Change Detection in Underground Limestone Mines Using LiDAR and Photogrammetry: Successes and Lessons Learned

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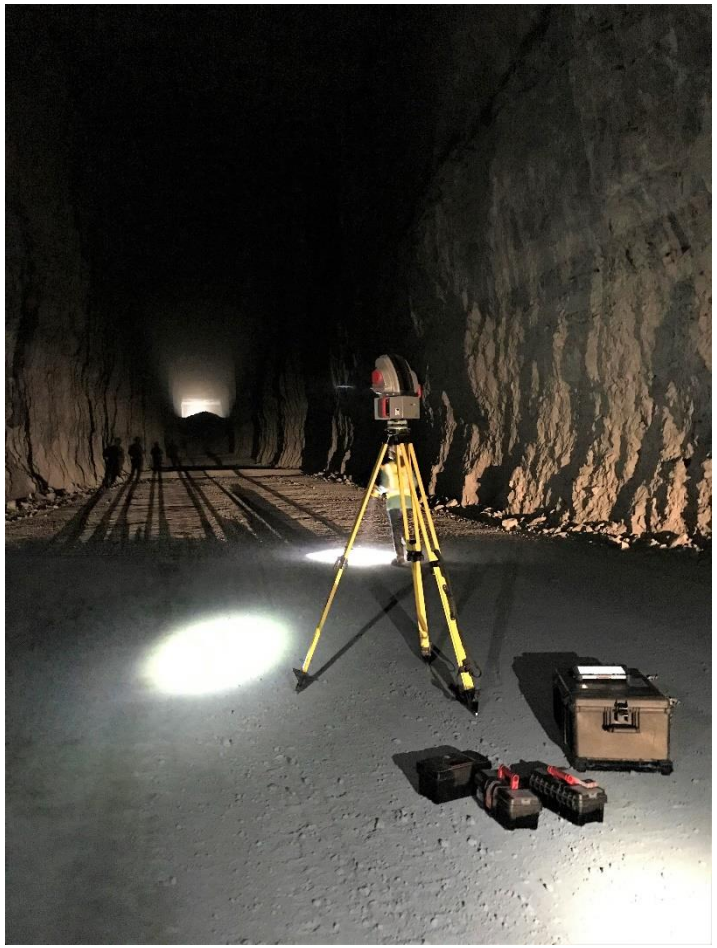
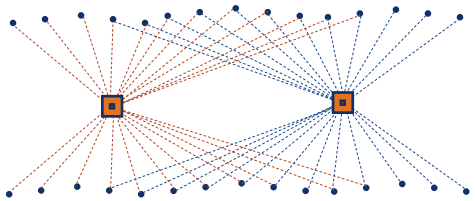
NIOSH Mining Program

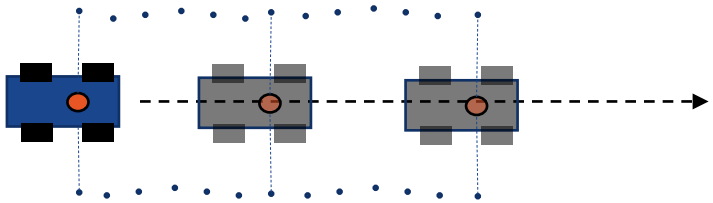
Underground mining case studies for ground stability using LiDAR and Photogrammetry

Stationary LiDAR

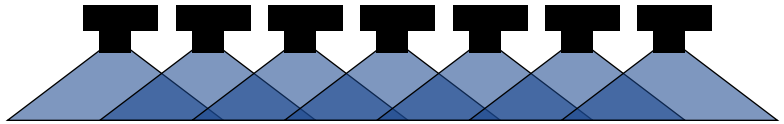




Mobile LiDAR



Close-Range Photogrammetry

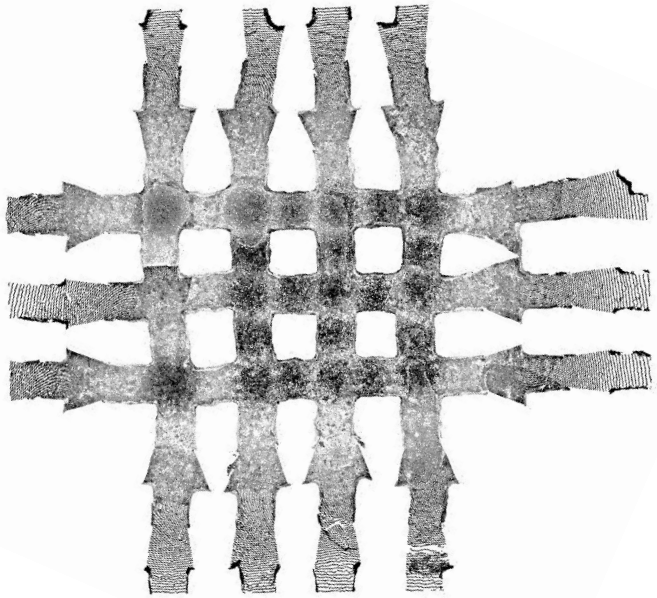


Which method should be used for which application?

- It's very difficult to generalize because the methods are changing constantly and every application has different requirements.

- In our experience the most important thing is to…**Know your accuracy and precision requirements and size of the job**
  - In underground mining, stationary methods will be poorly suited for measurement sites >1-2 km long. Mobile methods will be poorly suited for detecting movements <1-2 cm. Many people report the theoretical precision of the instrument instead of the accuracy of the final product.

