Disruptive new sensor for monitoring rock bolt load and assessing rock movement

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Contents

The NRC at Glance

Three key roles:

Business innovation
Advancing knowledge
Federal policy mandates

- 3,700 scientists, engineers, technicians and other specialists
- Over 20 research facilities
- Variety of industry sectors, from mining to aerospace
- $1.1 B annual budget including

Developing, testing and transferring technology to the industry

NRC’s in Mining

Energy, Mine and Environment Research Center

- Four facilities: Montreal, Boucherville, Ottawa and Vancouver
- Over 200 researchers
- Extensive infrastructures for the development and validation of technology, process and prototypes

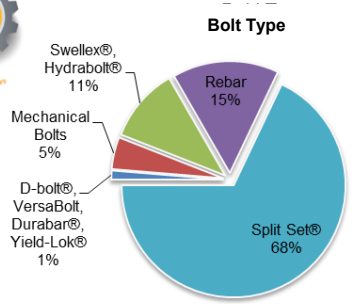
Exploring Mining Application for Ultrasonic Sensors

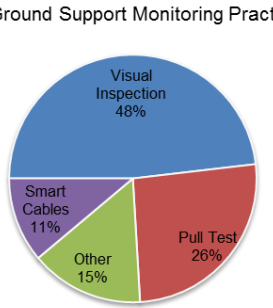
- Rock bolting for ground support became industrial practice around 1950
- In 2011, the global usage of rock bolts worldwide was in excess of 500 million bolts per year
- Ground control issue has a major impact on mine safety and resource and productivity losses
- Failures of rock bolts occur as a result of overloading, corrosion, seismic burst and bad grouting

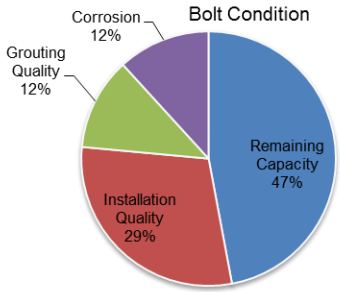
➢ In 2014, NRC started exploring the possibility to instrument fully grouted rock bolts with ultrasonic sensors

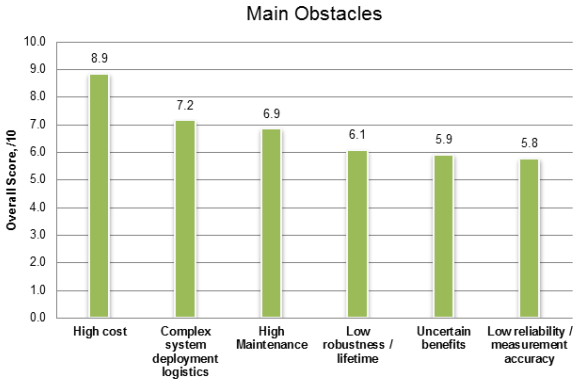
Techno-Economic Analysis of Instrumented Bolt

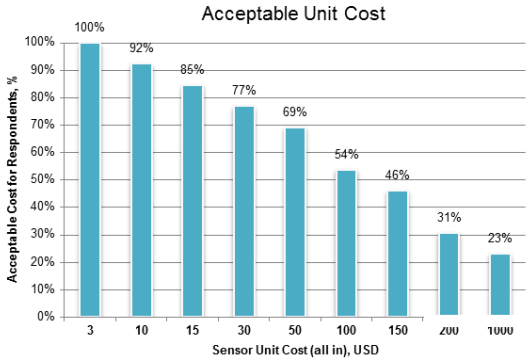
16 Study Participants from 8 Countries
1,137,500 bolts per annum



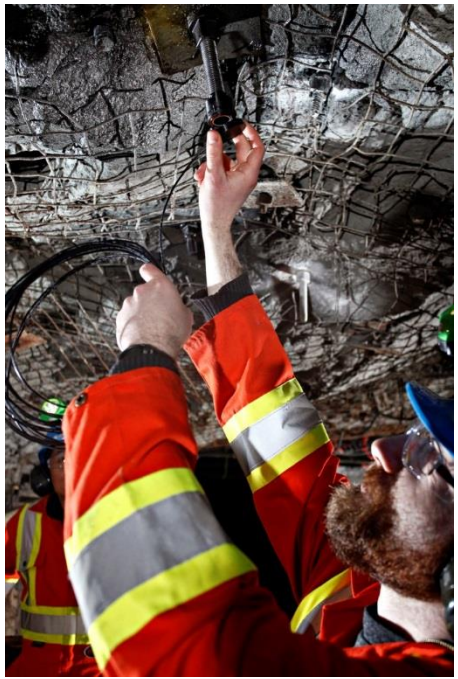








TEA Study Conclusion



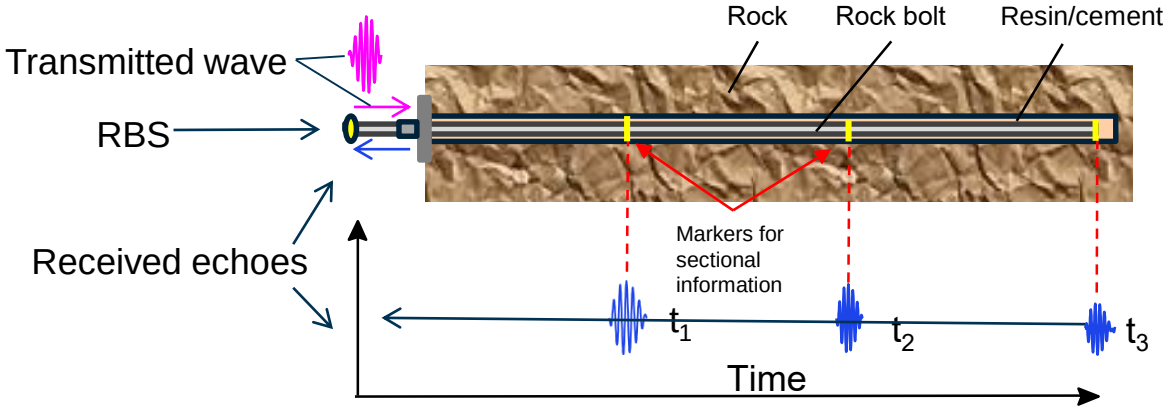
Current Instrumented Bolt Challenges:

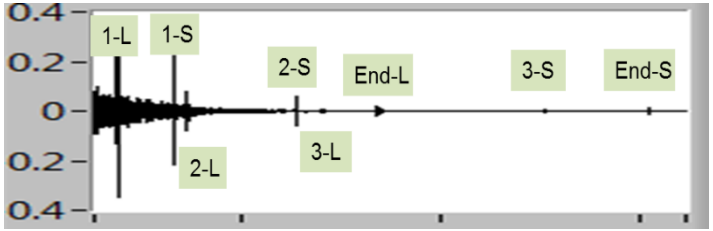
- Limited sensing dynamic range and information
- Expensive sensor limiting their deployment
  - Require specially engineered bolt
  - Require special handling and installation
- Often fragile to mining environment

Technology Requirements:

- Provide bolt load from installation up to rupture
- Must be inexpensive (below $100/sensor)
- Suitable for use with standard “off-the-shelf” bolts
- Minimal changes to bolt installation procedure
- Meet mining robustness criteria

RBS™ Ultrasonic Sensor Principle

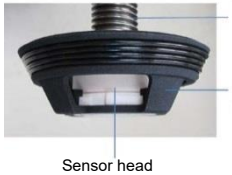




The RBS™ Concept

Passive Sensor & RFID Tag

Connector cap to MHUB



Connector cap to RPR

RBS™ Capabilities:

- Monitor load on full dynamic range from installation up to bolt rupture
- Detect plastic and elastic deformation and bolt rupture
- Record elongation and axial load on total bolt length and on segments of the bolt
- Integrated RFID tag for bolt identification and data integrity
- Low cost
- Minimal change to existing bolt installation procedure
- Minimal change to existing off-the-shelf rebar
- Robust to blasting and water proof
- Patent pending

RBS™ Portable Recorder (RPR)

Reading RBS Sensor with RPR

- Recorder sensor data and RFID tag
- Telescopic perch with magnetic coupling to sensor
- WiFi and LTE data transmission
- Safe data storage on USB key
- Battery operated

Multichannel Hub (MHub) for Real Time Monitoring

MHub preparation for wall installation

MHub connected to RBS by wiring

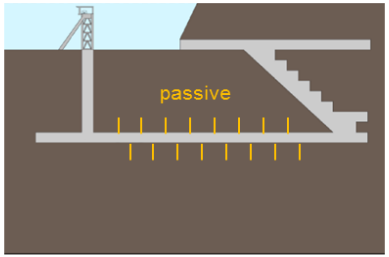
MHub Capabilities

- MHub read data from up to 16 sensors
- Up to 50 m cable distance between sensor and MHub
- Two-way communication with WiFi, LTE or cable
- Remote control
- Dual power sources (Battery and AC)
- Water and vibration resistant
- Rock wall-mountable

RBS™ Deployment Flexibility
MHub and RPR Are Interchangeable

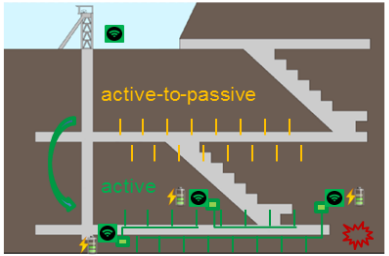
Rock Bolt Monitoring

Manual Monitoring



Stable areas of mine are manually monitored with RPR

Hybrid System

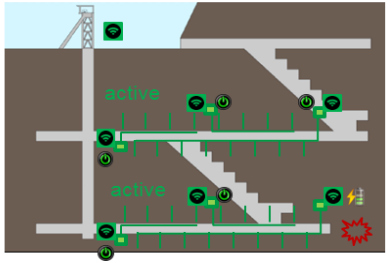


Real time and manual readout by mine personnel

MHub units are moved from stable areas to more active zones

Ground Control Application

Integrated Ground Control



Fully automated mine-wide monitoring system

Could be integrated with microseismic and other monitoring system

Event and operator could trigger reading time and frequency

Mine Trial #1
Description of Testing on

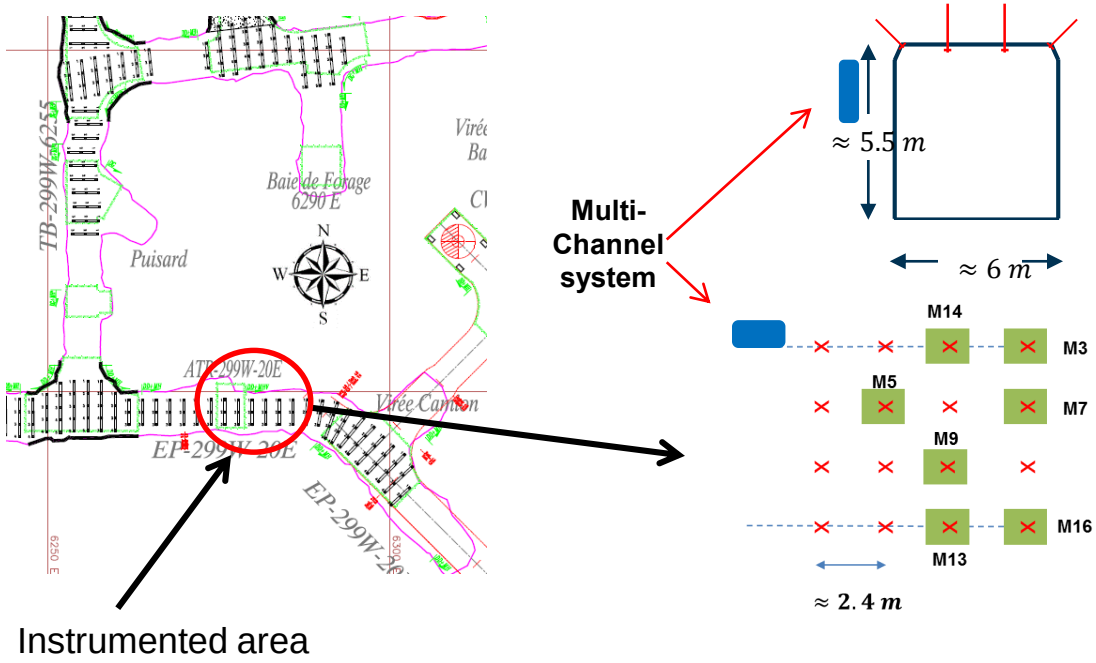
MacLean bolter was used for the installation of 6-ft rebar of 22-mm diameter (#7)

