Ground Support 2023 – J Wesseloo (ed.)
© 2023 Australian Centre for Geomechanics, Perth, ISBN 978-0-6450938-5-8
doi:10.36487/ACG_repo/2325_01

xCell Cyclops: a new technology for an efficient way of monitoring convergence in underground mines

O Vallati *Sandvik, Australia*

M Farrington *Agnico Eagle Mines, Australia*

P Young *Sandvik, Australia*

S Weaver *Sandvik, Australia*

Abstract

Mines are looking for efficient ways to improve their day-by-day operations while enhancing safety. When it comes to instrumentation and monitoring, the solution should be simple to use, easily installed and economical. Good monitoring practices should minimise personnel effort by promoting a more intelligent use of technology.

In this context, this paper presents the xCell Cyclops that Sandvik has recently developed. With the xCell Cyclops monitoring system, it is possible to get a real-time flow of convergence measurement data delivered straight into the cloud-based application. The xCell Cyclops is directly mounted to MD, MDX and Kinloc bolts or through use of low-profile adaptors any standard threaded bolt. Once installed, the xCell Cyclops continuously measures the distance from one side of the excavation to the other using precision laser technology. With wi-fi connectivity, the data is instantly available in the web and iOS interface. If wi-fi is not available, the xCell Professor, a Bluetooth low energy gateway, is mounted on already existing vehicles for drive-by data collection.

When compared to current measuring methods, the xCell Cyclops allows for a deeper understanding of rock mass behaviour by providing timely and continuous readings collected with minimum effort by site personnel. This technology leads to a safer, more sustainable work environment, can assist in ground support design, and improve the cost efficiency of ground support by optimising ground support utilisation.

Keywords: *monitoring, convergence, IoT, digitalisation, safety, MDX, xCell Cyclops*

1 Introduction

In the past decade, the entire mining industry has been experiencing a push for new technologies to optimise day-by-day operations, increase safety and improve productivity. New technologies in ground support can be found in every aspect of the ground support cycle. Starting from the design, new guidelines have been developed (Potvin et al. 2021). New bolting products are now optimised for quicker and more reliable installation while enhancing support capabilities (Stiehl et al. 2018). New and more intelligent bolting machines, with their autonomous and remote controls, offer high levels of safety, efficient data acquisition and processing (Sandvik 2021).

Ground support and strata monitoring technologies are following the digital transformation. Vallati et al. (2020) reviewed new technological trends in ground support monitoring, identifying two main disruptive technologies. The first is the use of LiDAR scanning, which, when paired with robotics or drones, allows for a very efficient monitoring method. The second technology of interest is networks of sensors, which allow for real-time and continuous monitoring. This can be used in real-time risk assessment, ground support design optimisation and, eventually, for advanced analytics and artificial intelligence.

Considering these digital trends, Sandvik has developed the xCell monitoring system: a new and efficient way to monitor convergence in the underground mine.

Convergence is a plastic deformation process of the rock mass that results in displacement of the walls, back and floor over time. Excessive convergence can lead to rockbolt failure and excavation shrinking, increasing ground falls and operational delays. To mitigate such risk, convergence monitoring is included in ground control management plans.

Traditionally, convergence monitoring is carried out by measuring the distance wall-to-wall using tape extensometers or manually with a laser range finder. These methods are time consuming, can be prone to errors and can expose personnel to significant underground hazards. More recently, mines have extrapolated convergence from 3D scans using stationary and mobile LiDAR scanners. Subsequent scans, which are carried out in the same location at different times, can be compared and quantitative information of the ground movement can be generated. The efficiency of LiDAR scan for convergence detection has been discussed by many authors (Jones & Beck 2017; Lynch et al. 2017) but data processing time may take up to several hours (Potvin et al. 2021). Also, data collection is not carried out frequently and is often undertaken sometime after the excavation has been opened.

The authors identified a gap in the industry for a real-time continuous monitoring system to measure convergence. The system provides a deeper understanding of rock mass behaviour with timely and continuous readings. Once installed, the system is totally unmanned (it does not require any manual operation), minimising worker effort and reducing exposure to underground hazards. Other features include simple installation that reduces personnel effort, robust and resilient design construction, fully automated operation, flexible and scalable deployment and does not require an ad hoc network. The system can be used alongside current methods, such as LiDAR , as an early warning detection method.

