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Unconventional remote prism installation using a modified heavy payload release drone at Savage River mine

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Abstract

Monitoring prisms are a vital tool in open pit mining operations, providing critical information on the stability of highwalls. However, installation of these prisms can be challenging and time consuming, particularly in areas that are difficult to access on foot or where personnel may be exposed to geotechnical hazards. This paper explores the use of a modified heavy payload release drone (HPRD) to remotely install monitoring prisms in an open pit context, focusing on how the methods and technology were developed in partnership with Grange Resources and Taz Drone Solutions at the Savage River mine in Lutruwita/Tasmania.

Installation involves securing the prisms to a prism holder specifically developed for this task, and then flying them into place with a HPRD. This paper outlines the technical requirements for the HPRD and prism holder as well as the key considerations when preparing for the installation campaign, such as identifying suitable locations to install prisms, planning take-off areas and conducting risk assessments.

This paper covers examples of situations in which installation using a drone is warranted and outlines the risks and challenges faced during the installation process, such as landing in poor terrain and flying near magnetic rock and into deep pits with limited satellite coverage.

This paper summarises the key advantages of using a HPRD to install monitoring prisms in an open pit context and provides planned areas of improvement. It also gives valuable insights into how to plan and execute a prism installation campaign using the HPRD, drawing on a specific case study from the Savage River mine.

Keywords: *drone technology, prism installation, slope monitoring, risk management, automated total station monitoring*

1 Introduction

Monitoring the stability of highwalls is crucial in open pit mining operations (Welideniya et al. 2021). Monitoring of highwalls can be done through several means, one of which is the installation and constant reading of survey reflective prisms into the walls at set intervals (Read & Stacey 2009). Traditional installation of monitoring prisms can be challenging, time consuming and risky, particularly in inaccessible or hazardous areas (Little 2006). However, the emergence of drone technology offers new possibilities for remote operations in various industries, including mining. This paper explores the use of a modified heavy payload release drone (HPRD) for the remote installation of monitoring prisms in open pit mining, focusing on the collaborative efforts between Grange Resources, Taz Drone Solutions, and the Savage River mine in Lutruwita/Tasmania. The paper discusses the technical requirements for the HPRD and prism holder, campaign-preparation considerations, scenarios where drone installation is warranted, encountered risks and challenges, advantages of using a HPRD and areas of improvement, from the Savage River mine case study. Utilising drones for prism installation enhances safety, efficiency, and data collection in highwall stability monitoring.

2 Background

The Savage River mine, located in northwest Lutruwita/Tasmania, has been in operation since 1968, producing iron pellets from a magnetite orebody. Ore is currently mined from two open pits: North Pit and Centre Pit (Figure 1). The ore is crushed at a mill on site and then transported via an 85 km slurry pipeline to Port Latta, where it is processed into pellets and shipped to customers domestically and internationally.

Figure 1 Satellite image of Savage River mine

Prism monitoring has been utilised at Savage River since 2003 to assess the stability of the open pit highwalls, tailings storage facilities, and the ore conveyor (Hutchison & Widelski 2007). In the open pits, prisms are generally installed on the highwall at 50 m horizontal spacing and 30 m vertical spacing. Additional prisms are also installed strategically in areas where the geotechnical engineer has identified potential hazards that require specific monitoring. The type of prism holder used for the installation depends on where the prism will be installed. When installing the prism on the crest of the batter, a flat base or star picket style prism holder is used (Figure 2). When installing the prism into the face of a competent batter, a threaded bar prism holder is used (Figure 2a). After the prism has been installed, its location is precisely measured every six hours by an automated total station (ATS). This location data is then translated into movement data for each prism. The movement data collected from these prisms provides valuable information for identifying slope instabilities and making informed decisions regarding the safety and operational efficiency of the mine.

(a) (b) (c)

Figure 2 Conventional prism holders: (a) Threaded bar; (b) Flat base; (c) Picket

A problem commonly encountered with prism monitoring at Savage River is the inability to access and install prisms in locations where the prisms would provide useful data. For example, on suspected moving areas or around existing geotechnical hazards are locations that would be useful to monitor with prisms but are not safe to access. It was recognised that if the prisms could be installed remotely, using a drone, it would greatly improve the prism monitoring system. Examples of situations where remote prism installation would be beneficial are summarised in Table 1.