Site 290W
- Manual Recording
- Active ground activities
- Manual inspection on a weekly basis using a RBR portable recorder

Site 299W
- Real Time Recording with MHub
- Moderate ground activities
- AC power supply, wired and wireless (LTE) network to above-ground server
- No direct exposure to blasts

Site 299W
MHub and RBS Deployment

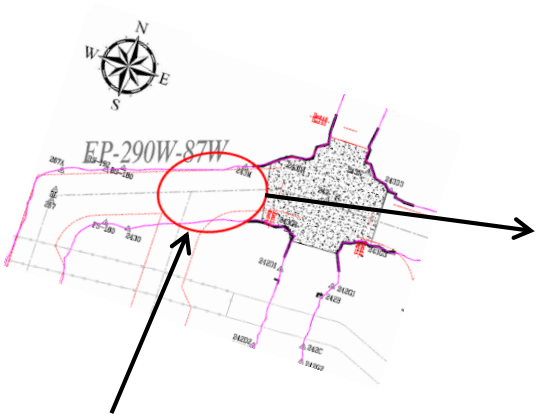
Site 299W



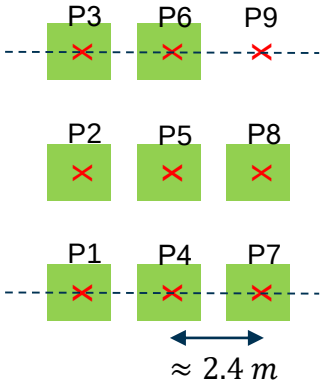
Instrumented area

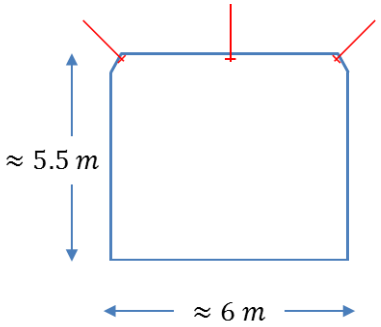
Site 290W
RBS Deployment for RPR Reading

Site 290W



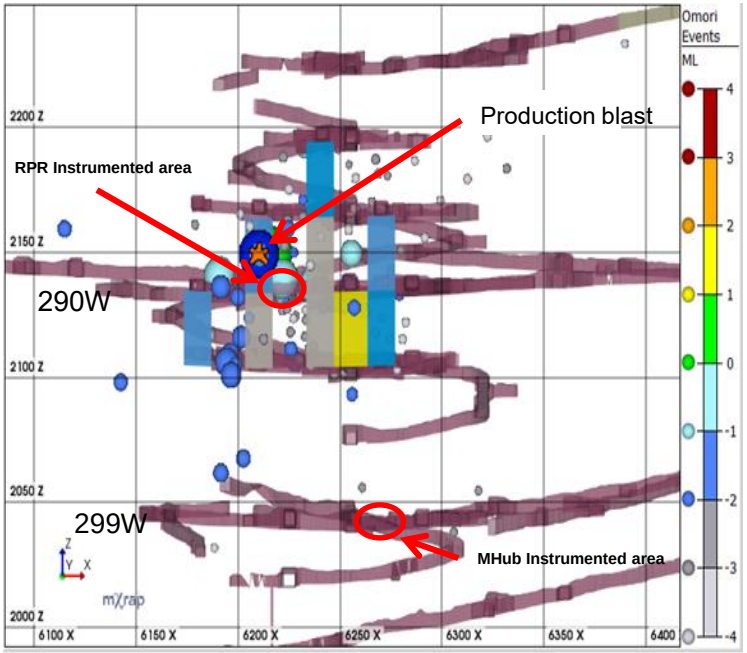
Instrumented area



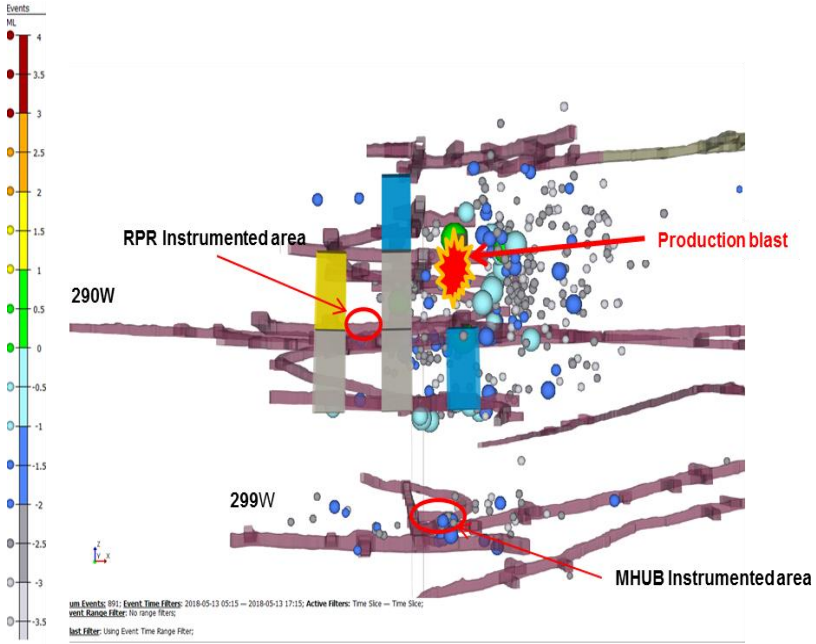


Seismic Response Within 12 Hours Period Following Production Blast on April 15 and May 13