2 xCell convergence system

The system is composed of three main parts. The xCell Cyclops is the sensor that measures distance, the xCell Professor is the data harvesting device, and the user interface is for configuration and visualisation.

2.1 The xCell Cyclops

The device is simply installed on an existing bolt, it has a socket for direct mount onto Sandvik's MD, MDX and DSI's Kinloc bolts and, with an adaptor, to any other threaded bar. The adjustable ball-mount mechanism allows the sensor to be oriented with a flexibility of +/- 15°, the installation is easy and simply secured with a single Allen key. Once installed, xCell Cyclops measures the distance from itself to the opposite side of the excavation at a user-defined rate. It uses precision laser technology with a 20 m range and an accuracy of 2 mm. Accuracy of the sensor is affected by the underground environment (dust in the air and reflecting surface) but convergence trends can be easily identified having ongoing stream of measurement.

The xCell Cyclops device has wireless connectivity. When connected to wi-fi, the device reports measurements directly to the cloud, and is remotely configurable. Bluetooth connectivity is used for data harvesting (with xCell Professor) and for local communication. In local mode, the device can be accessed using a Bluetooth-enabled device (laptop, tablet, or phone) within a range of 300 m.

The device is battery powered and can operate for up to three years taking hourly measurements and uploading once a day, without having to change batteries. The three alkaline AA cells are replaceable by removing the back plate and the battery cover.

The LEDs are a user-friendly method to troubleshoot and locate the device underground. They will blink when the device is powered-on or gets connected to a Bluetooth device. During data harvesting, the device lights up a blue coloured LED when the communication with the xCell Professor is established, and green colour when data transfer is completed. A flashing red indicates a hardware problem or low battery. LEDs can also be activated from the application to locate the device in the dark underground environment.

The rugged design is optimised for mining applications, where the low profile allows the sensor to be less prone to impacts from passing machinery. The enclosure is IP66 rated and allows the device to be washed if dust deposits over the lens obstructing the laser beam.

The xCell Cyclops device and components are illustrated in Figure 1.

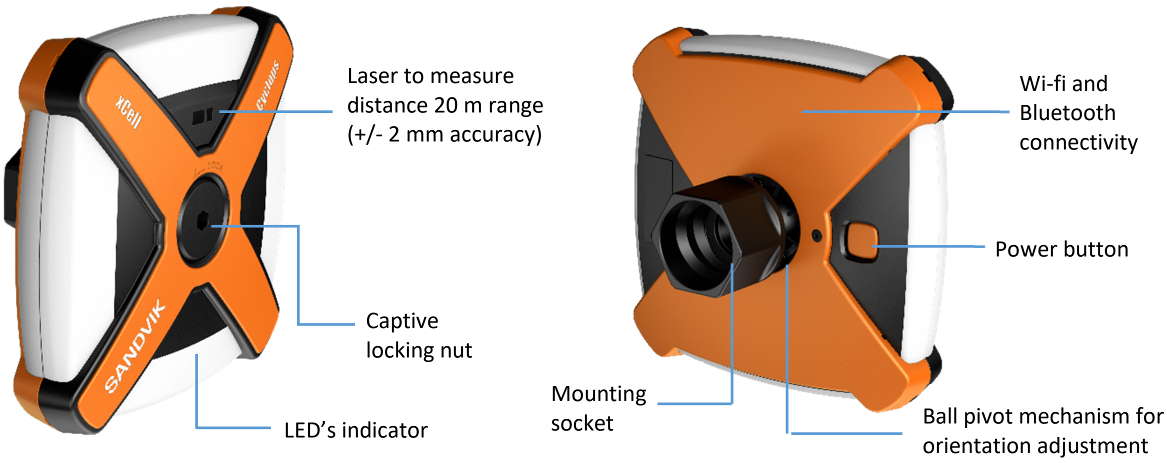


Figure 1 xCell Cyclops

2.2 The xCell Professor

The xCell Professor is the data harvesting tool which is mounted in light vehicles for mine areas without wi-fi. When the vehicle passes near a sensor, it automatically downloads the data stored in the memory of the sensor without needing to stop the vehicle.

The communication between the xCell Professor and the xCell Cyclops utilises Bluetooth low energy and is optimised for this application. It allows collection of data at drive-by speeds up to 30 km/h. When a cluster of sensors is detected, data is downloaded following a priority algorithm that prioritises sensors that measure high ground movements. Once the xCell Professor connects to wi-fi, the data is automatically uploaded to the cloud.