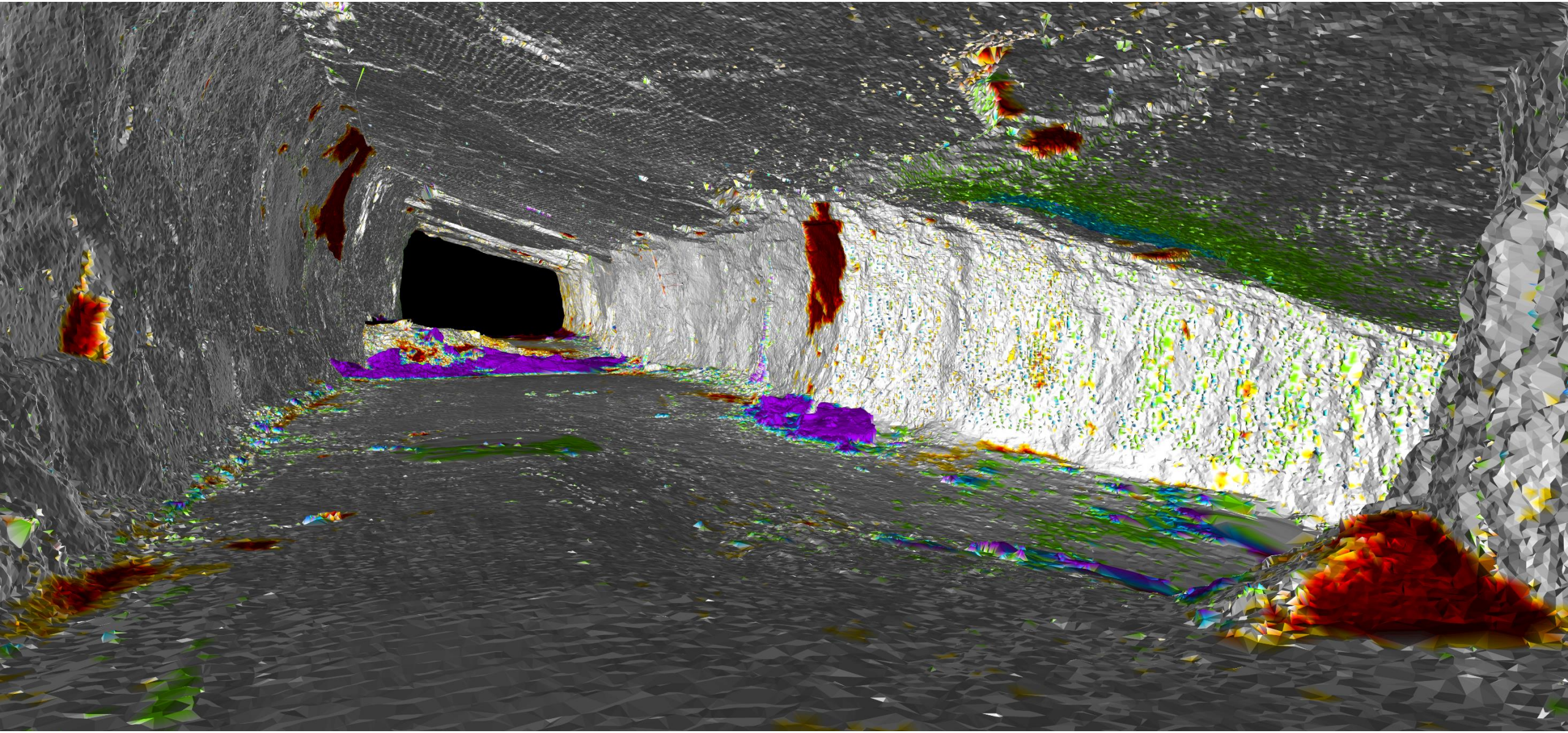
Stationary LiDAR (how we actually performed this): 4 hours



