been able to look at one of our loaders, which is in an area we are not currently physically entering.

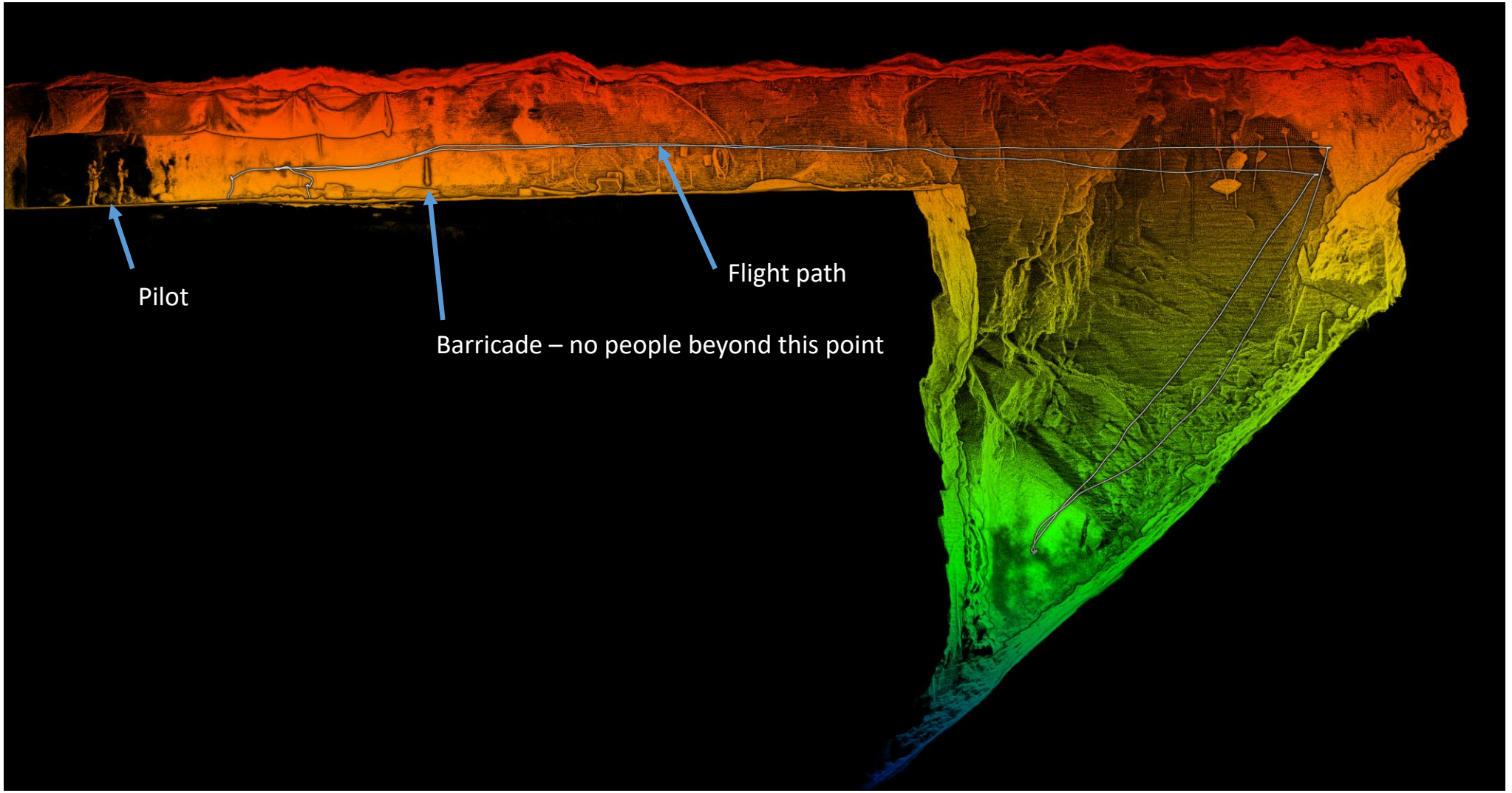
The drone is good tool**, but the scanner is truly revolutionary.**

The scanner is definitely here to stay and will be used for a variety of purposes in the future. "

Per Brännman, section manager LKAB, Kiruna

LKAB AMKVO emesent

STOPE MAPPING



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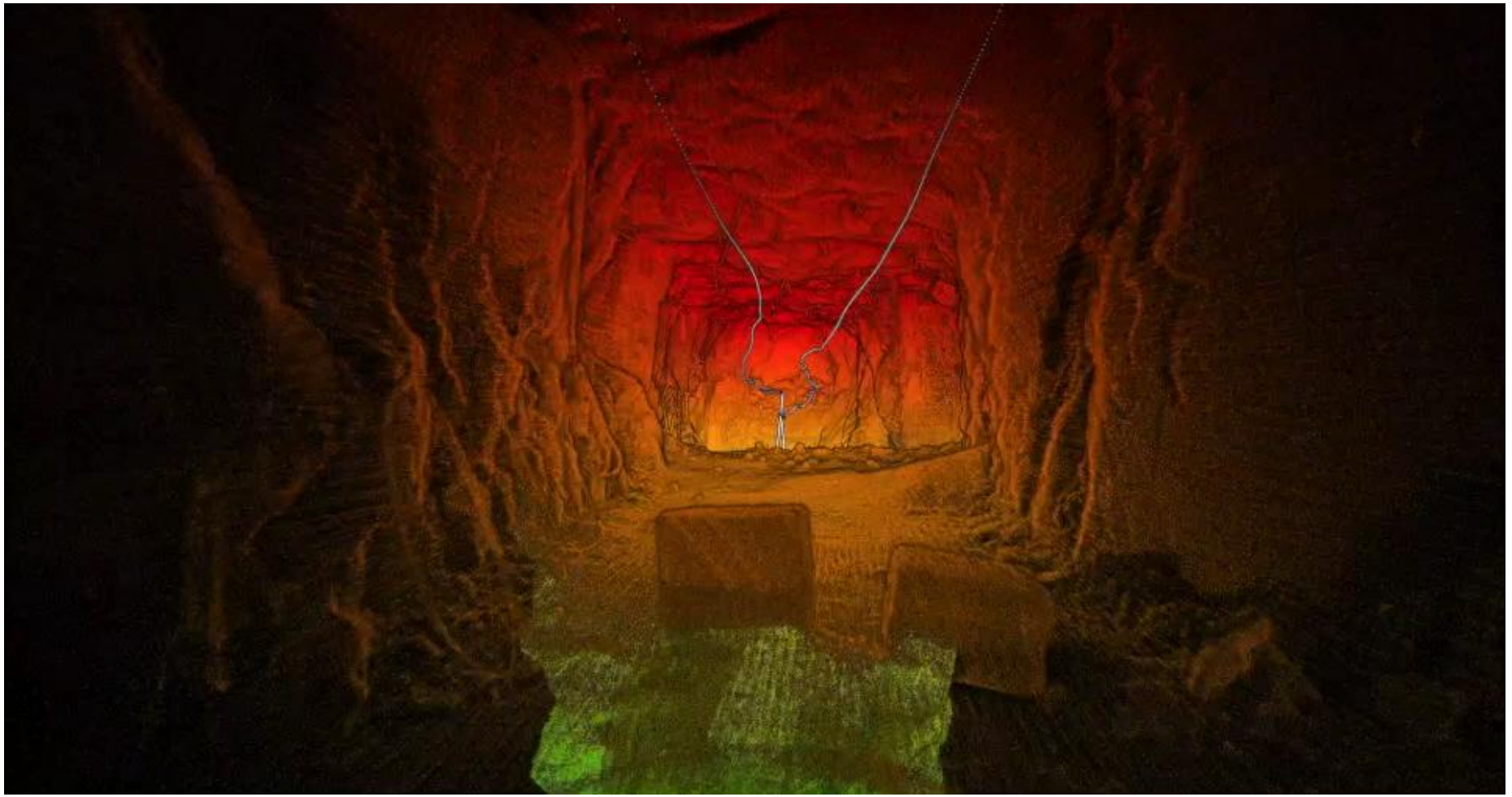
POINT CLOUD FROM BVLOS STOPE FLIGHT