Power is provided to the xCell Professor by directly hardwiring the device to the 12 V vehicle ignition circuit. A battery pack is included in the device to provide extra power when the vehicle is turned off in the parking bay and the device needs to upload data to the cloud.

The xCell Professor device and components are illustrated in Figure 2.

Figure 2 xCell Professor

2.3 The Convergence application

The xCell convergence app is a cloud-based, internet platform for managing the xCell Cyclops and xCell Professor. The app is available as a progressive web application for PC, tablets and as a dedicated iOS app for Apple devices. These technologies allow the apps to be cached to work offline. Measurement data can be accessed even if the mine does not have internet access underground.

The app allows the user to configure and add devices to the system. Configuring is carried out by pairing the app with the device through Bluetooth communication. Configuration items for the xCell Cyclops include wi-fi details, rate of acquisition and upload, installation location and threshold for alarms. Thresholds can be set to maximum amplitude for convergence and maximum amplitude for rate of convergence. Configuration of the xCell Professor only requires wi-fi details and vehicle ID.

The xCell Cyclops and xCell Professors connected to the customer account are visualised on the dashboard pages. The pie chart view quickly shows sensors status and any active alarms. Plots and measurements from the sensor can be viewed and downloaded on the detailed page.

The event list shows the alarms raised by the sensors, where an event can be excessive convergence or convergence rate (when it exceeds the user-set threshold), an offline sensor, or a hardware fault. Typical hardware faults include low battery status or if the sensor detects dust obstructing the lens of the device.

The local mode scene is used to pair directly to nearby xCell Cyclops, and shows the sensor's status and the recorded measurement, as shown in Figure 3.

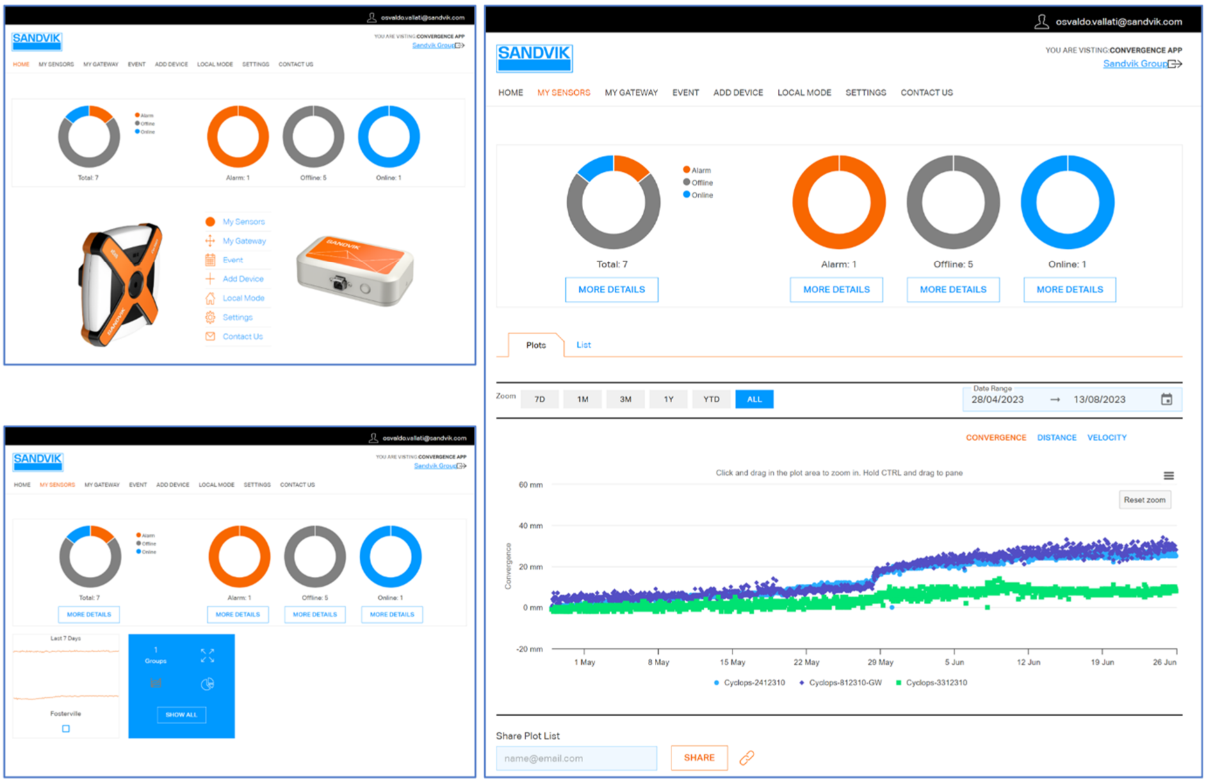


Figure 3 xCell Convergence app: (a) Home page; (b) Sensor dashboard; (c) Detailed view