Table 1 Situations where remotely installed prisms would be beneficial

Situation	Comment
Installation of prisms onto failure areas	Once a failure has started, access near or on the failure area is restricted. It would be useful to have prisms on the failure to monitor its movement
Installation of prisms onto berms with high geotechnical risks	Some areas of the North Pit are completely closed to personnel due to the high rockfall risk and remain unmonitored by prisms
Establishment of a prism network in a pit that did not have one or had insufficient density	The density of prisms along the east wall of the North Pit is insufficient for effective prism monitoring. A section of highwall 1 km long and 350 m high only has 40 prisms in locations that are not particularly useful for monitoring. Most of the berms where prisms would be desired are inaccessible on foot
Installation of prisms in key areas based on radar or InSAR data, or more closely spaced prisms based on existing prism data	If an area has been identified as moving, it would be useful to be able to install additional prisms to track the movement
Replacement of prisms on inaccessible berms	Prisms damaged by rockfalls or covered by mud or vegetation require fixing or replacing. However, if the berm has experienced a large amount of crest loss or is covered with failed material, it can no longer be accessed on foot
Installation of prisms at times that do not rely on the mining schedule	If prisms are installed prior to blasting the trim shot, they often become damaged during the blast. Installation of prisms after the trim can be difficult to coordinate the mining cycle and can often be delayed by bad weather

3 Development

3.1 Assessment of requirements

It was determined that utilising a drone would be the most appropriate way to remotely install prisms onto inaccessible or high-risk berms. To address the issue of remote prism installation, it was necessary to create both a suitable custom drone and a prism holder. The drone would have to be able to grip the prism holder, fly it to the desired location on the berm, orientate the prism towards the ATS, drop it in place and then fly back to the starting point. To enable the remote prism installation, a HPRD was developed as a collaboration between Grange Resources and Taz Drone Solutions. The initial stage of the process was to adequately describe the requirements of the drone and prism holder, which are summarised in Table 2. This stage presented clear requirements during the design process for the HPRD and the prism holder.

Table 2 Table of Requirements

Requirements	Reason
Prism holder is as heavy as practicable, with a low centre of mass and inherently stable	Stability of the prism holder is crucial to achieve high-quality prism data
Prism holder is easily visible from afar	The prism needs to be easily visible so it can be added to the ATS system
Prism holder can be cheaply constructed on site	High volumes of prism holders are required; therefore, it is important to keep the unit cost down
Prism holder can be recovered from the berm	If a prism holder falls over, stops functioning or is no longer useful, it can be picked up and fixed or reused
Prism holder can be secured to the drone during the flight	If the prism holder swings during flight, it will disrupt the drone. Also, it needs to maintain the same direction so that it can be orientated towards the ATS
Drone needs to be able to carry heavy payload	The drone needs to have sufficient power to accommodate prism holder, camera, and battery
Drone can accurately position the prism holder in the planned location	Accurate positioning is important to enable targeting of specific areas
Drone needs to be able to orient the prism towards the ATS	Round prisms are directional, so the prism needs to be orientated towards the ATS
Drone can drop the prism holder into place, without the need to land on the berm	The closer the drone gets to the berm, the more risk there is of crashing
Drone needs to have a custom-built payload release mechanism	A custom fabricated payload release system and trigger is required to ensure accurate and safe payload delivery

3.2 Development of HPRD and prism holder

Based on the list of requirements, it was determined that the easiest way to construct a HPRD drone was to modify a DJI MG-1 drone—an agricultural waterproof spraying drone, which has a maximum payload capacity of 10 kg and a safe operating range of 1,000 m. A custom prism holder, payload release mechanisms and a payload frame were developed. The prism holder was constructed by connecting 3 × 100 mm steel fence-post sections orthogonally to form a tripod. The prism was attached to the top of the tripod with a 6 mm thick rod welded to the tripod frame with a 5/8" UNC straight circular coupler. The rod can be bent to adjust the angle that the prism is facing. On the very top of the tripod is a hole suitable for attaching a carabiner, which is then connected to the payload release mechanism on the drone. The prism holders were spray-painted bright yellow to make them more visible (Figure 3). Several versions of prism holders were tested: one with extra-long tripod legs so that the prism would be visible over the top of windrows on the edge of the berm, and another filled with ballast at the bottom of the tripod legs to lower the centre of mass and improve the stability of the prism holder. The prism holders weigh 7 kg, but the amount of ballast used could be adjusted on the specific operational requirements.