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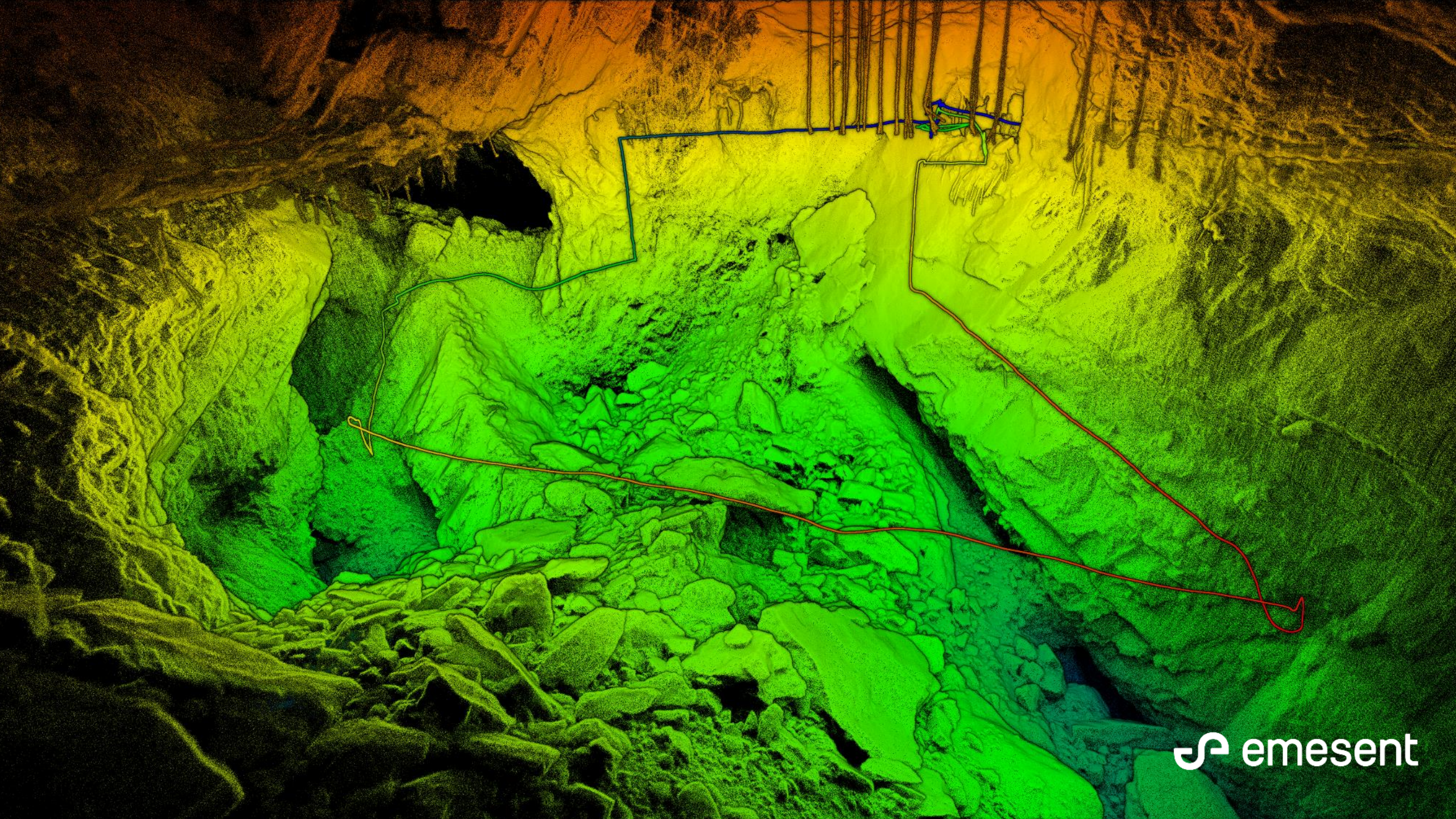
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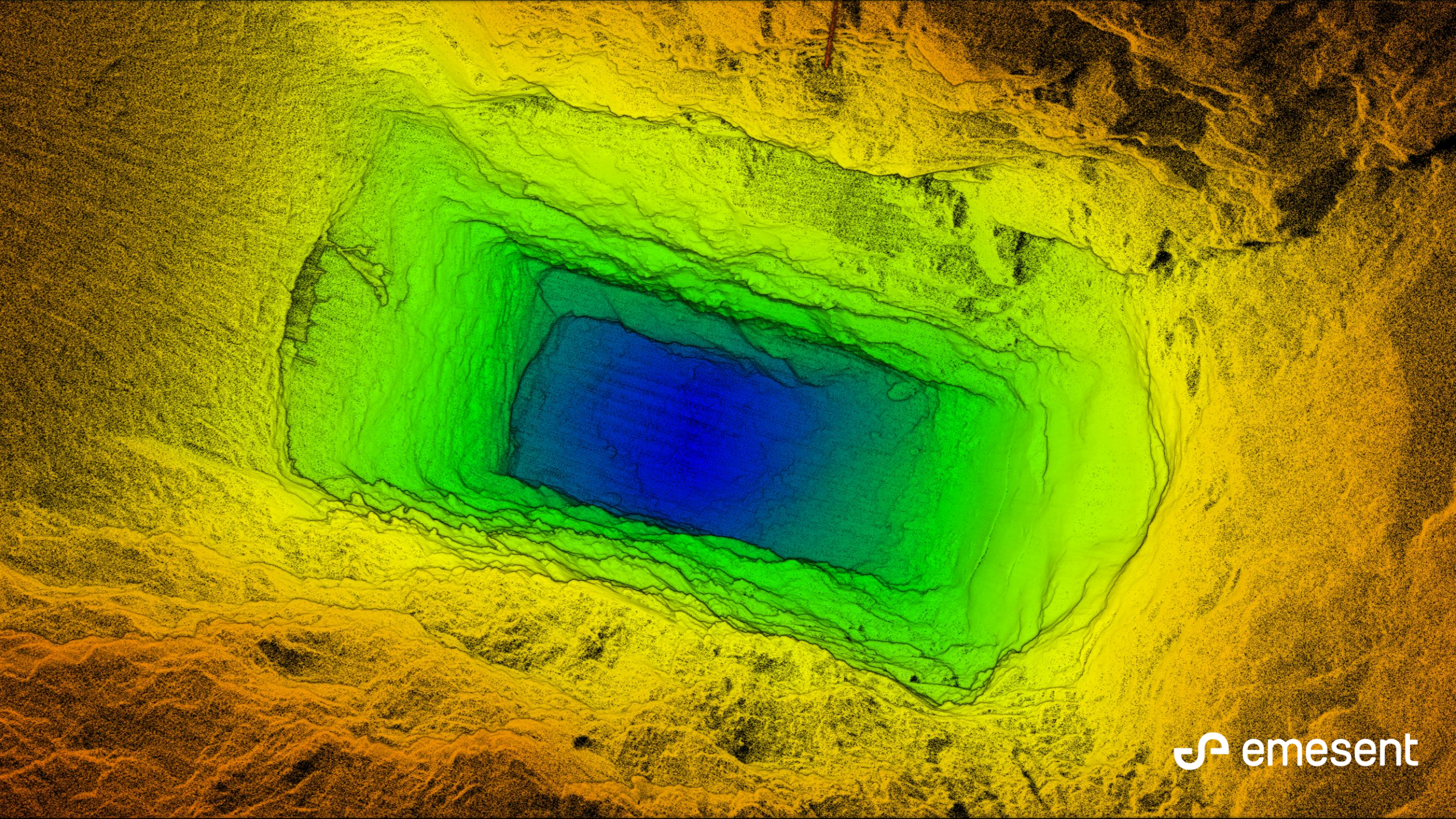
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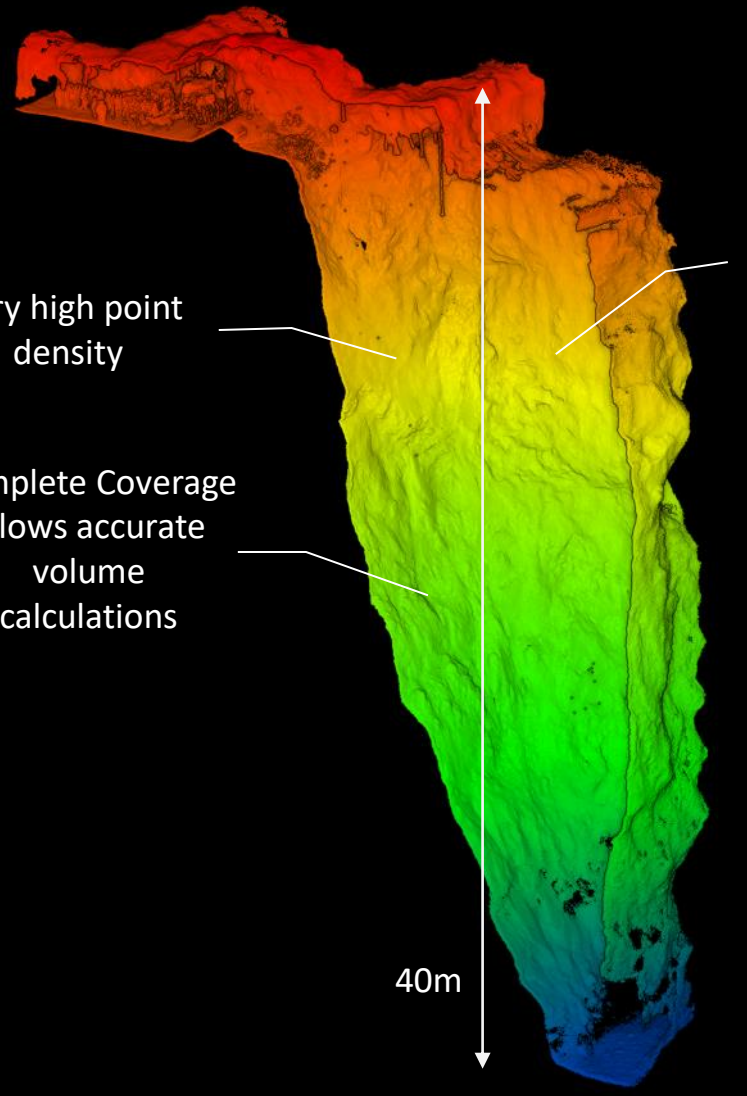
CMS VS HOVERMAP DATA

Low point density

Missing Data (shadowing)

CMS SCAN



Very high point density

Complete Coverage allows accurate volume calculations

Level of detail allows valuable identification of geotechnical structures such as faults and fracture planes