3 Case study

Three xCell Cyclops were installed as part of this investigation. They were installed on the upper shoulder of the excavation using existing MD bolts, and oriented to point to the opposite lower wall.

The sensors were configured to measure distance at 1-hour intervals while data collection was carried out with the xCell Professor.

3.1 Test location

The sensors were installed at Agnico Eagle's Fosterville Gold Mine located near Bendigo in Victoria, Australia, which has a history of squeezing ground and, as it reaches deeper areas, increasing stress brings increased deformation, rock mass damage and seismicity. The geology is characterised by interbedded sandstone and shale which undergo shear deformation and bulking, more so in drives mined north–south, parallel to bedding strike. Bedding dips at approximately 65°, resulting in asymmetric deformation with kick-out of the lower east wall and upper west wall. A particular drive could experience well over 500 mm of convergence throughout its lifetime.

The selected testing area is a drive mined parallel to the bedding where shear movement causes buckling and bulking of the east wall. Thirty days after the installation of the sensors, a stope was fired 20 m away.

The mine's typical deformation monitoring includes telltale indicators, manual point-to-point laser measurements, borehole extensometer and time domain reflectometer to identify shear planes. More recently, convergence in the mine has been extrapolated using sequential LiDAR scans. xCell Cyclops will complement the mine deformation monitoring program as an early indicator for convergence.

The installation location of the devices is shown in Figure 4. The Cyclops are installed on the upper west shoulder and are aimed to target the lower east wall, both zones of past and probable future deformation.