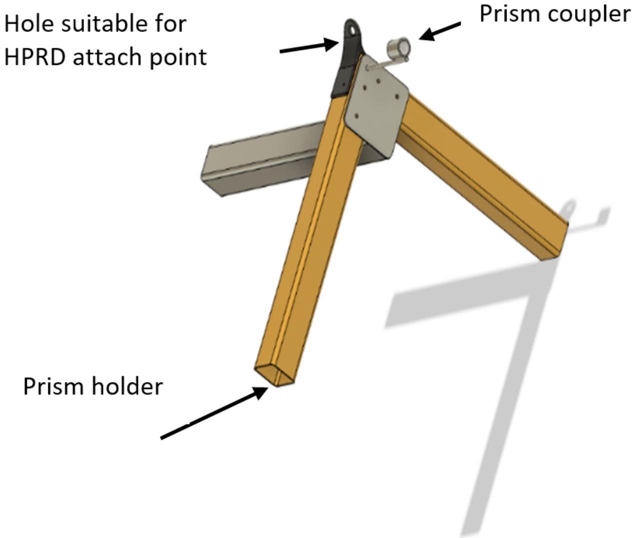

Figure 3 Drone prism holder designed for use with the HPRD

3.3 Prism holder stability assessment

One concern during development was whether the drone prism holders would be as stable as the existing prism holders. To test this, a drone prism holder was installed in proximity to existing prism holders and measured by the ATS situated approximately 800 m away over a period of six months. The stability of the drone prism holder was accepted as suitable as there was little difference in the movement rate and variance between the drome prism holder and the conventionally installed prisms situated nearby (Figure 4).

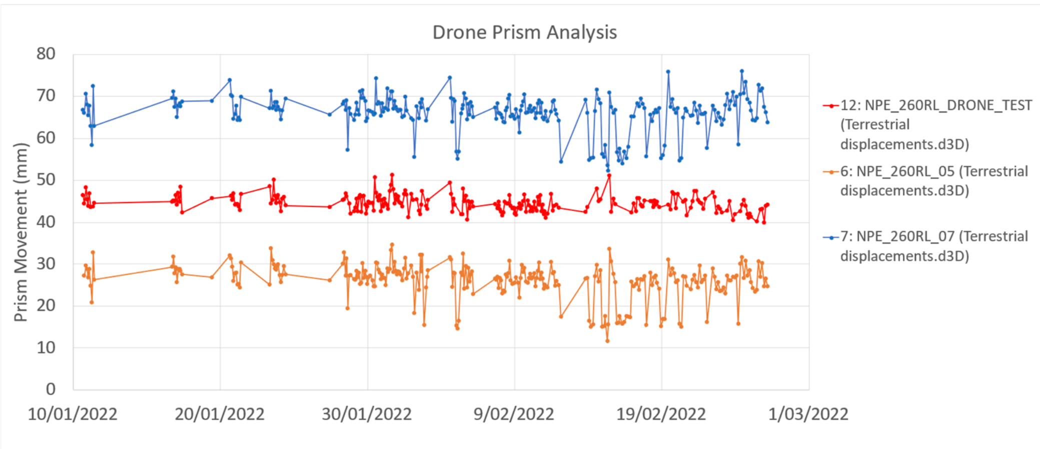

Figure 4 Prism 3D movement data showing the comparison of the prism installed on a HPRD prism holder (red) with the nearby prisms

3.4 Payload holder development

To ensure stability and prevent interference with the drone during flight, a specially designed prism holder was developed. A frame was created using a 3D printer, allowing the prism holder to be securely positioned between the legs of the drone (Figure 5). This arrangement facilitated the attachment of the prism holder before take-off and enabled the drone to land without removing the prism holder.