40m

Hovermap Scan (cross-section)
Captured by 5min flight

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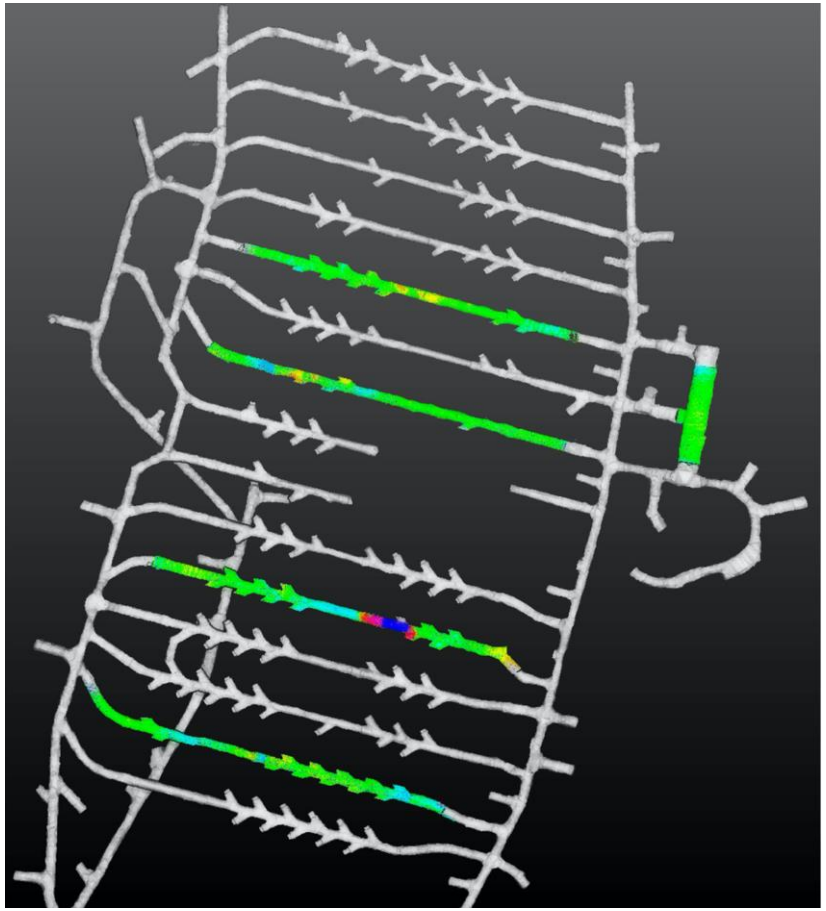
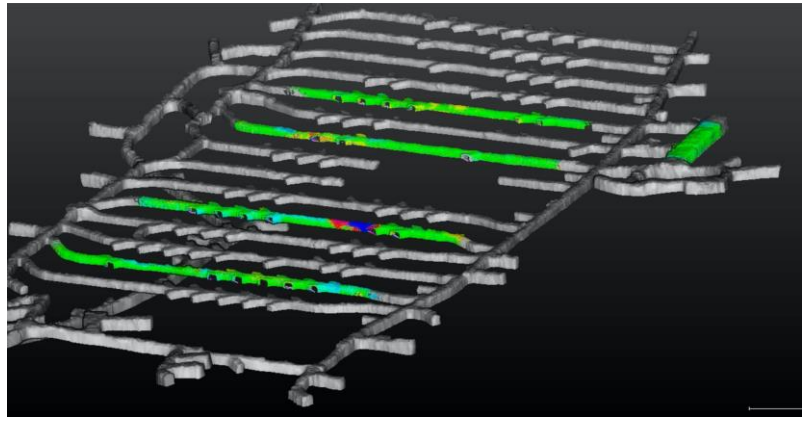
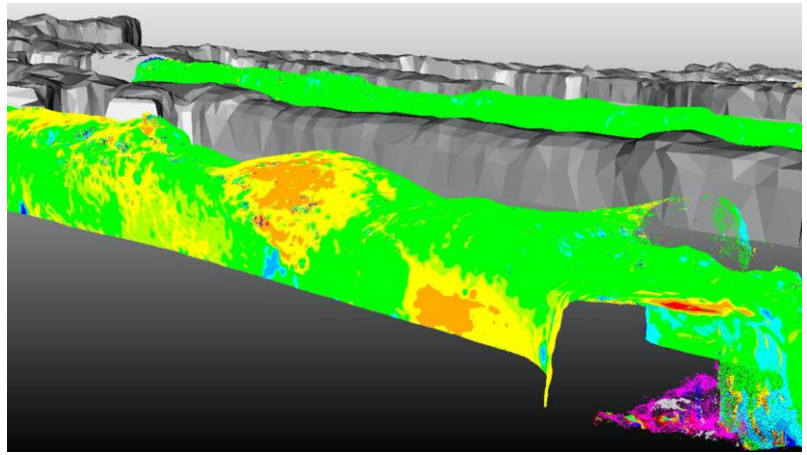
CONVERGENCE MONITORING TRIAL







- Scans captured 3 months apart
- Walking and vehicle mount
- Compared to extensometer:
  - Capture and processing time
  - Precision
  - Integration into mine model

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CONVERGENCE MONITORING TRIAL – EXEC. SUMMARY

- Data for a complete extraction drive (approximately 200m) could be collected in 7 minutes.
- A point cloud could be generated in 20 minutes with processing of displacement taking approximately 1 hour per extraction drive (using manual processing).
- Results had an **average difference of 2.1mm to conventional tape extensometer** readings but showed a significant increase in coverage area.
- Data was directly overlain onto the existing mine wireframes to allow improved data visualisation and integration with other data sources (faults, lithology, monitoring, production data)
- The LiDAR point cloud methodology **does sacrifice a moderate amount of precision but obtains significant improvements in time management, data collection, safety and coverage area.**

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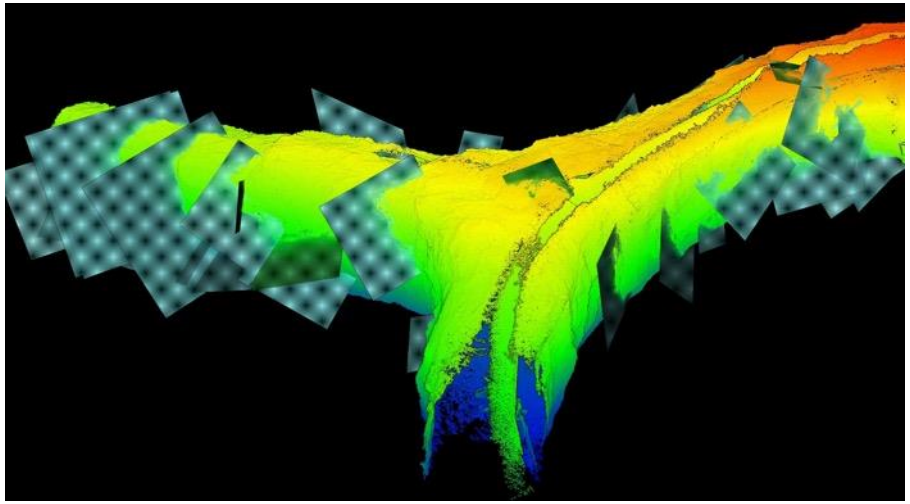
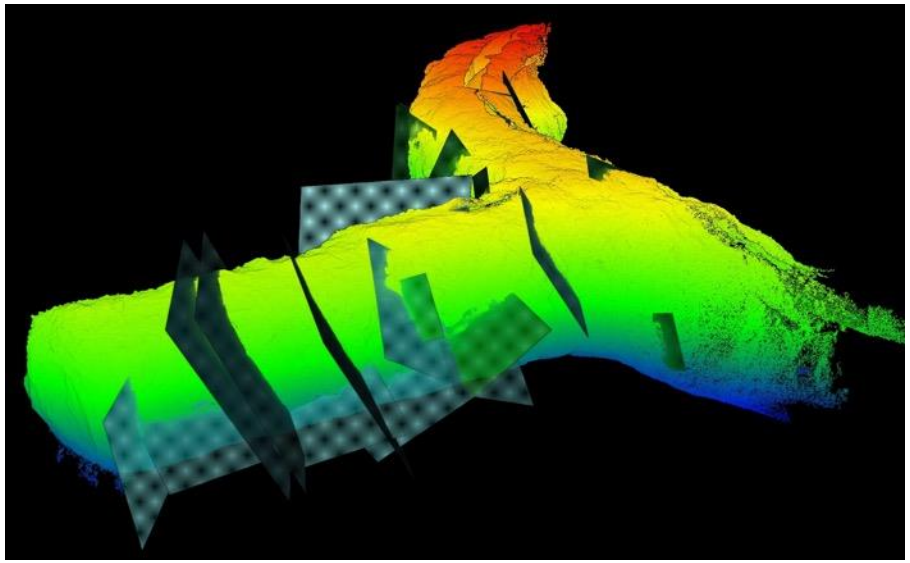
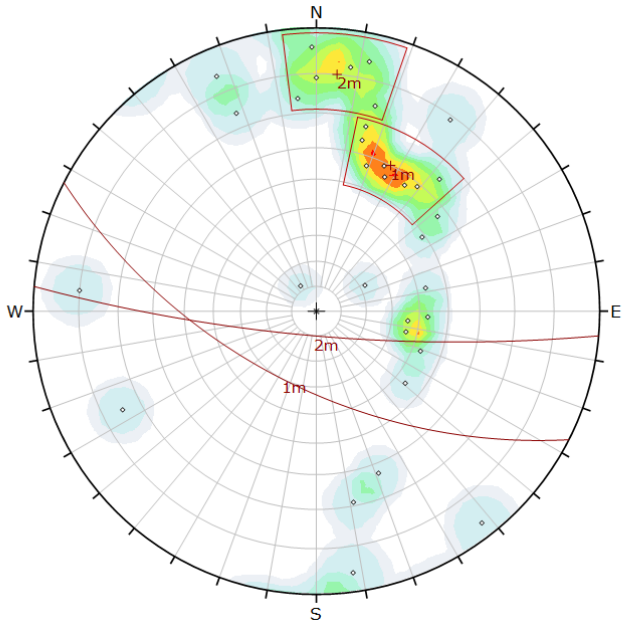
GEOTECH STRUCTURE MAPPING IN DRIVES







Symbol	Feature
◦	Pole Vectors

Color	Density Concentrations
	0.00 - 1.20
	1.20 - 2.40
	2.40 - 3.60
	3.60 - 4.80
	4.80 - 6.00
	6.00 - 7.20
	7.20 - 8.40
	8.40 - 9.60
	9.60 - 10.80
	10.80 - 12.00
Maximum Density	11.03%
Contour Data	Pole Vectors
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		60	207	
2m		80	185	

Plot Mode	Pole Vectors
Vector Count	33 (33 Entries)
Hemisphere	Lower
Projection	Equal Angle