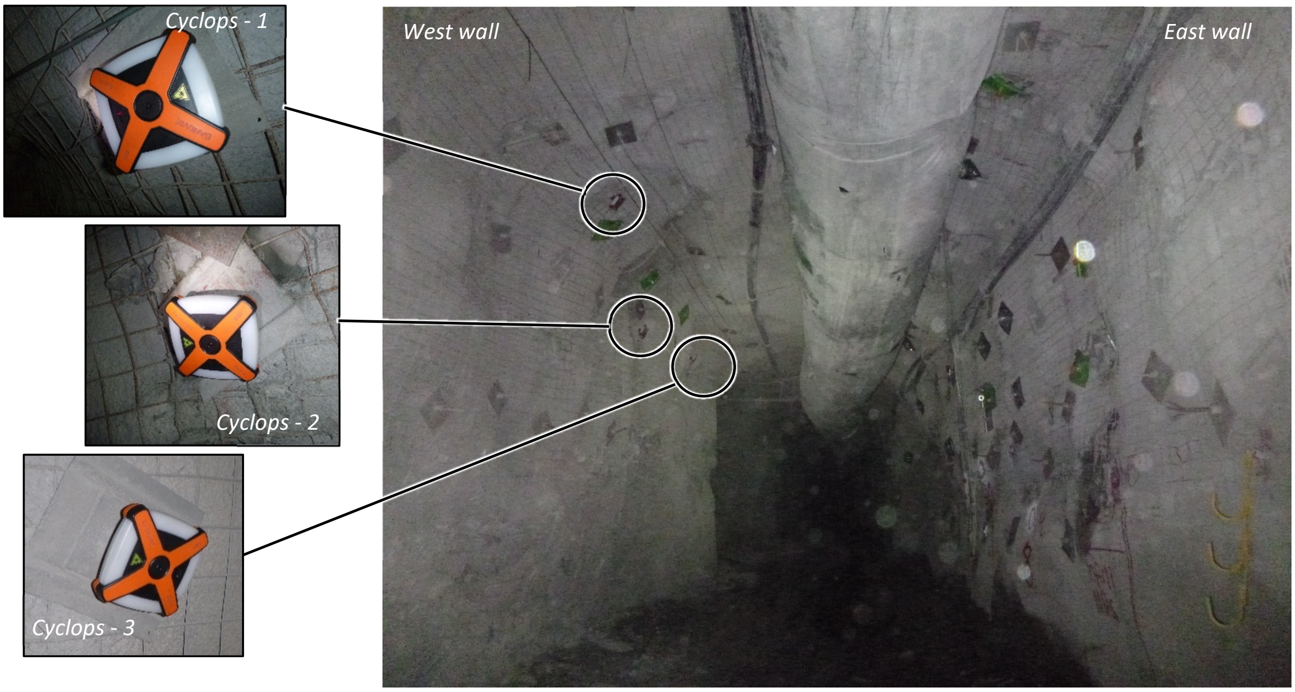


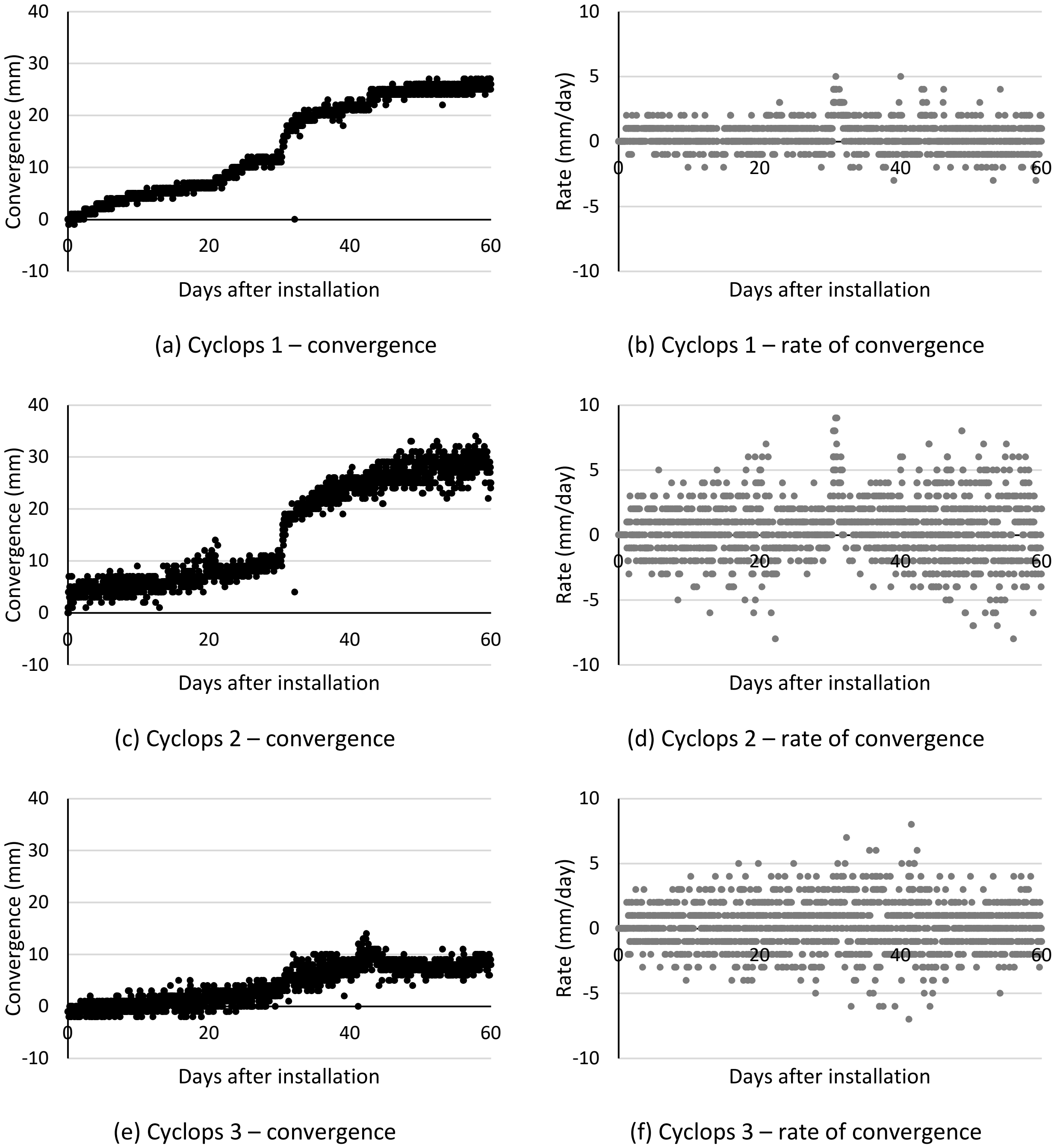
Figure 4 Overview of the testing area

3.2 Measurements

The three xCell Cyclops consistently recorded distance over the entire testing period. Raw data was uploaded to the cloud using the data harvesting mode (through the xCell Professor) and analysed to calculate convergence from the installation date and rate of deformation. The results are shown in Figure 5.