Mobile LiDAR (hypothetical alternative): 20 minutes

Pleasant Gap Mine – Stationary LiDAR

Pleasant Gap Mine – Stationary LiDAR used for ground movement detection

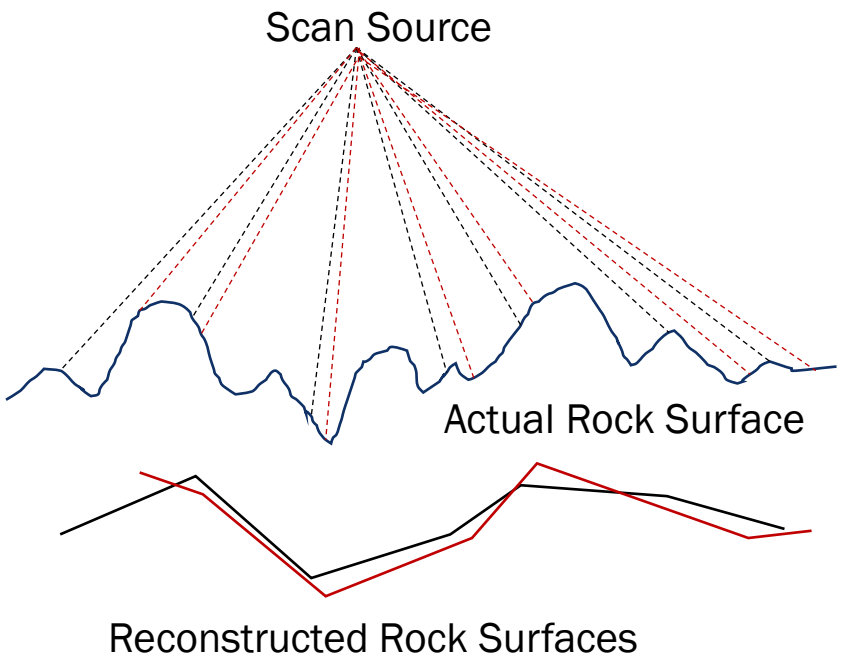


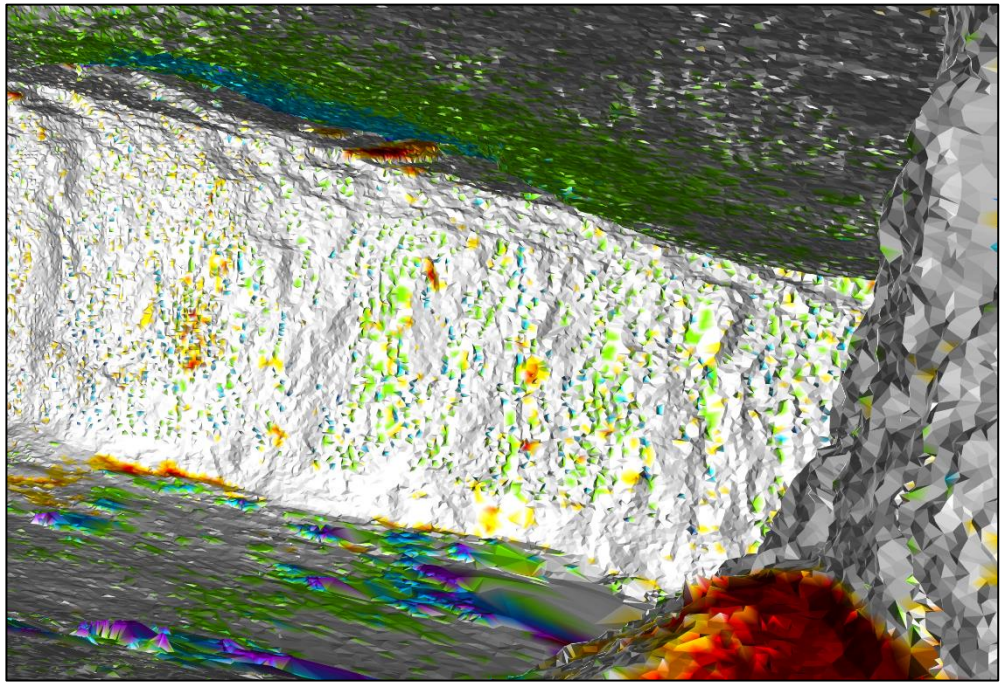
Warm colors = Rock disappearing

Cool colors = Rock moving into the opening

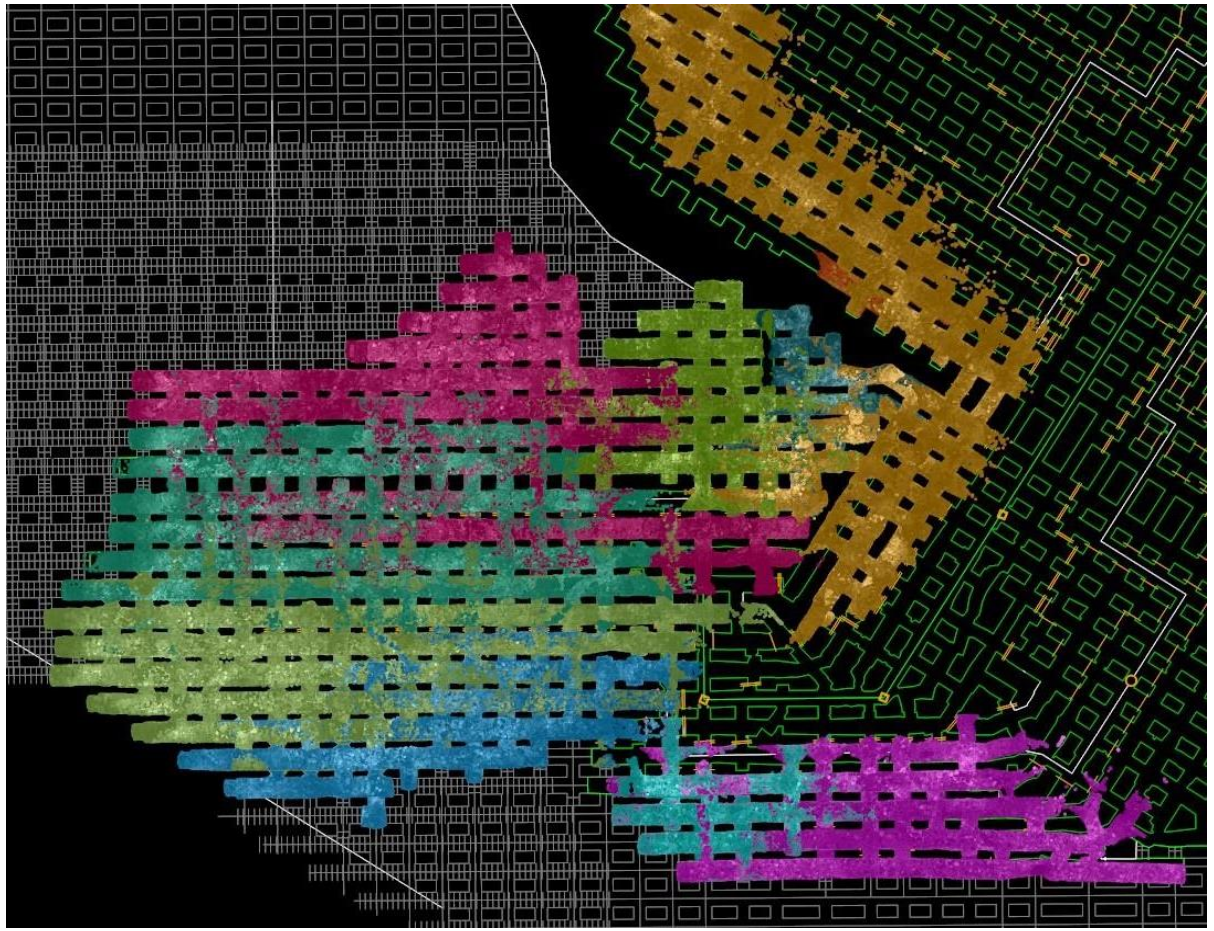
What to make of the apparent widespread and random movement?

- **Point density and distance to target** – Not only will precision of the measurement tend to degrade with distance, but the resolution of the subject will decrease. When performing time-lapse analyses on surfaces, two coarsely reconstructed surfaces will show a lot of false movement.