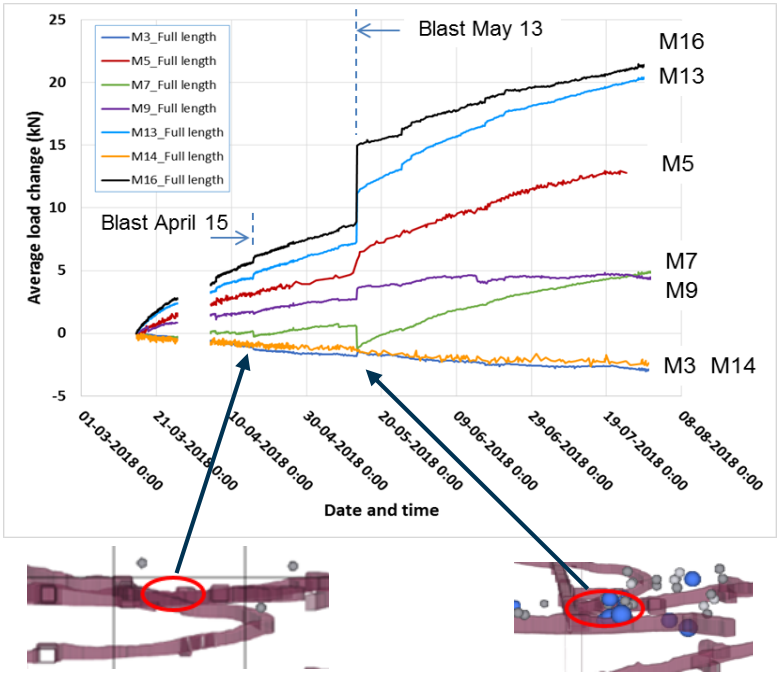
April 15 blast

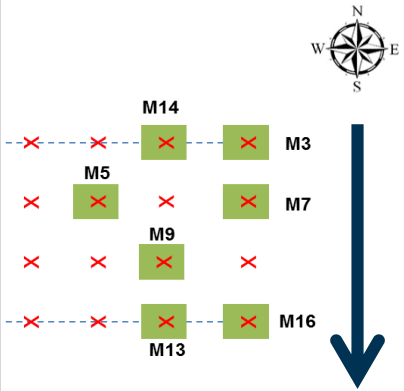


May 13 blast



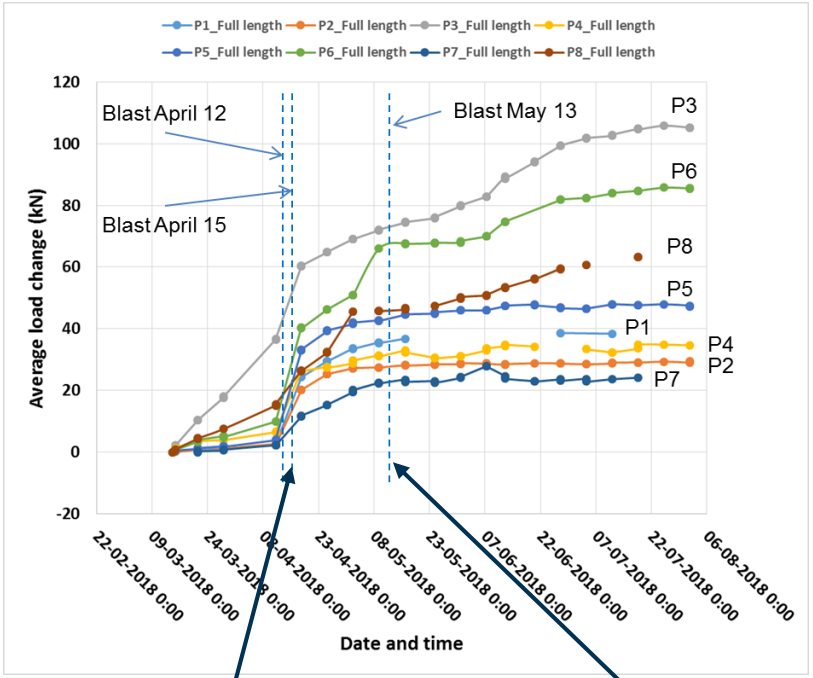
Site 299W
Full Length Automatic Monitoring with MHub

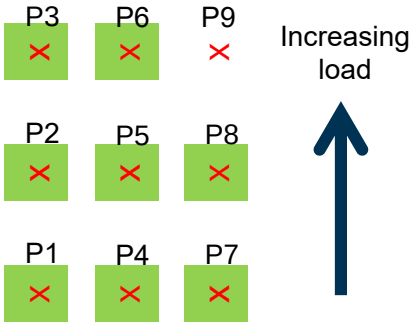




- Production blasts on April 15 and May 13
- Time delay of 1 to 3 hours for load change to transfer throughout the rock mass