During the first month, the sensors recorded a steady increase in convergence. After 30 days, a stope 20 m away was fired, causing an increase in the rate of the deformation that lasted for three days. After that, the ground continued moving with the steady trend experienced in the first month.

When looking at the rate of convergence plots, it can be observed that data is spread over the scale of the graphs. This is caused by the noise in the convergence measurements produced by the dust in the air; nevertheless, a peak convergence rate is clearly observed at 30 days from Cyclops 1 and 2.



(a) Cyclops 1 – convergence (b) Cyclops 1 – rate of convergence

(c) Cyclops 2 – convergence (d) Cyclops 2 – rate of convergence

(e) Cyclops 3 – convergence (f) Cyclops 3 – rate of convergence

Figure 5 Measurement over the testing period

3.3 Comparison with LiDAR monitoring results

The LiDAR convergence monitoring results over the testing period are shown in Figure 6. The magnitude and location of deformation is consistent with the xCell Cyclops data. In this case, there were very low levels of deformation on the wall and shoulder where the sensors were installed, so the change in distance measured by the xCell Cyclops was equal to the target wall deformation of between 10–30 mm.

Mounting the Cyclops directly to bolts limits the amount of rotation that could occur from ground movement where the sensor is mounted. Any rotation of the sensor may affect the drive closure measurement. Regardless, the xCell Cyclops data provides a trigger for taking a LiDAR scan to assess the deformation in the area.