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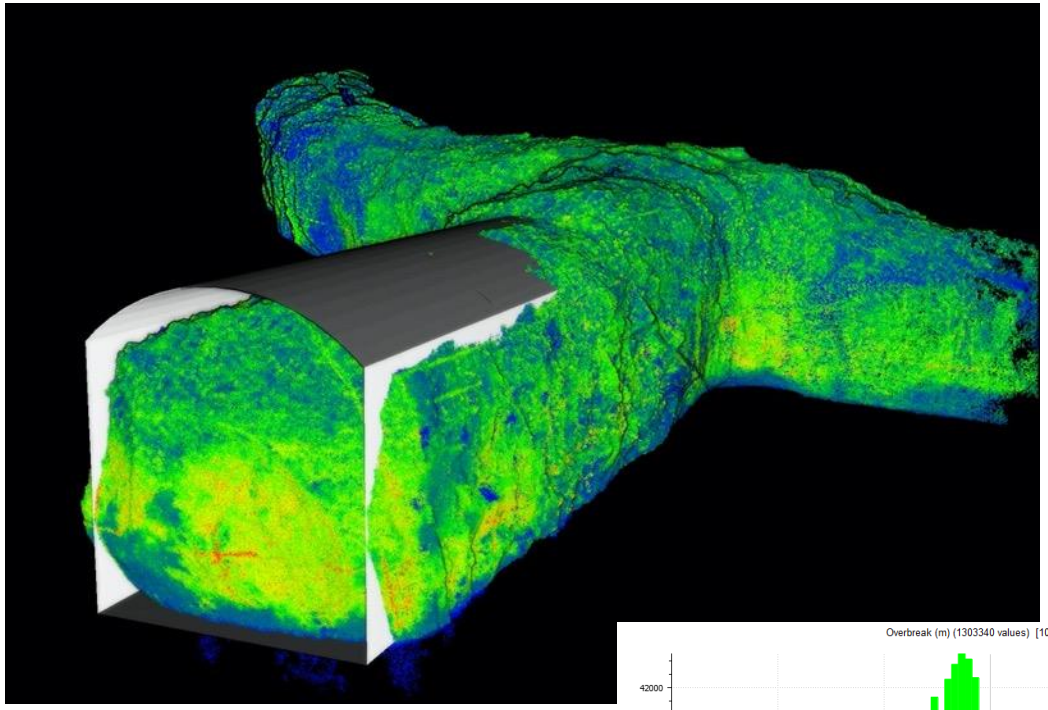
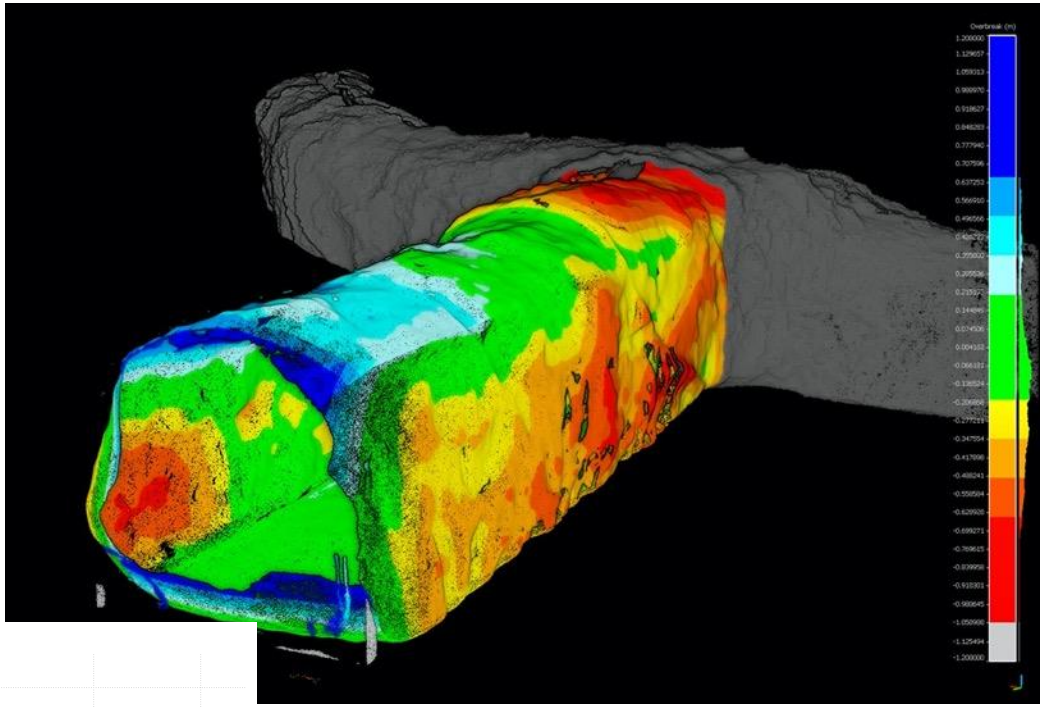
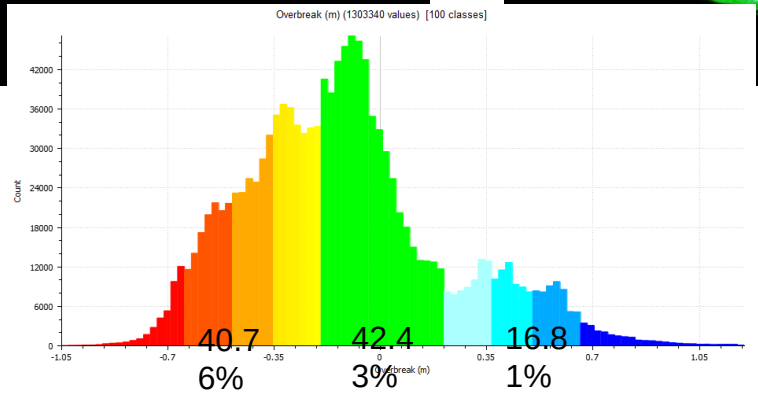
OVERBREAK / UNDERBREAK CALCULATIONS







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DRAWPOINT INSPECTIONS

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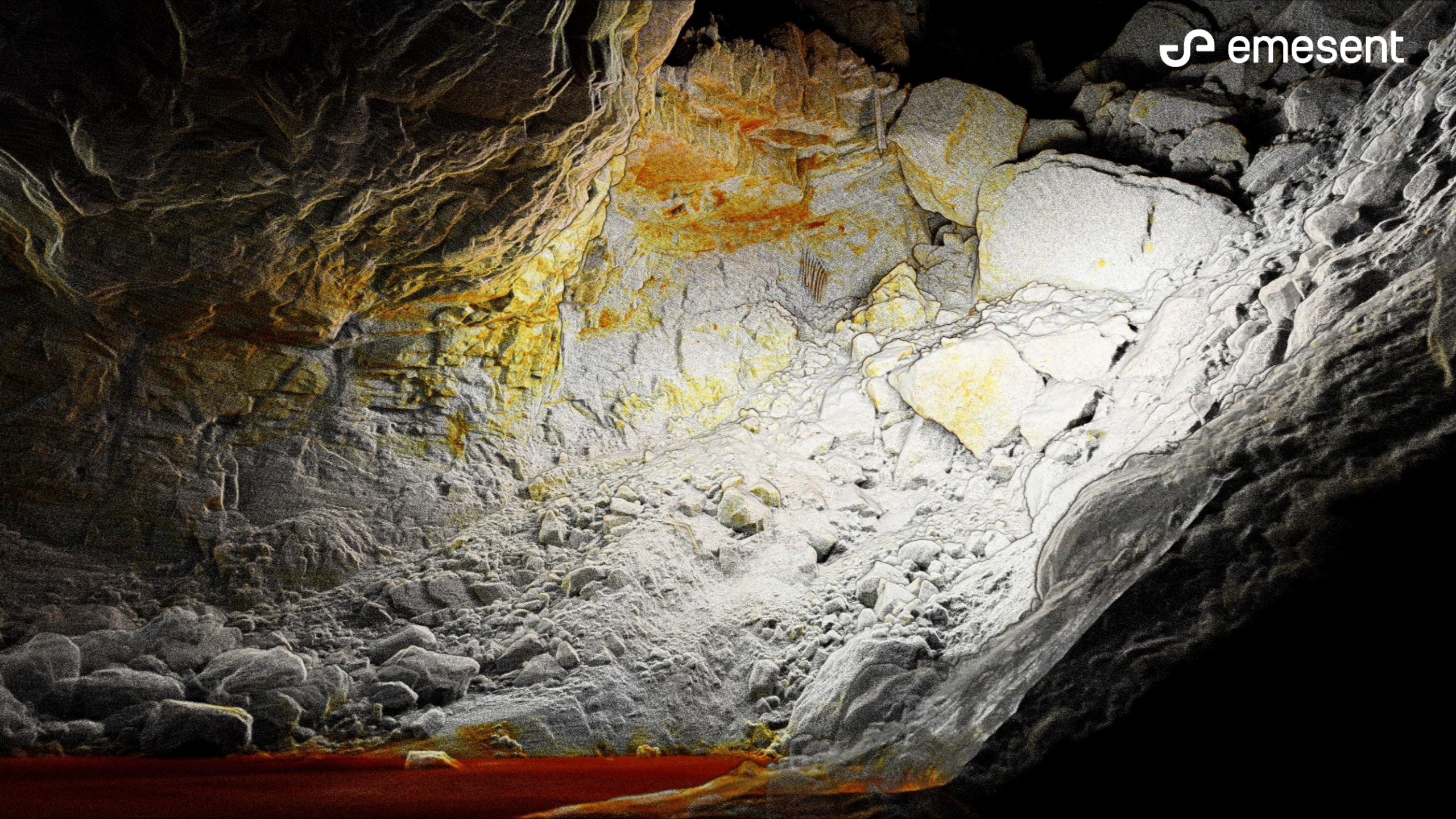
LiDAR data and images captures of hang up