Figure 5 Payload frame (orange) to secure prism holder

3.5 Payload release mechanism

The final step to complete the HPRD was to construct a release mechanism that would secure the prism holder to the drone during flight and that could be remotely operated to drop the prism holder into place once the drone had reached the target location. Several different iterations of the release mechanism were prototyped. In the final version, a servo is employed to control the movement of a clamp, which firmly grasps a D-shackle attached to the top of the prism holder. The drone flight controller is programmed so that when a button is pressed on the controller, the servo opens the clamp and releases the prism holder. For safety reasons, it was important that the release mechanism was reliable and was able to hold the weight of the prism holder. The release mechanism was tested to carry up to 25 kg, which is more than three times the normal operational weight of the holder. During testing, the release mechanism showed no major signs of deflection and was determined fit for purpose.

4 Installation campaign

4.1 Risk assessment and flight planning

The Savage River site poses significant challenges for drone operations due to multiple factors, including limited satellite coverage within deep pits, magnetism produced by the magnetite ore interfering with the drone's navigation instruments, rapidly changing weather conditions and the presence of wedge-tailed eagles that may attack drones during flight. Consequently, Taz Drone contractors were employed to run the program, given the advanced skill set required for prism installation under such conditions. To ensure the safe execution of the project, a collaborative job hazard analysis was conducted in partnership with Taz Drone Solutions. The assessment primarily focused on two major risks: the potential unexpected release of the prism holder during flight and the possibility of a drone crash while the prism holder remained attached.

In preparation for flight, the site's geotechnical engineer identified specific areas on the pit highwalls where the prisms were to be installed. These designated locations were then uploaded into the drone software, enabling the drone pilot to establish waypoints for each prism installation site and develop a flight plan. Areas of the pit above which the drone would be flying according to the flight plan were cordoned off, preventing drone flight over personnel. A take-off and landing spot was established in a location that would always have a clear line of sight to the drone and would be close to where the prisms were to be installed to minimise the required flight time. The drone pilot was assisted by a spotter to keep track of the location of the drone and to alert the pilot if there were any nearby wedge-tailed eagles. A flight plan was carefully built prior to flight, with numbered waypoints for each planned prism uploaded to ensure the pilot could achieve each of the planned prisms exactly where they were required (Figure 6). Once the mission parameters and plan were established, test flights were completed in an area where the drone could be easily recovered if it were to crash. Once this had been completed, the flight plan was attempted in the field.

Figure 6 Flight plan for installing prisms on the east wall of Centre Pit

4.2 Installation methodology

Before attempting to install prisms using the HPRD, a preliminary test flight is carried out using a smaller drone, such as a DJI Phantom or Mavic. This test flight aims to ensure adequate satellite coverage, detect any potential magnetic interference, and visually inspect the suitability of the berms as landing spots for the prism holders. It is important to confirm that the landing spot is clear of debris and that the prism holder will have a line-of-site to the ATS. After confirming the designated landing locations, the prisms are affixed to the rods on the prism holders. The rod is then carefully bent to ensure that once the prisms are in place, they will be orientated at the correct angle towards the ATS. The prism holder is attached to the payload release mechanism at the bottom of the drone using a carabiner. The pilot then takes off and flies the drone towards the prism installation location. To drop the prism into location, the HPRD needs to fly close to the highwall. Due to the challenge faced by the pilot in accurately assessing their proximity to the highwall using the drone’s on-board camera, an additional pilot operates a small drone near the HPRD. The second pilot positions the camera of the smaller drone in a way that provides the HPRD pilot with a secondary perspective of the HPRD’s position. Using the view from the smaller drone as a guide, the HPRD pilot hovers the HPRD approximately 1 m above the desired landing spot. They orient the drone’s camera downward and confirm that the landing spot is suitable. They then rotate the drone so that the prism holder is facing towards the ATS location and activate the payload release mechanism. The prism holder drops into position onto the berm. The HPRD (Figure 7) then returns to the landing area, and the smaller drone flies to the tripod to capture precise location data to pinpoint exactly where the tripod was installed in relation to the flight plan. This data can be used to add the prism to the ATS system and commence monitoring.