Site 290W
Full Length Manual Monitoring with RPR





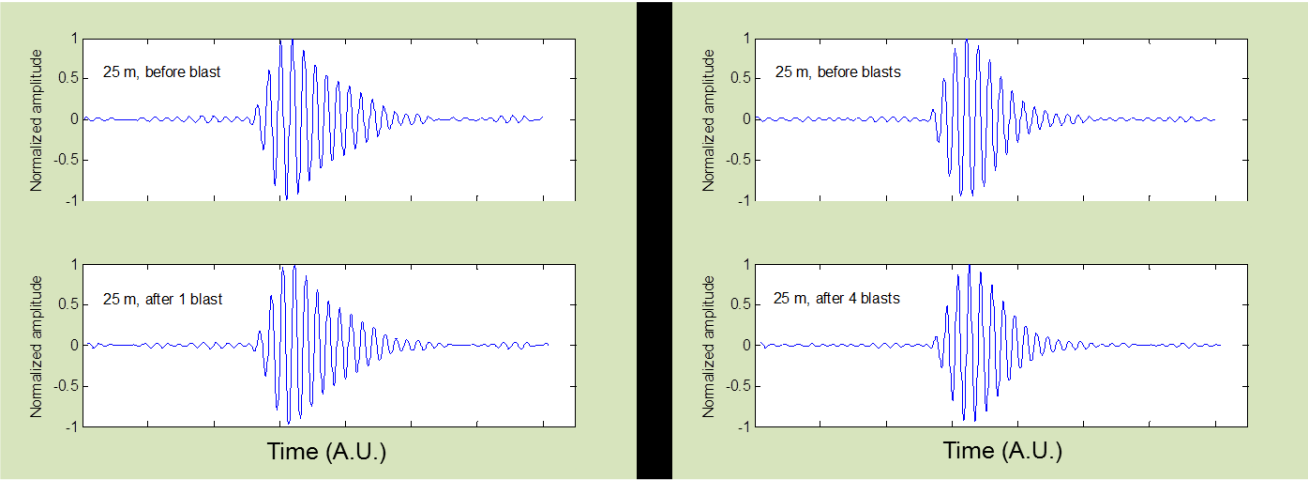
RBS^{TM} Resistance to Blast

25 m from face: 1 blast

25 m from face: 4 blasts

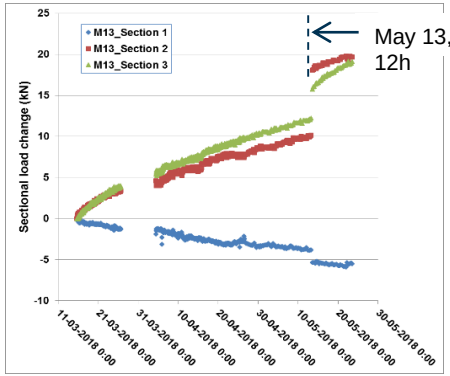
Before blast

After Blasts

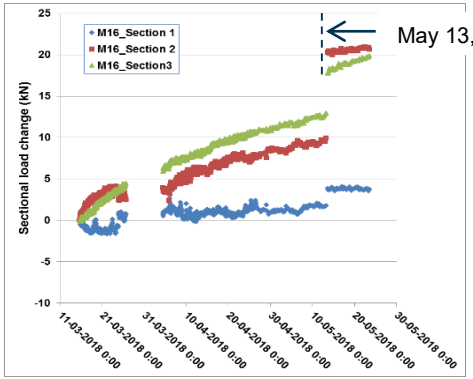


Site 299W
Sectional Load Change with MHub

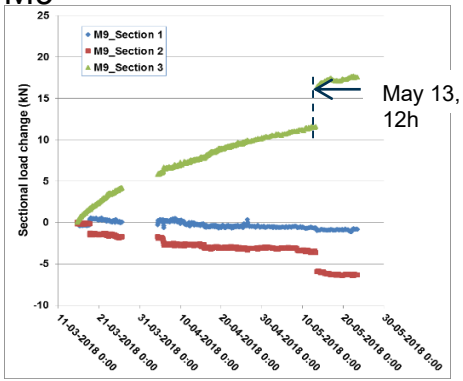
M13

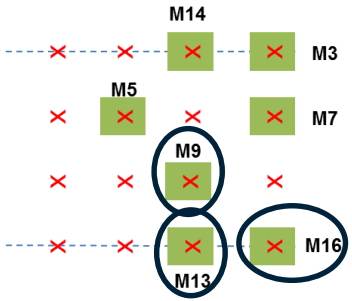


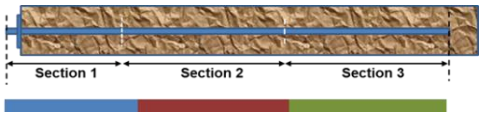
M16



M9



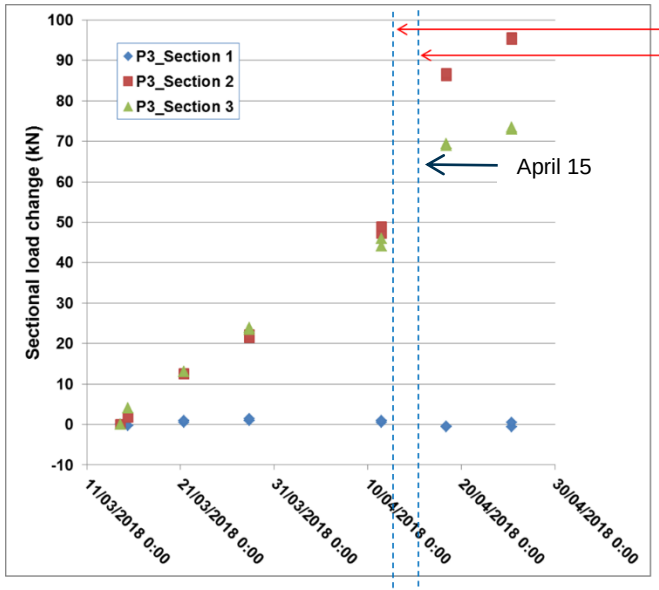


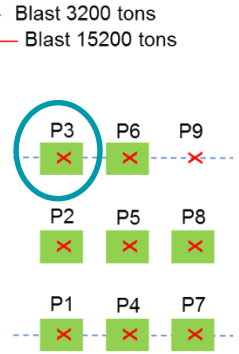


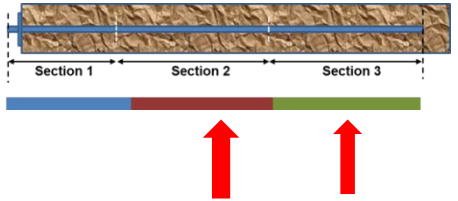
- No load on Section 1
- Section 2 and 3 show various load distribution
- M13 and M16 follow a similar pattern

Site 290W
Sectional Load Distribution in P3 with RPR

Load distribution varying with sections





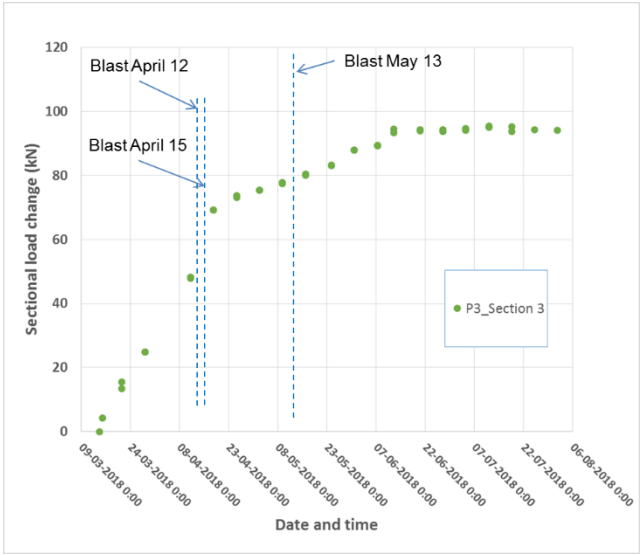


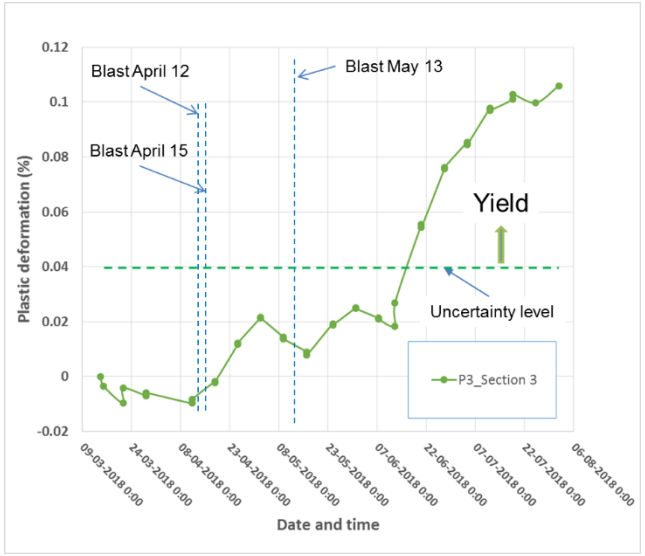
- Section 1 (head) no load
- Section 2 (middle) most loaded after blast
- Section 3 (foot) loaded