Section through point cloud from autonomous flight into blocked draw point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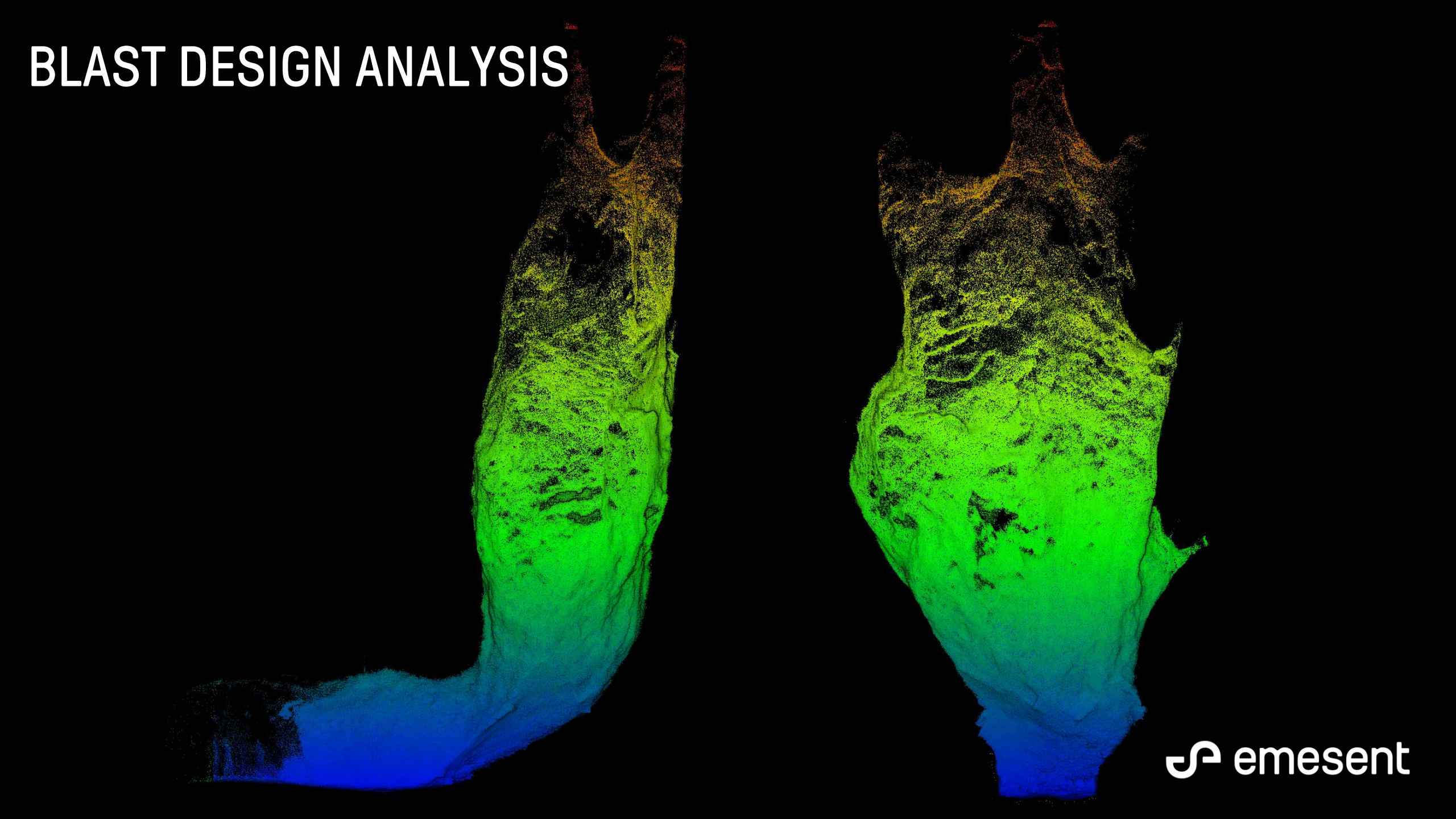
BLAST DESIGN ANALYSIS



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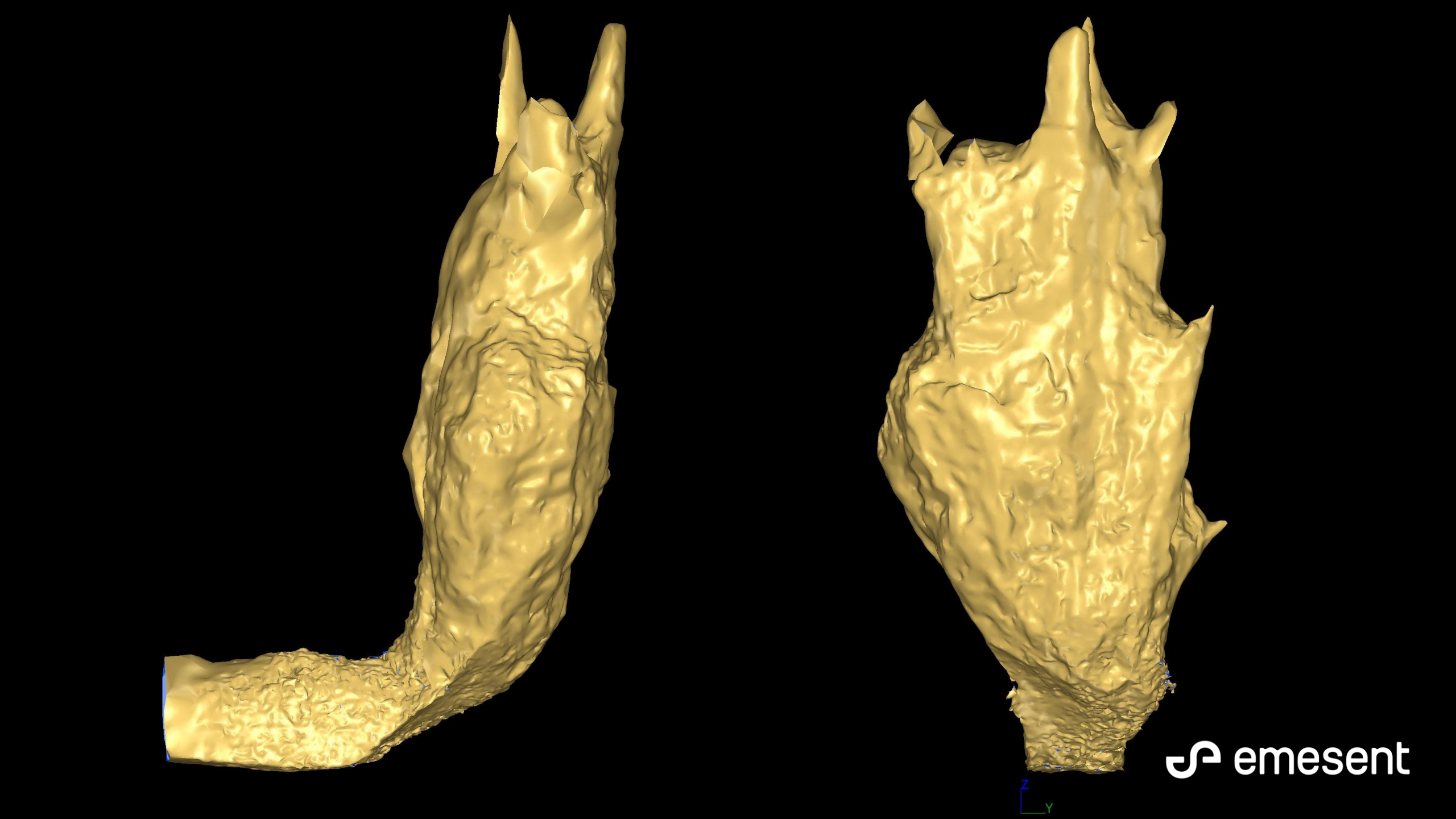
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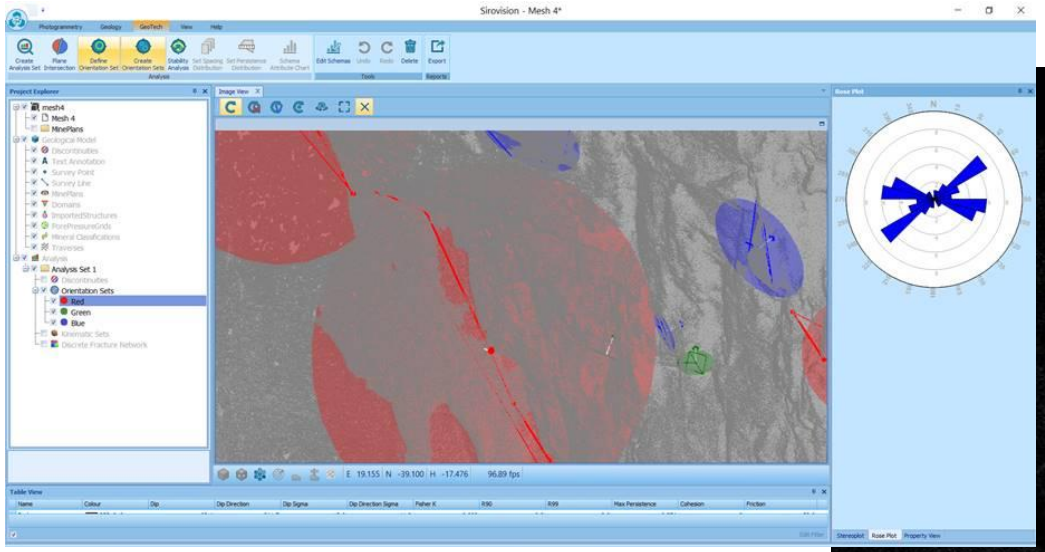
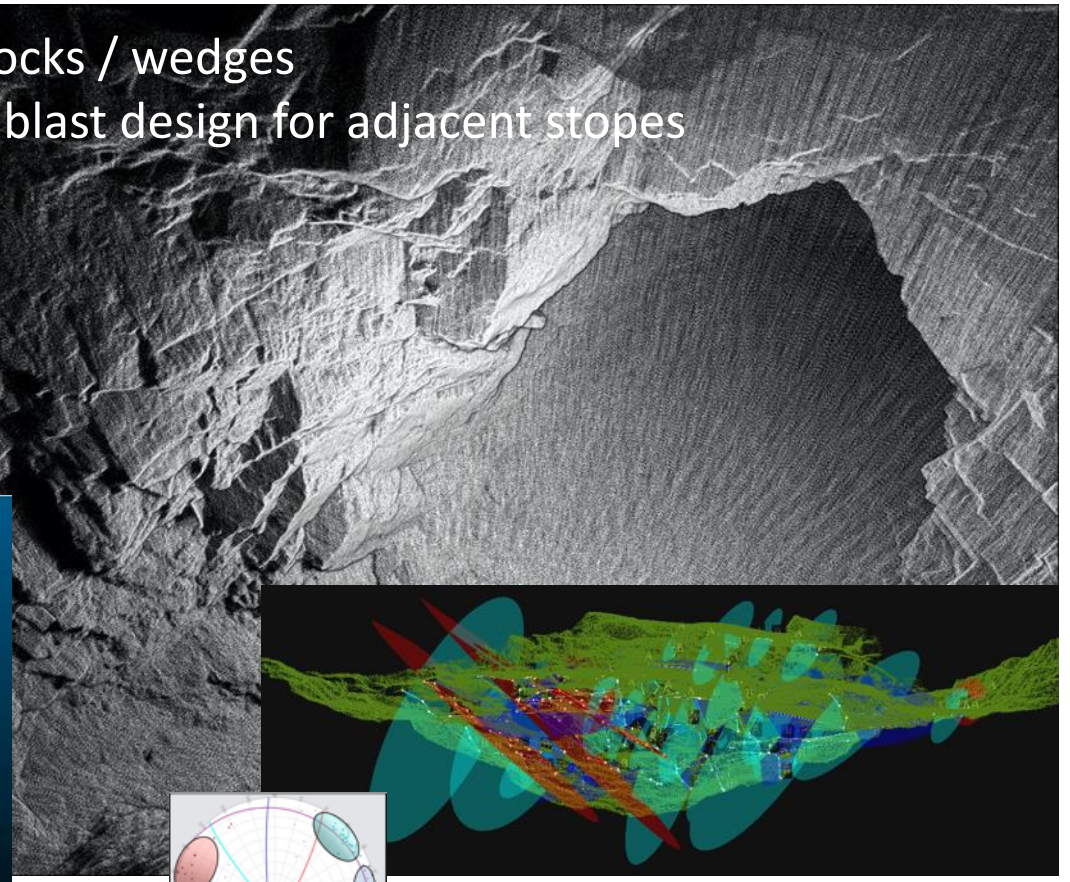
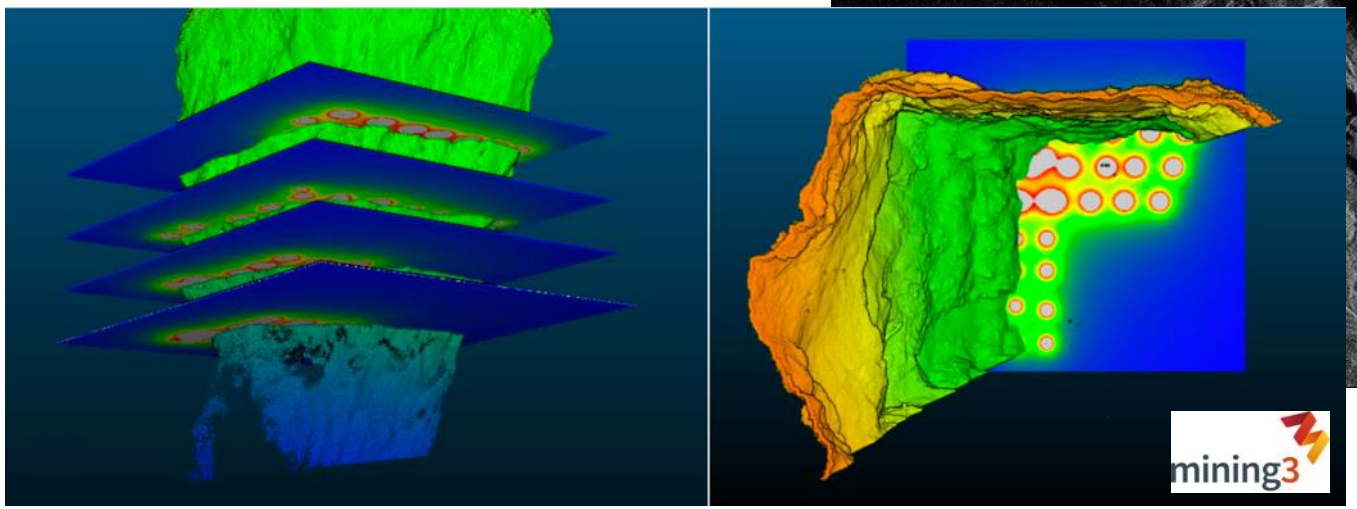
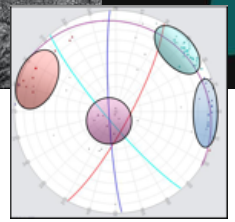
GEOTECH STRUCTURE MAPPING IN STOPES