Figure 7 HPRD taking off after dropping a prism in place on a berm

5 Summary of installation at Savage River

The Savage River project consisted of a total of 71 prisms installed across both North Pit and Centre Pit. Thirty-two prisms were installed in North Pit on the West Wall, and the remaining 39 were installed in Centre Pit on the East Wall. All prisms were successfully added to the ATS monitoring rounds and are being used for slope stability monitoring at the time of writing. Throughout the study at Savage River mine, numerous flights were carried out without any occurrences of failed critical components on the drone or prism holders. Additionally, there were no incidents during the operations conducted at that time.

The primary challenges encountered were related to magnetic interference, adverse weather conditions, GPS issues, berm quality and limited line of sight. These factors resulted in a prolonged duration for the overall project, taking approximately 48% longer than the initial planned time to complete the installation of the 71 prisms; however, the rates of installation increased throughout the project as familiarity was gained and some problems overcome. With some of the issues rectified, towards the end of the project, rates of ~10 prisms per day were achieved, subject to location.

5.1 HPRD-installed prism data verification

The installation of HPRD prisms has proven to be valuable for monitoring movements. An example of this is one of the HPRD prisms installed on the east wall of Centre Pit, which is showing a linear movement trend (Figure 8). This was verified by cross checking this movement with another slope monitoring tool, the InSAR, and other adjacent prism trends. The InSAR data showed that the area where the prism was installed is showing linear deformation commencing in late May 2023 (Figure 9) – also indicated by the HPRD prism. This and the adjacent conventionally installed prism data both suggest that the HPRD prisms are adequately installed to be able to track slope movements.

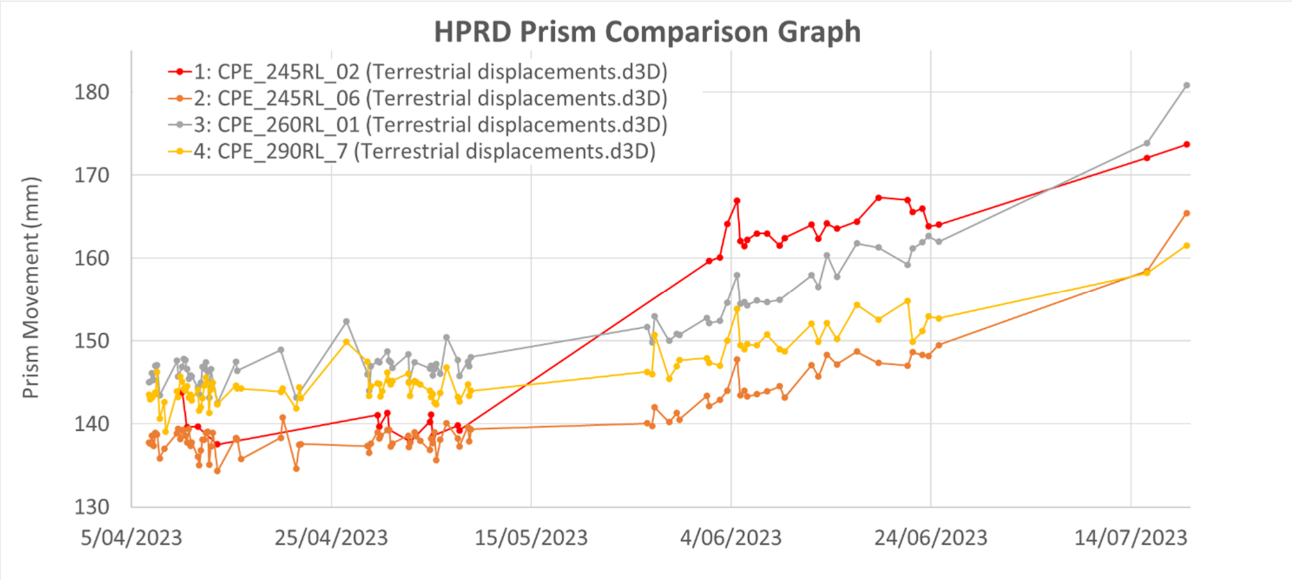

Figure 8 HPRD prism 3D movement data (red) in comparison with adjacent conventionally installed prisms (grey, purple, gold), all showing an increase in deformation from early May 2023