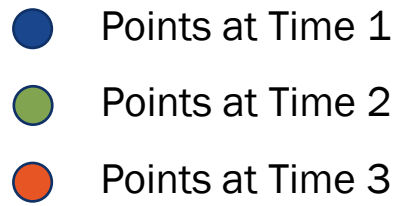


Subtropolis Mine – Mobile LiDAR and Photogrammetry



It's important to understand precision requirements and the size of the job

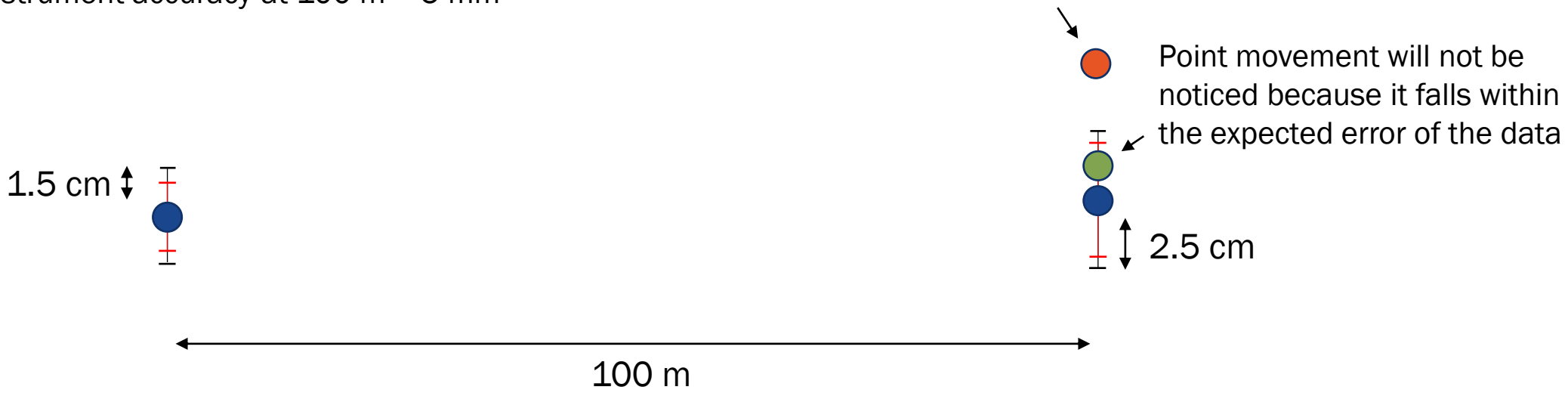
- **Error** – If performing a job that spans a large continuous distance, registration error (how well scans are stitched together) and surveying drift (compounding error as you get further away from a known point) can be far more important than instrument precision. Minimize scan length or have a plan to account for this error.



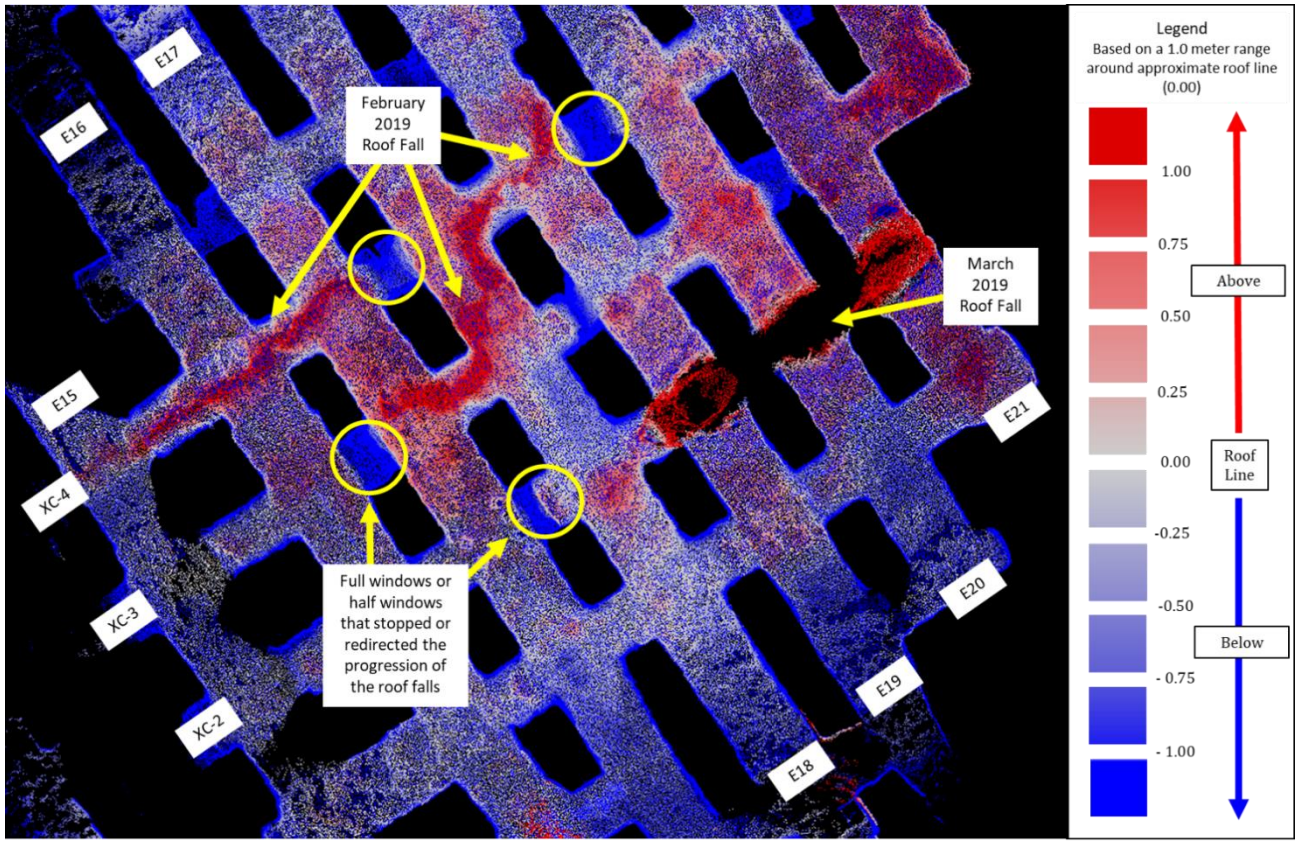
Error source examples:

Surveying Drift = 1 cm/100 m
Registration Error = 1 cm
Instrument accuracy at 100 m = 5 mm

Movement is higher than expected error, so it will be noticed, but quantifying the magnitude will be difficult because the movement is still a small distance relative to the error

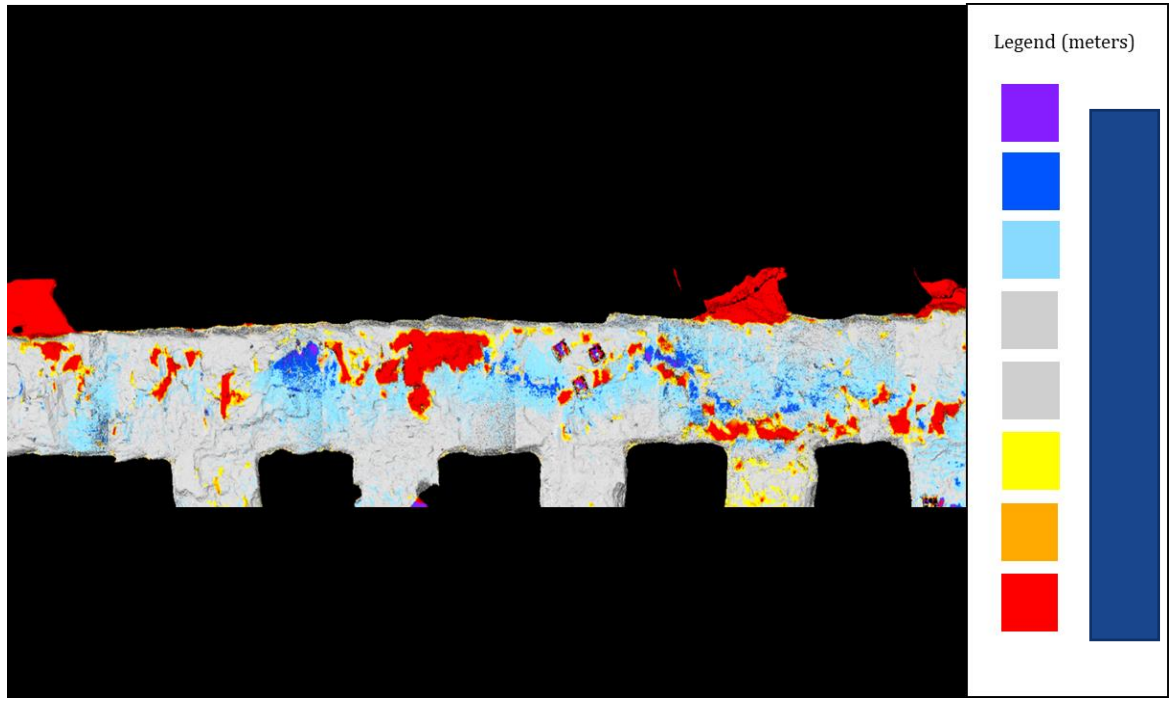


LiDAR for Monitoring Mine Roof Movement

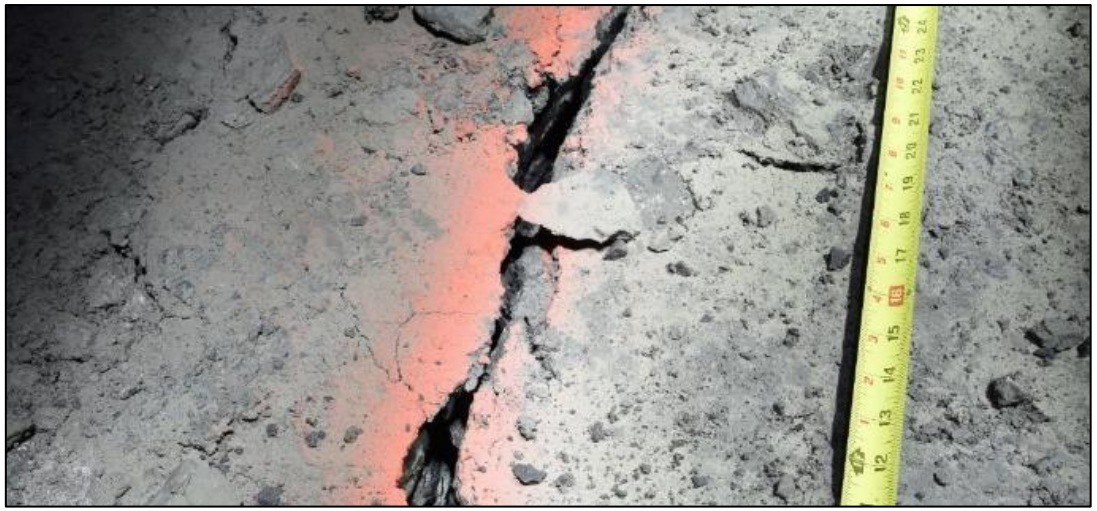


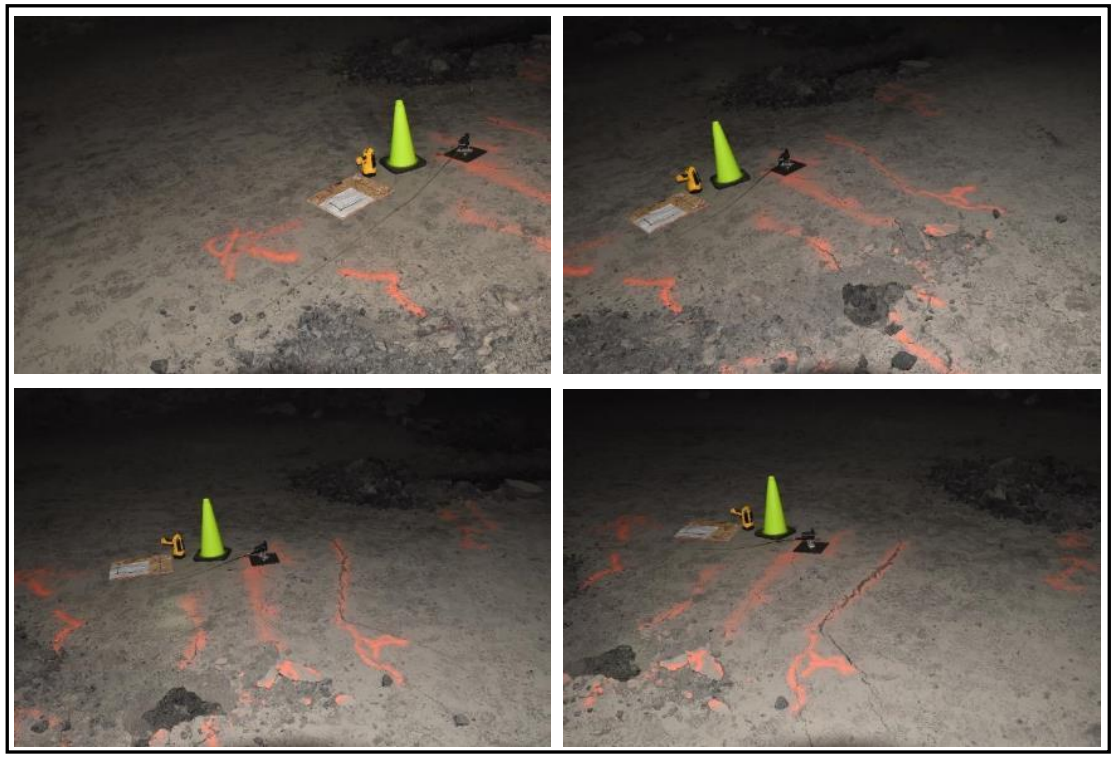
Analysis performed on **one** scan: areas of higher roof elevation (red) indicate damage before scan occurred

Analysis performed on **two** scans: areas of higher roof elevation (red) indicate falls between scans