- Locate blocks / wedges
- Optimize blast design for adjacent stopes







Blast Energy / Stope Shape Analysis

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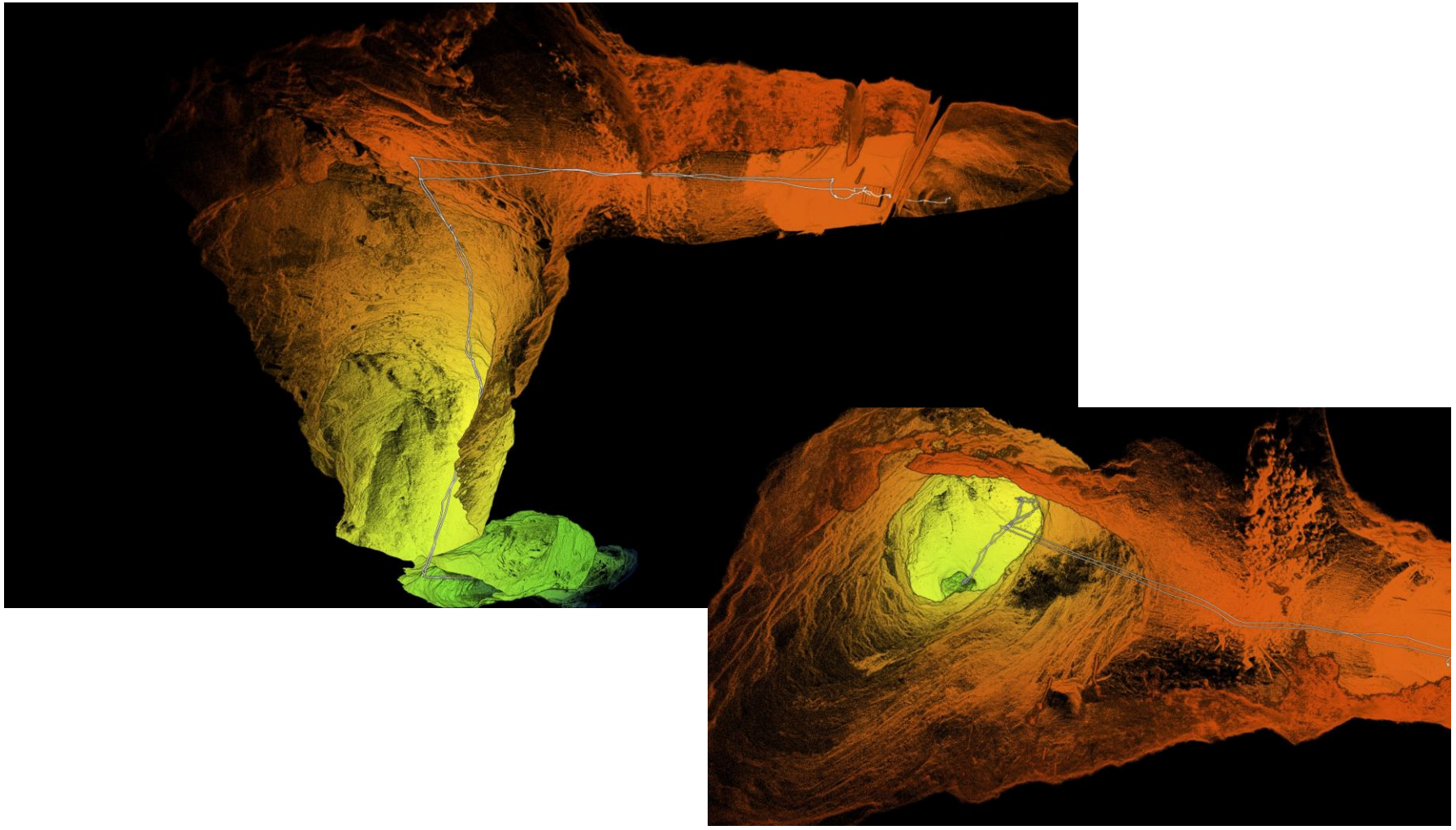
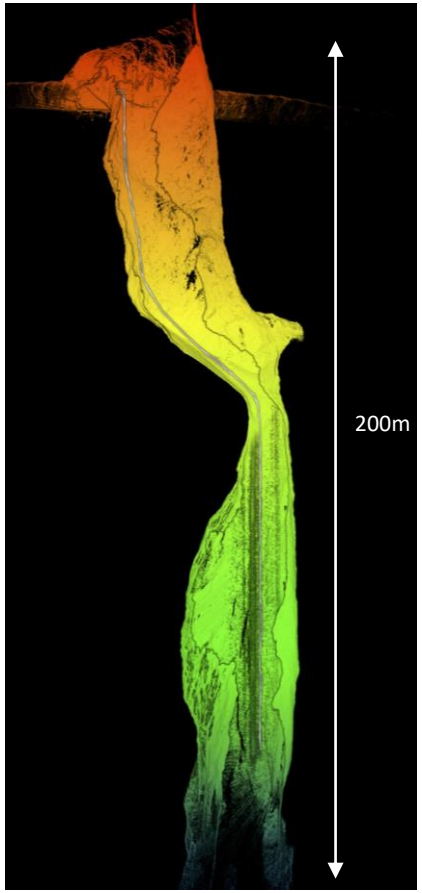
ORE PASS MAPPING – DRONE FLIGHT