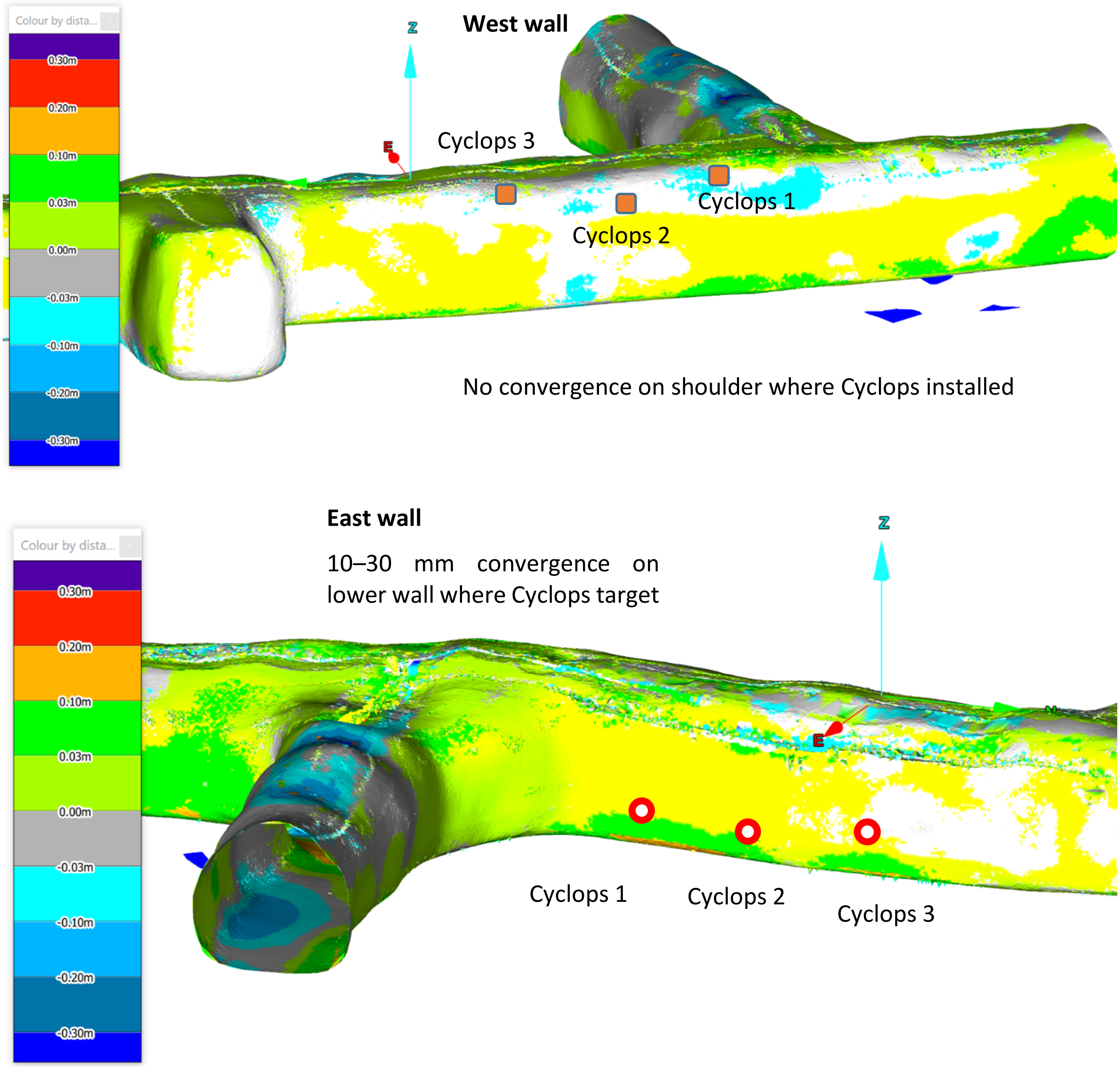


Figure 6 LiDAR convergence monitoring results over the testing period

Long-term deformation over the preceding 17 months is shown in Figure 7. The drive was developed two years prior with some deformation occurring before the baseline LiDAR scan was taken.

Regular LiDAR scans and point cloud comparisons take considerable time and resources, and it is not possible to form a complete set of development deformation results more than once a month at best. Operations embarking on the use of LiDAR technology may have a long backlog of scan data to process, only processing scans where damage has been reported and excessive deformation may occur before data is processed. The use of the Cyclops sensors and Convergence app allow the mine to target scanning and processing efforts, where required, for early detection of deformation.