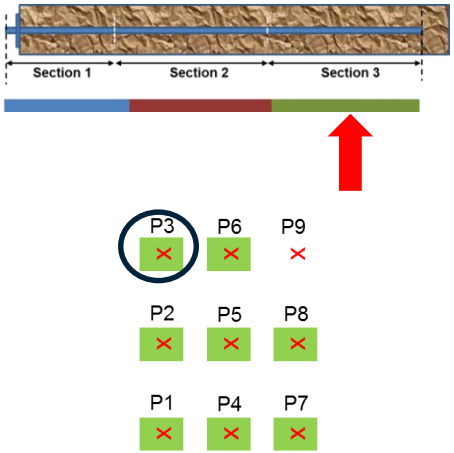
Site 290W

Measurement of Plastic Deformation on P3 (section 3) with RPR

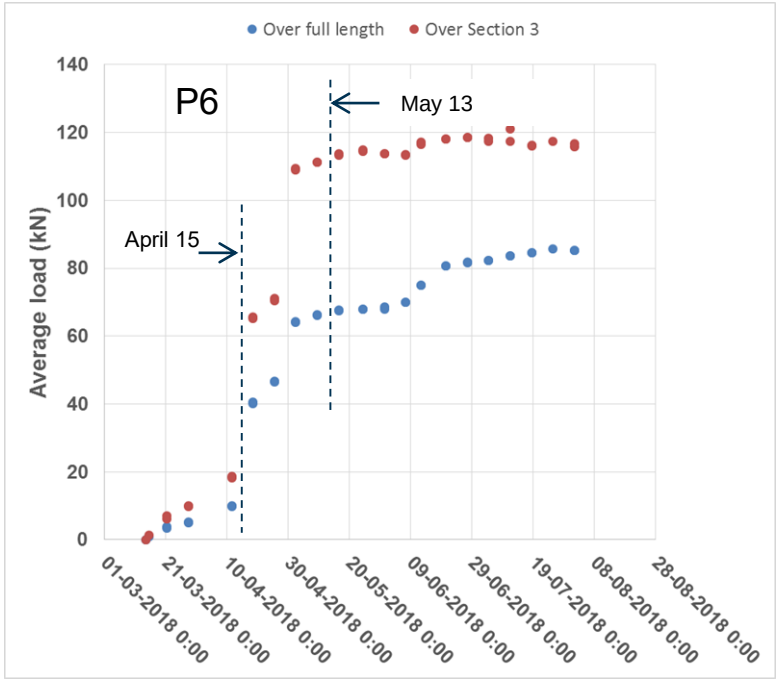
P3 has yielded at Section 3

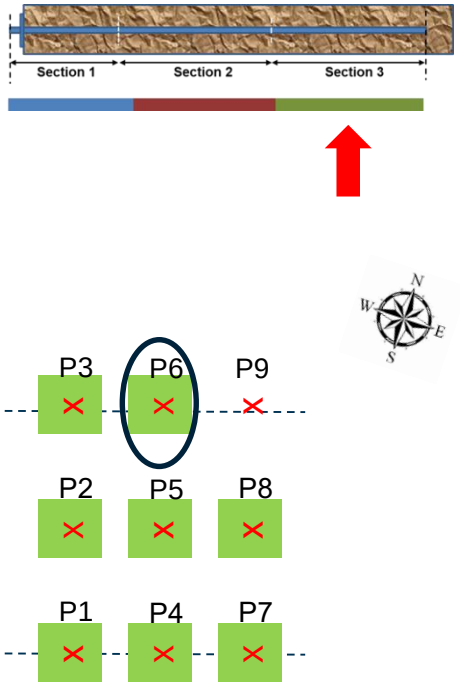




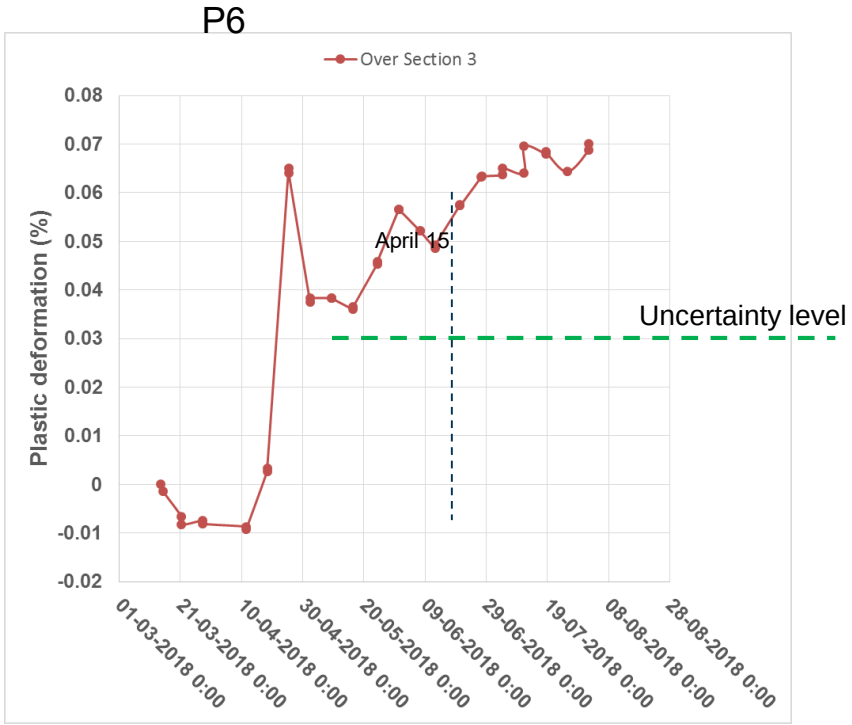


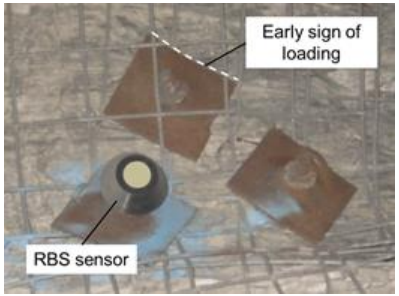
Site 290W
Evolution of P6 Load Change with RPR, March to August 2018