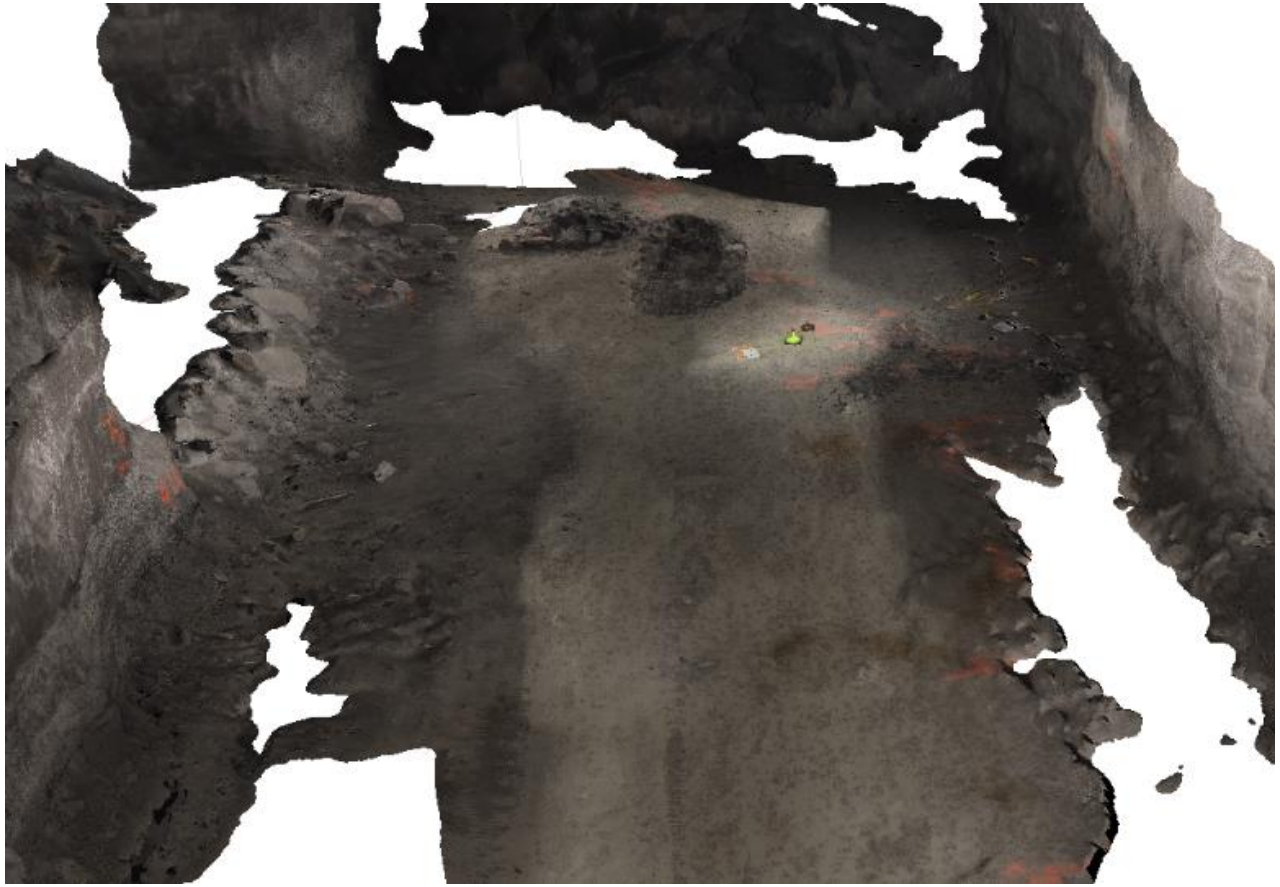


Photogrammetry for Monitoring Floor Movement



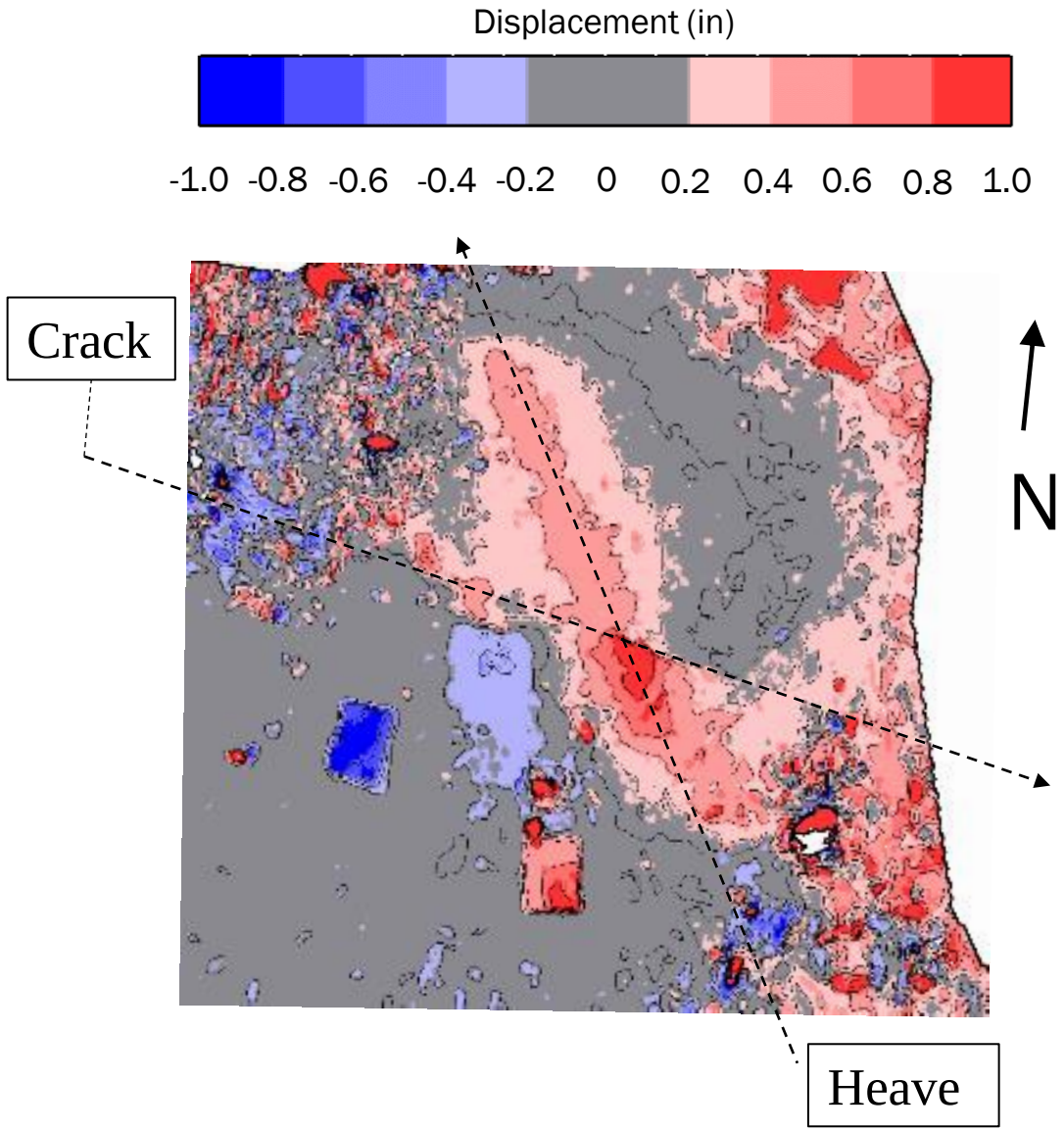


Reconstruction using ~30 photographs

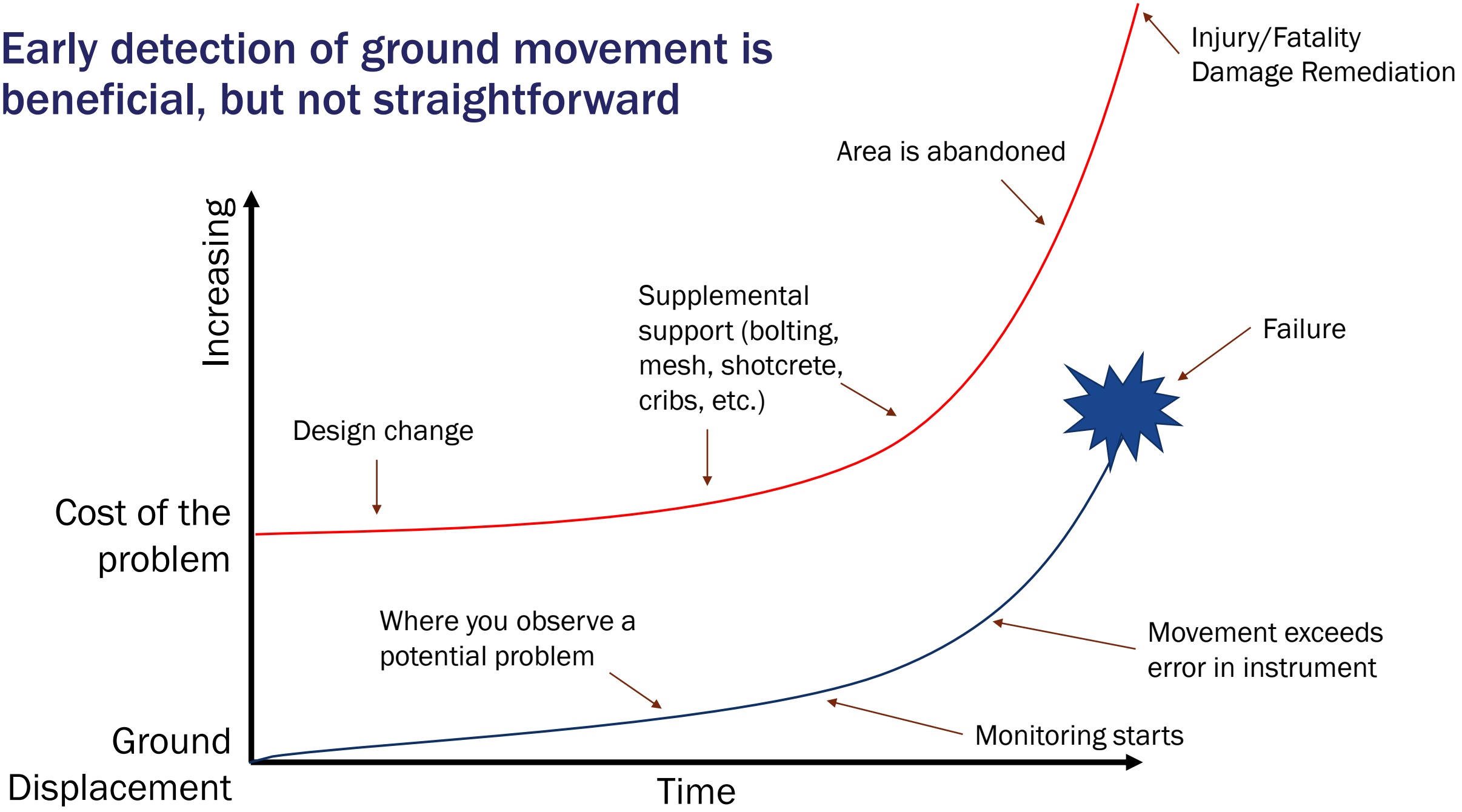


Note how some areas are missing due to poor photograph overlap or water