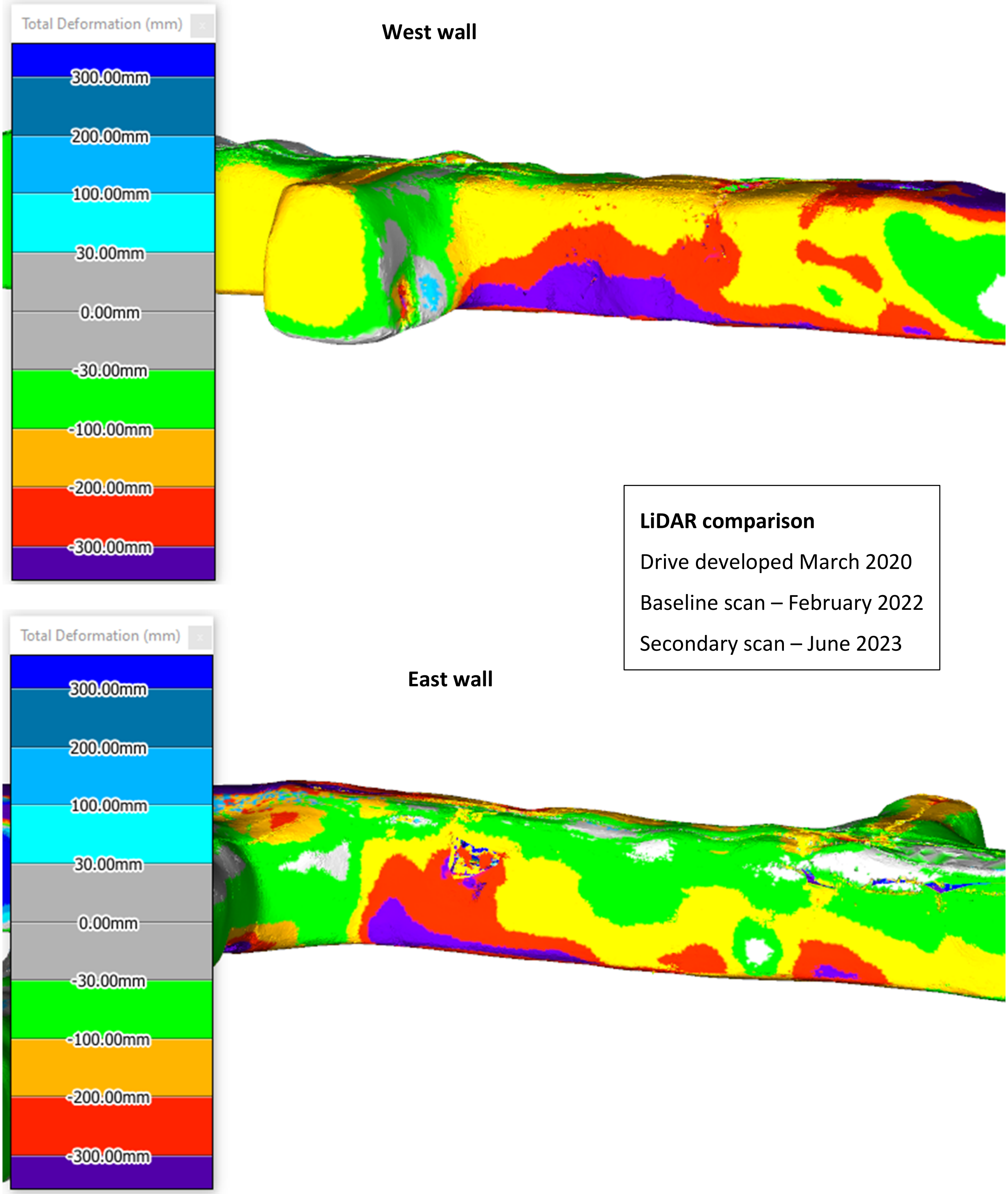


Figure 7 Long-term LiDAR convergence monitoring results

4 Concluding remarks

A new system for monitoring convergence in the underground mine has been developed and presented in this paper. The value of the xCell Convergence system is exemplified when optimised for the individual underground operation and their unique challenges. The xCell Cyclops is easily installed on existing rockbolts to measure distance continuously from one side of the excavation to the other. Data is reported directly to the cloud with wi-fi connection or through the xCell Professor (the Bluetooth data harvesting tool). Once installed, the system is totally unmanned, minimising worker effort, and reducing exposure to underground hazards. The user-friendly application allows device configuration, data visualisation and to setup thresholds for notifications. Data from the xCell Cyclops can be used to plan rehabilitation work, back-analysis ground support design and to trigger more in-depth geotechnical investigation and monitoring.

Acknowledgement

During the process of producing this paper, the work was the joint effort of the authors along with the employees of Agnico Eagle Fosterville Gold Mine that supported the testing.

References

Jones, E & Beck, D 2017, 'The use of 3D laser scanning for deformation monitoring in underground mines', *Proceedings of the 13th AusIMM Underground Operators' Conference 2017*, The Australasian Institute of Mining and Metallurgy, Carlton.

Lynch, BK, Marr, J, Marshall, JA & Greenspan, M 2017, 'Mobile LiDAR-based convergence detection in underground tunnel environments', https://qspace.library.queensu.ca/bitstream/handle/1974/15638/Lynch_et_al_2017_Mobile_LIDAR.pdf?

Potvin, Y, Wesseloo, J, Mbenza, J, Cumming-Potvin, D, Sewnun, D, Egan, A H, ... Morissette, P 2021, *Ground Support Systems Optimisation Phase 2 (GSSO 2)*, Minerals Research Institute of Western Australia, Perth.

Sandvik 2021, *iSure® 8.1 Software, Drill and Blast Intelligence*, viewed 9 June 2023, https://go.rocktechnology.sandvik/l/490131/2021-03-24/8mg7w6

Stiehl, A, Darlington, B, Rataj, M & Young, P 2018, 'Application of the MD bolt in the Fosterville gold mine', *Rock Dynamics and Applications 3*, CRC Press, Boca Raton.

Vallati, O, Roach, W & Weaver, S 2020, 'Ground support and strata monitoring: what is needed?', in J Wesseloo (ed.), *UMT 2020: Proceedings of the Second International Conference on Underground Mining Technology*, Australian Centre for Geomechanics, Perth, pp. 285–296, https://doi.org/10.36487/ACG_repo/2035_13