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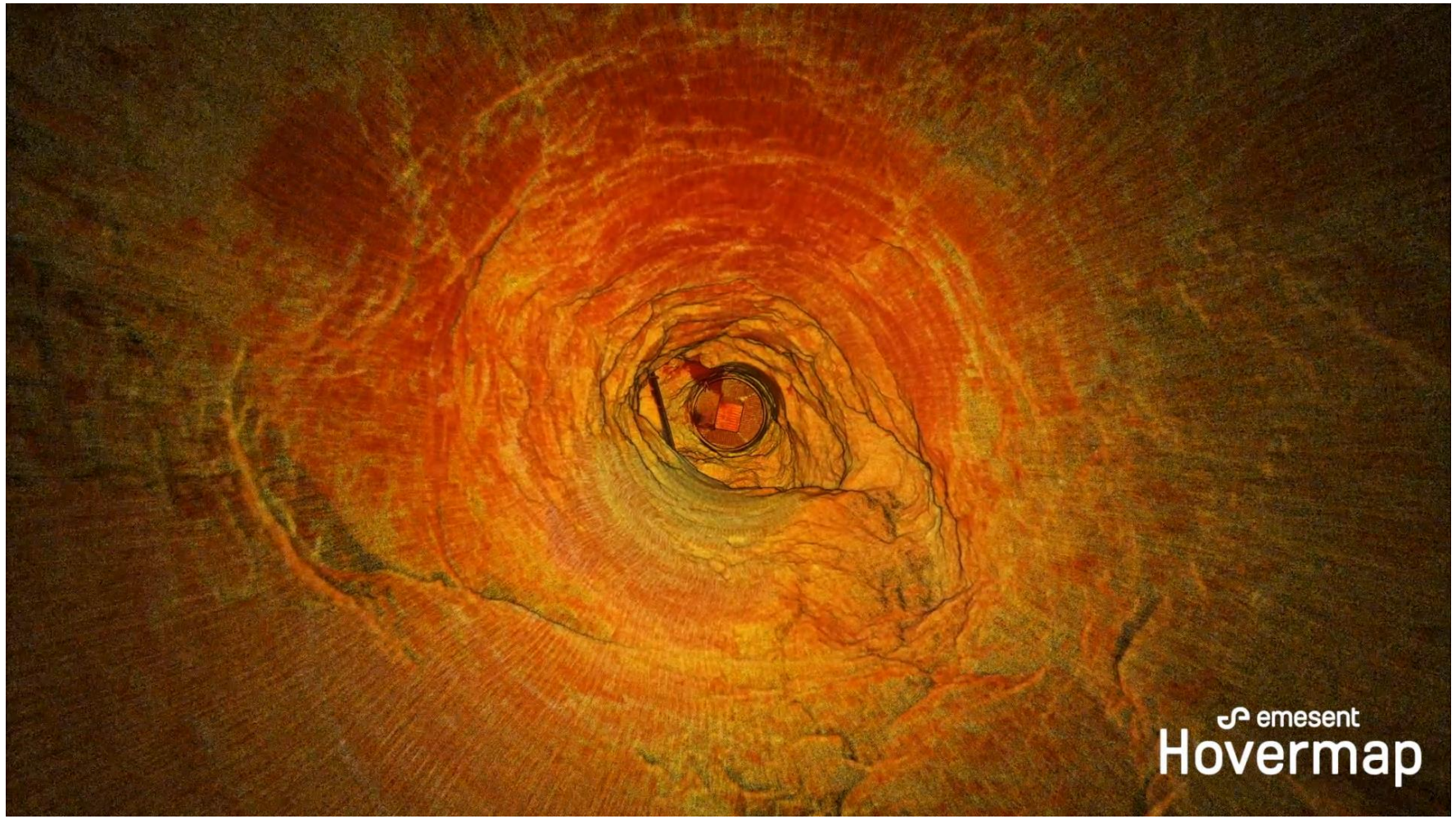
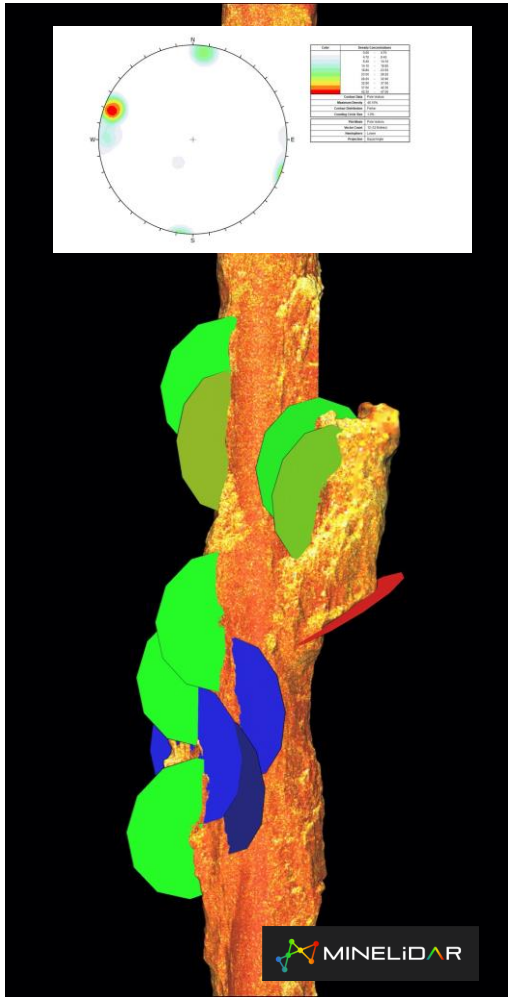
ORE PASS MAPPING – LOWERED VIA CABLE





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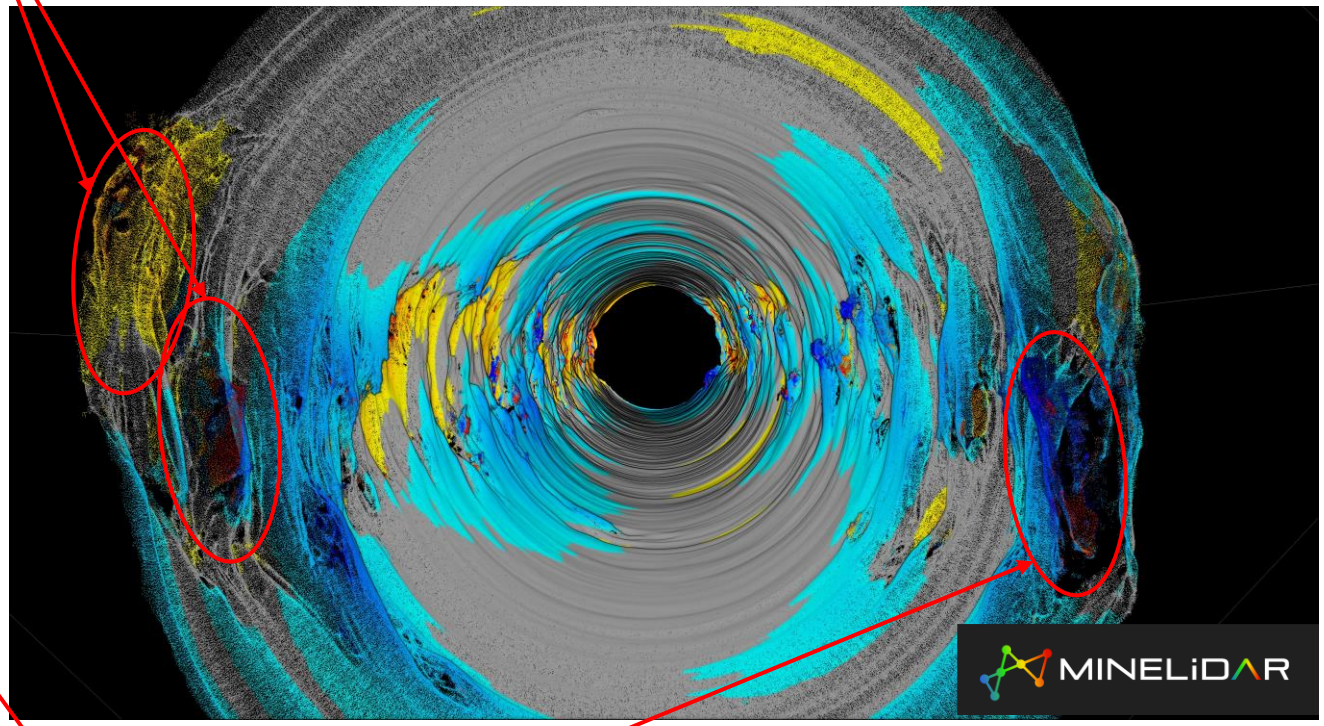
RAISE BORE MAPPING – LOWERED VIA CABLE



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DRONE + GROUND ROBOT TEAMS

Emesent Hovermap-enabled drone is carried by CSIRO Data61 Titan robot to access narrow spaces and preserve drone battery

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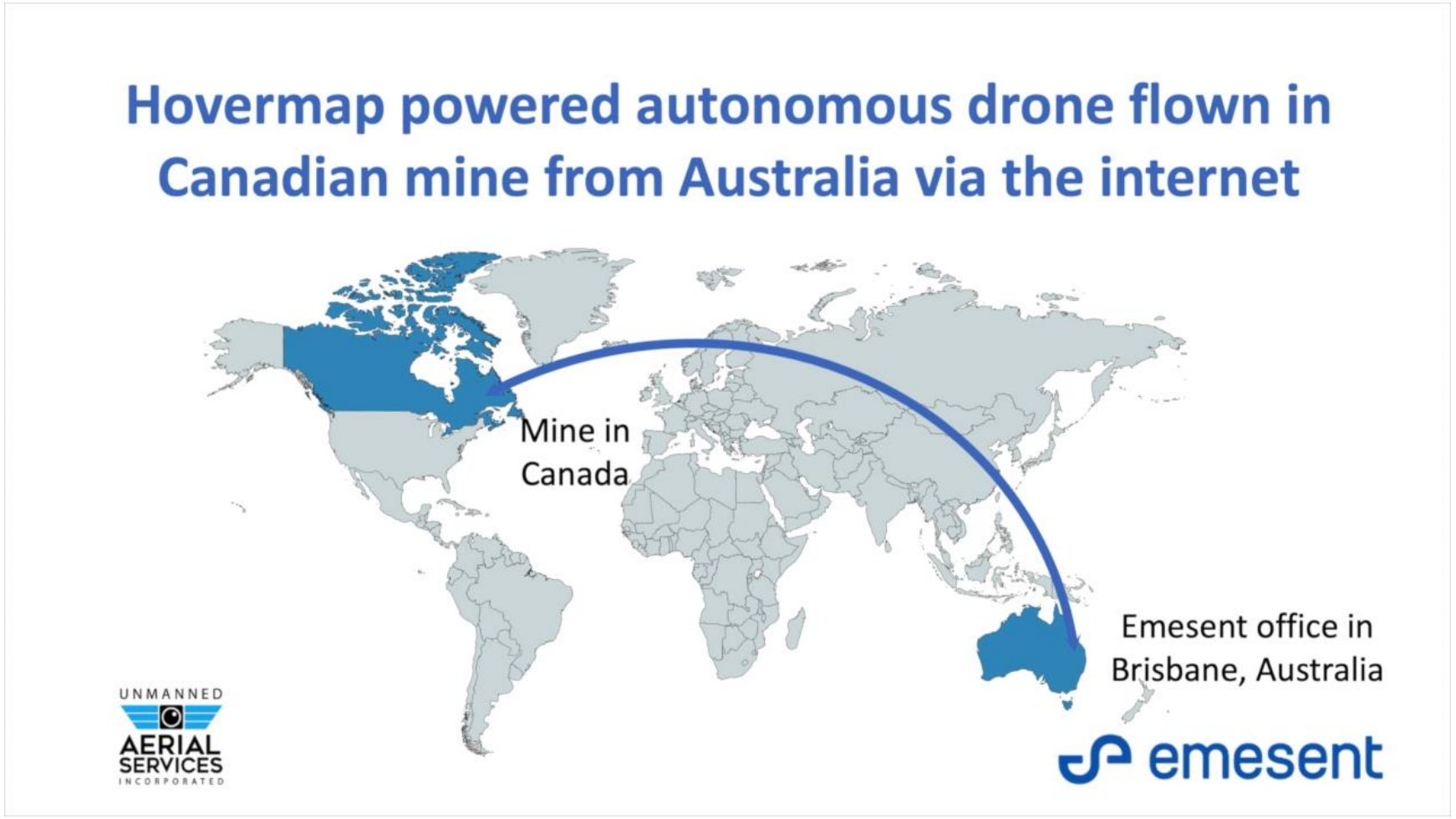
TRANS-CONTINENTAL REMOTE OPERATION