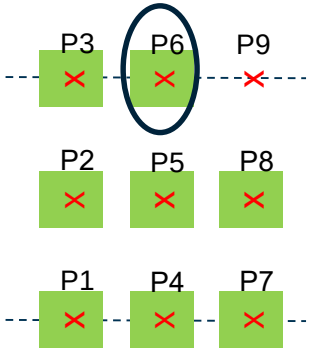




Site 290W
Measurement of Plastic Deformation in P6







Mine Trial #2
Description of Testing

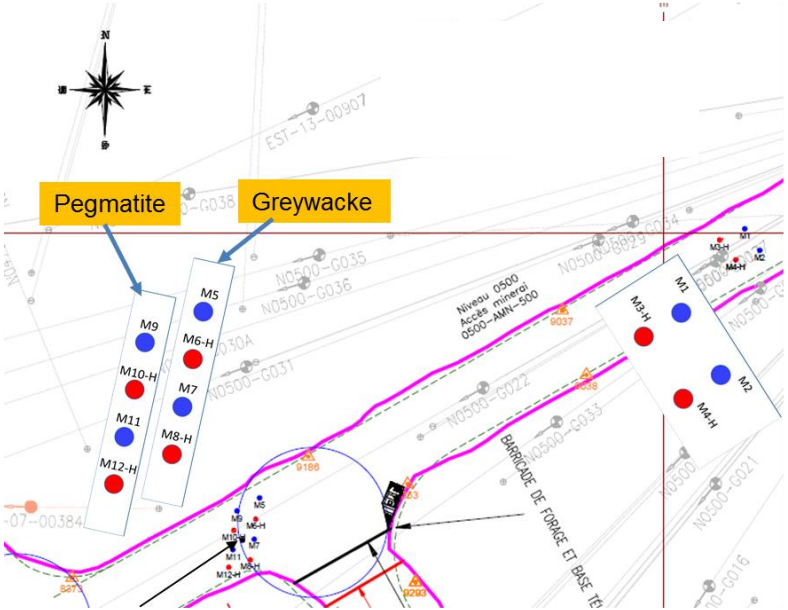
Test specifications

- 500-AMN-500: two rock types near active draw point (#7 8ft rebar 22mm and MHub)

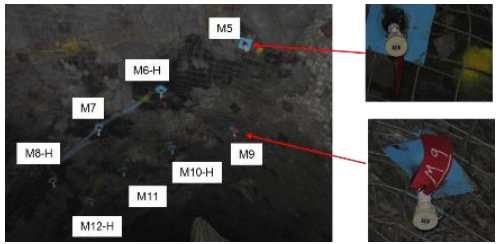
Compare bolt with holes vs bolt with no hole:

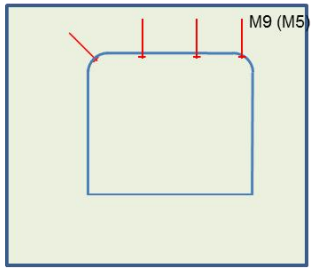
- 680-AMN-355: drift intersection (8ft rebar 22mm and RPR)
- 860-GRO-1S: near development face (8ft rebar 22mm and RPR)

500-AMN-500 with MHub Sectional Load (Ton)

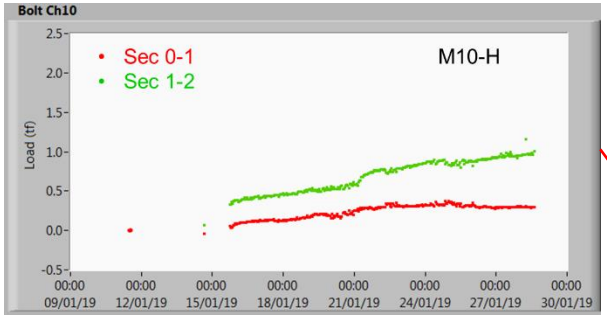


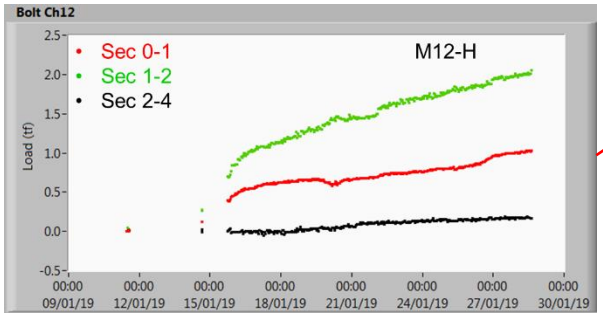
EU-S-N-DSS-0500
(500-AMN-500)

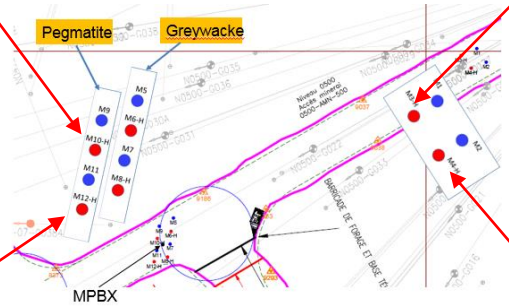


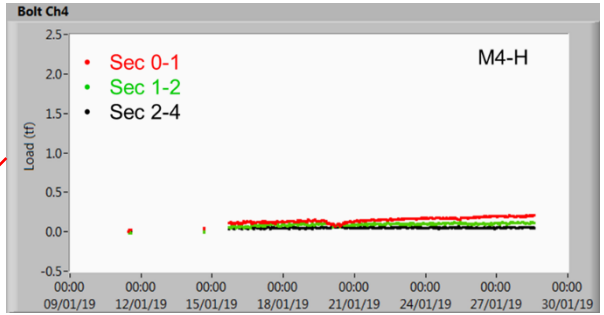


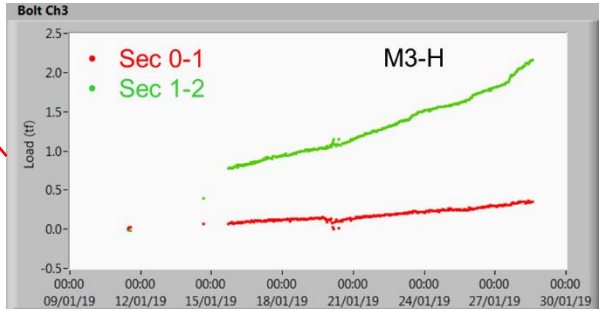
Site 500-AMN-500
Sectional Load Results with MHub