Photogrammetry for Monitoring Floor Movement



Early detection of ground movement is beneficial, but not straightforward



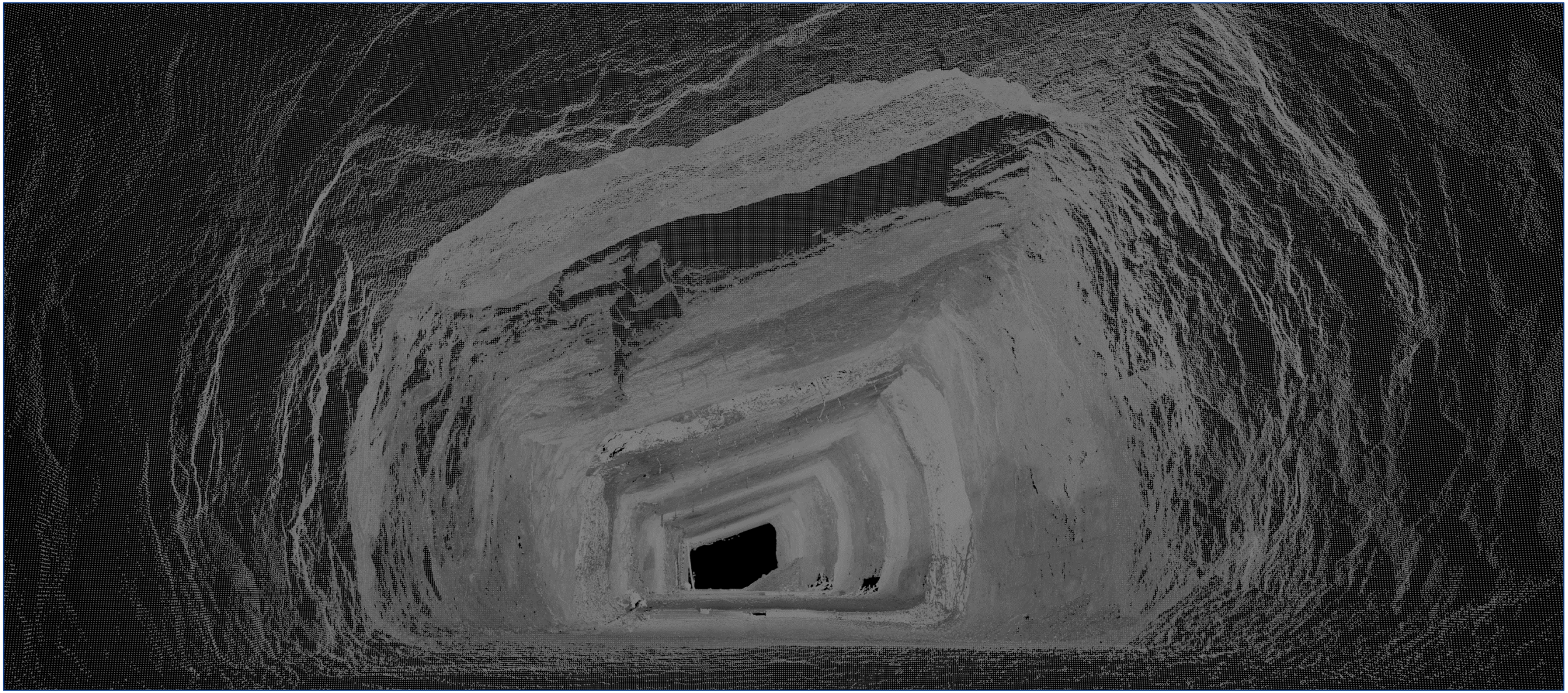
Final Considerations

- **Vegetation** – Growth or change in vegetation will appear as movement of the surface.
  - Who can spot the hill underneath my overgrown backyard?

- **Weather** – Fog, dust, water, etc. can interfere with picture quality or laser reflection.

- Don’t trust your data; triple check everything.

Questions?



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