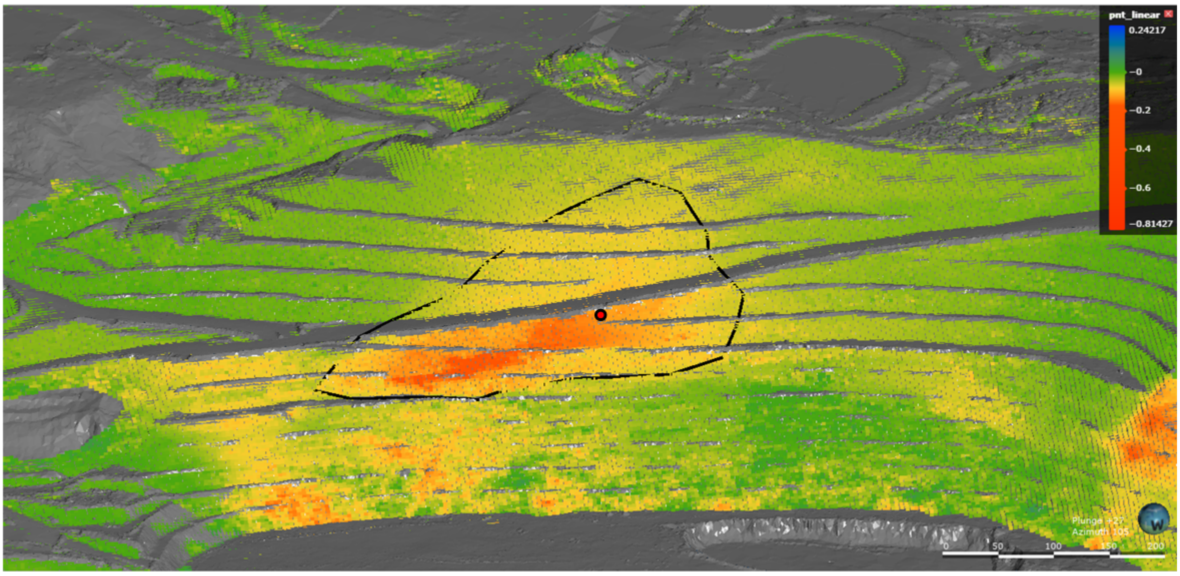

Figure 9 InSAR monitoring data of the East Wall of Centre Pit, Savage River, with zone of movement boundary in black, and HPRD prism installed in red

6 Goals for the future

This study has provided a good base upon which to build a procedure for remote prism installation using the HPRD and custom prism holders. Improvements to the current system have been identified during this study. They are:

- Improving on specific electronic parts within the drone to guarantee shielding from electromagnetic interference.
- Implementing a prism retrieval system for adjusting prism locations or recovering prisms before mining progression.
- Ensuring adjustable weight distribution for individual tripods for operational/location requirements.
- Developing and refining a prism cleaning service.
- Redesigning the tripod for scalable manufacturing and facilitating logistics as a cost-saving initiative.

At the time of writing, the prism retrieval system and the prism cleaning service have been developed. The prism retrieval system has been field-tested and is functioning, allowing the movement of prisms after they have been deployed in the field. The prism cleaning service is still in development; however, some testing has begun on this technology (Figure 10).

Figure 10 Prism cleaning technology being tested at Taz Drone Solutions' testing area

7 Conclusion

The successful development and installation of prisms using the HPRD at Savage River has addressed the challenges of installing prisms in traditionally inaccessible zones due to elevated hazard levels or restricted/removed access. This achievement significantly reduced the risk to personnel that is associated with conventional prism installation methods. The installed prisms have shown to be adequate for use of monitoring slope movements, as the data recorded through monitoring them reconcile with conventionally installed prisms as well as the secondary slope monitoring tool InSAR.

The key to achieving a successful HPRD prism installation campaign lies in the implementation of thorough risk assessments and meticulous location and flight planning.

This successful use of the HPRD for prisms also opens avenues for a wider adoption of this technology in the open pit setting. The findings of this study demonstrate that the HPRD is a viable method for deploying, retrieving or cleaning instrumentation that weighs less than 10 kg in hazardous or restricted areas in an open pit setting.

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