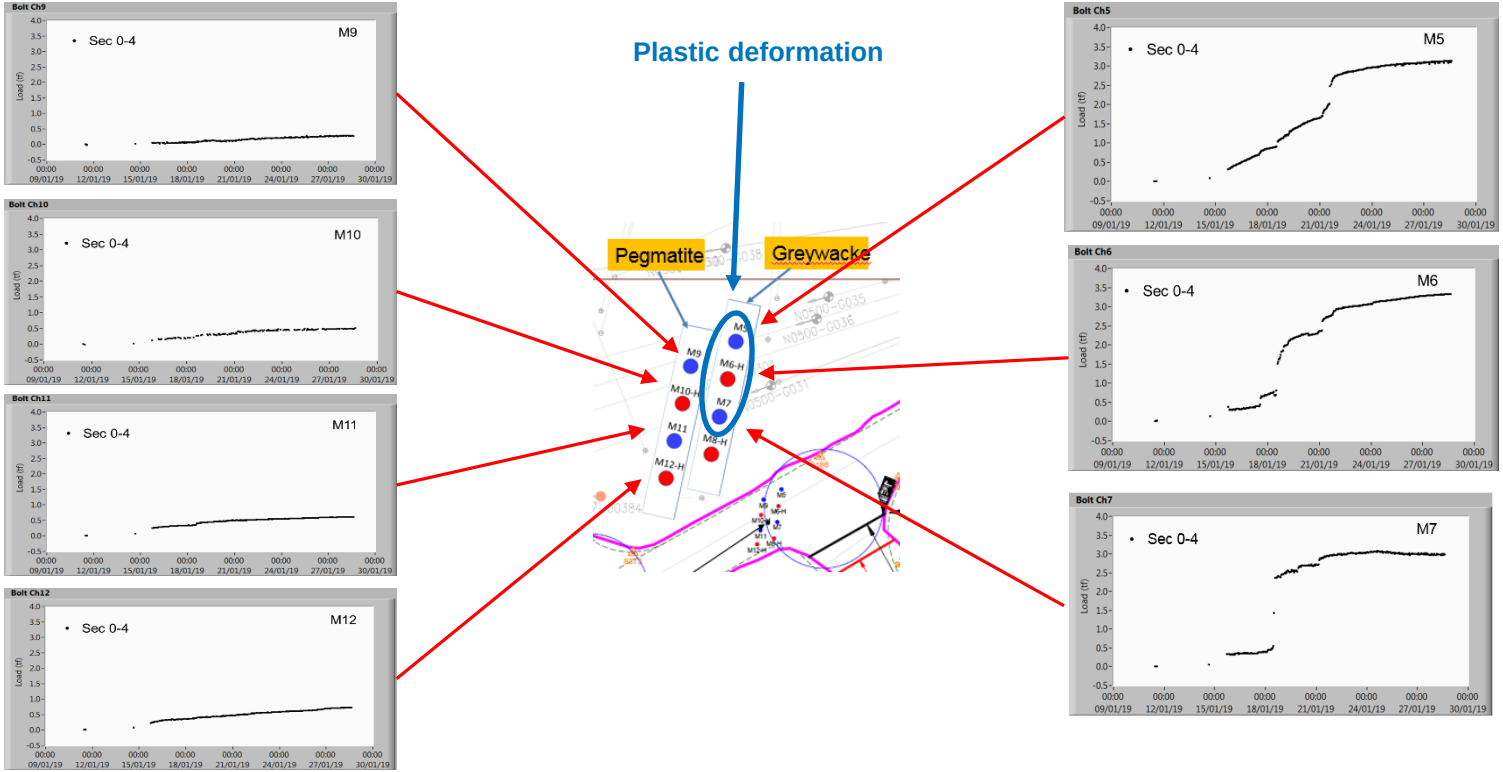






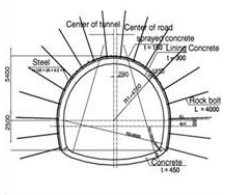


Site 500-AMN-500
Average Load Over Full Length with MHub

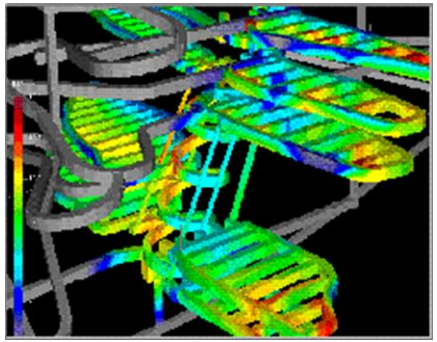


From Rock Bolt Monitoring to Better Geo-Mechanical Modeling

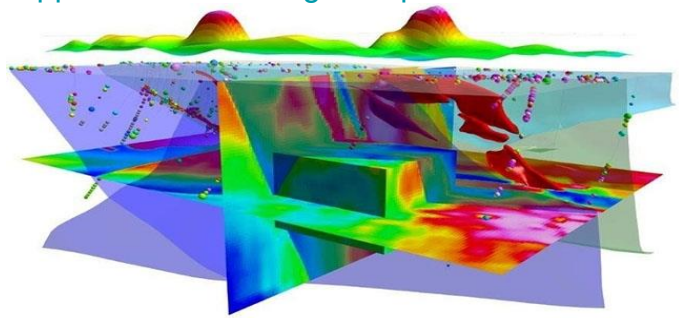
RBS™ technology transforms rock bolts into sensors



The integration of RBS™ data with microseismic, LiDAR and other technologies will provide better geo-mechanical understanding of the mine



In near future, RBS™ Sensor network will provide to ground control specialist a new tool to better assess extraction impact and rock movement in support of better design of operation



Conclusion

New tool for ground control engineer for safety, mine planning and processes design

Conceived for network deployment

Deliver extensive information on rock bolt status

Validated in operational mines

Now exploring data integration with other technologies

RBS Consortium

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- IAMGOLD
- Kirkland Lake Gold

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THANK YOU

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