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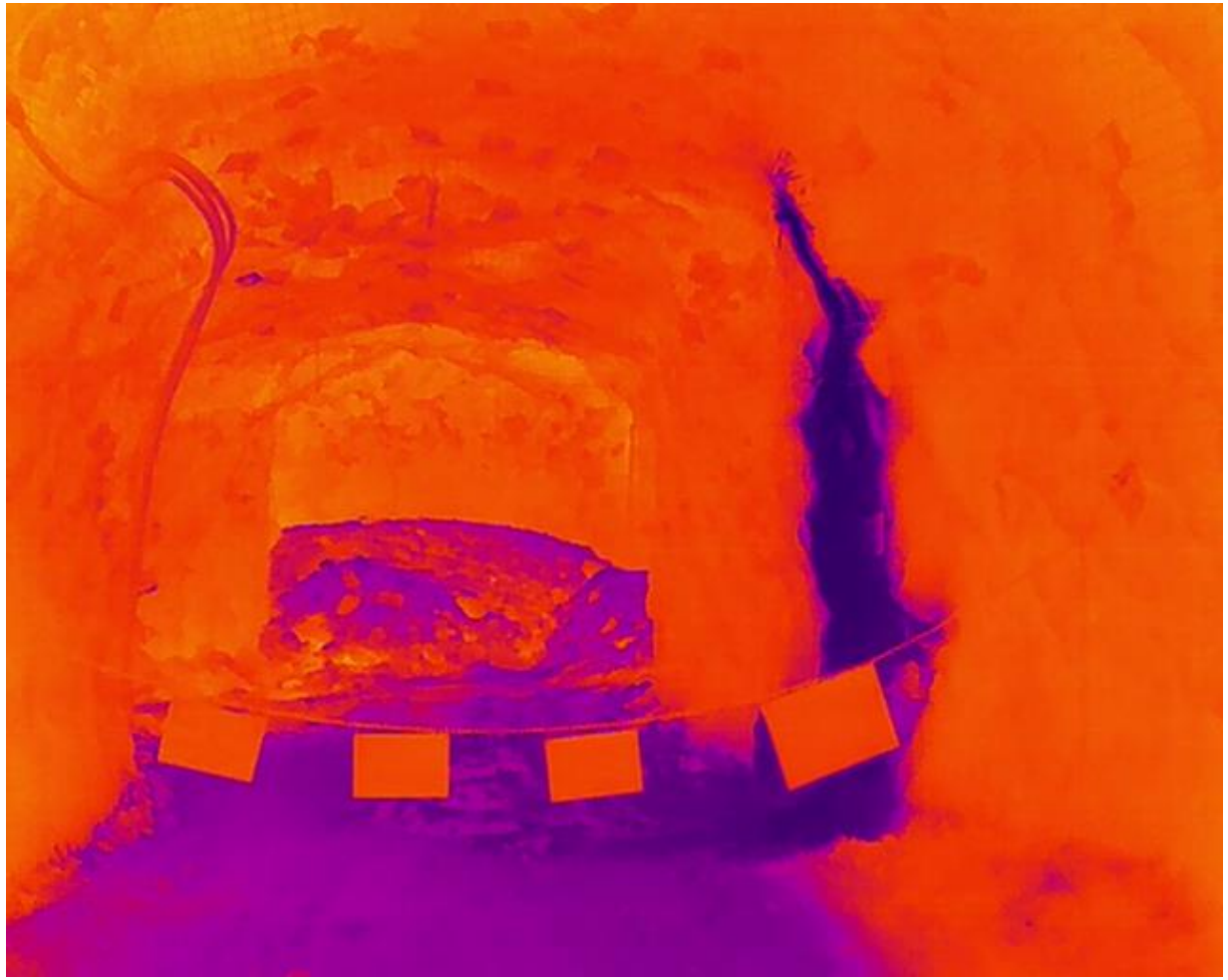
THERMAL UNDERGROUND



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THE DIGITAL MINE OF THE FUTURE

- Possible to map the entire mine in a day – even in previously inaccessible places
- Continuous monitoring by IoT sensors and autonomous systems
- Data processed automatically to derive insights and aid planning

How could this fundamentally change the way mines are planned and operated?

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THE DIGITAL MINE OF THE FUTURE

How could this fundamentally change the way mines are planned and operated?

- Greater height between levels? (fewer levels needed)
- Optimal pillar size?
- Improved bell design?
- Ventilation design based on accurate roughness models?
- Others…

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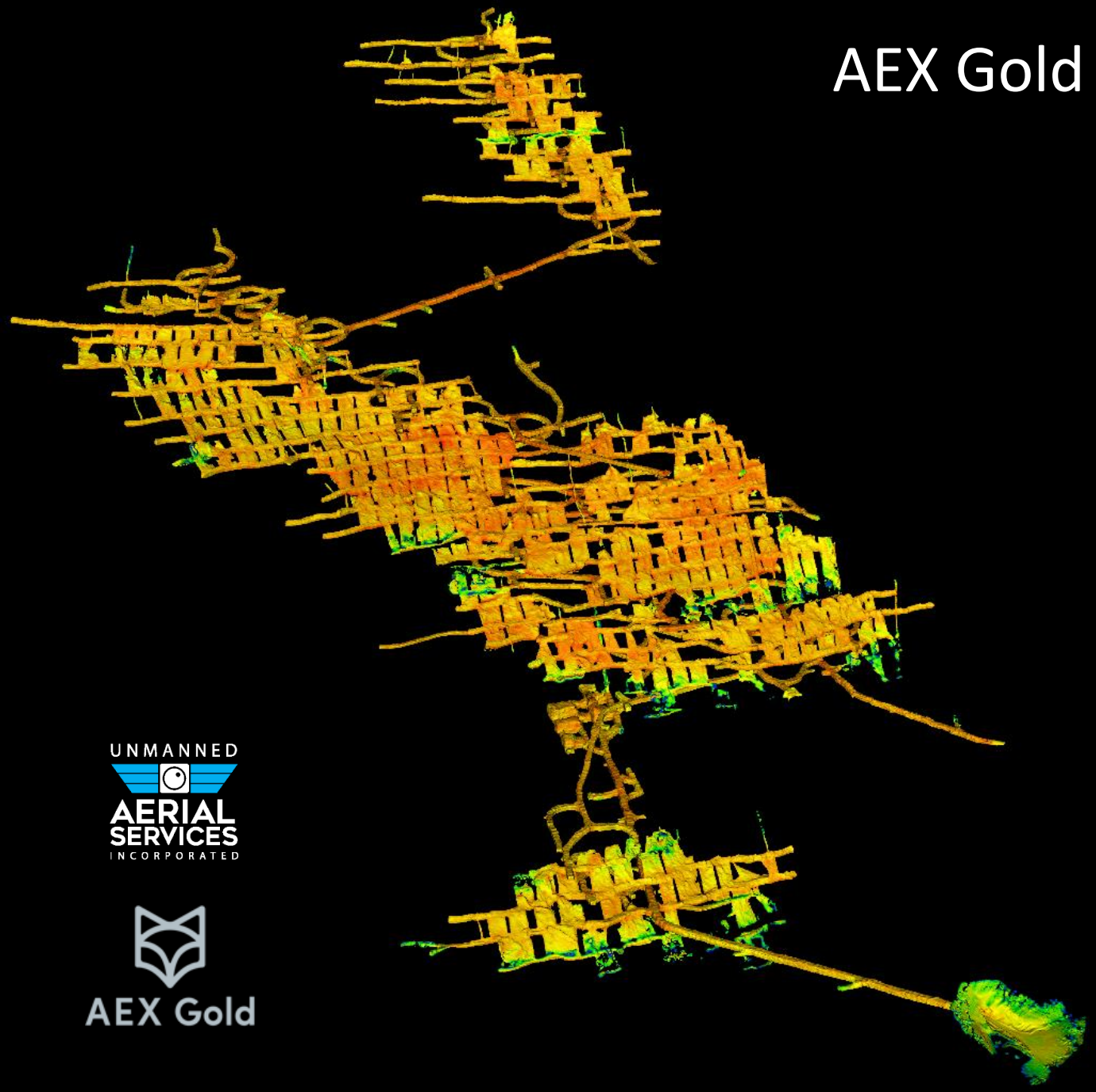
AEX Gold - Nalunaq Mine, Greenland



- Multiple Portals
- 36 Levels
- Kilometers of Drifts and Ramps
- Over 150 Stope Cavities
- Complete Underground Plant
- 151 Hovermap Scans
- 3 Days
- ½ Terabyte of Data

UNMANNED AERIAL SERVICES INCORPORATED

AEX Gold

AUTONOMOUS UNDERGROUND DRONES - BENEFITS

- Access to new data -> uncover new insights
- Efficiency of data capture -> allows regular monitoring
- Reduced skill level required for data capture
- Safety
  - Remove personnel from hazardous environments
  - Data captured provides a safer environment
- Key enabler for the digital mine of the future

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THANK YOU!

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https://vimeo.com/emesent