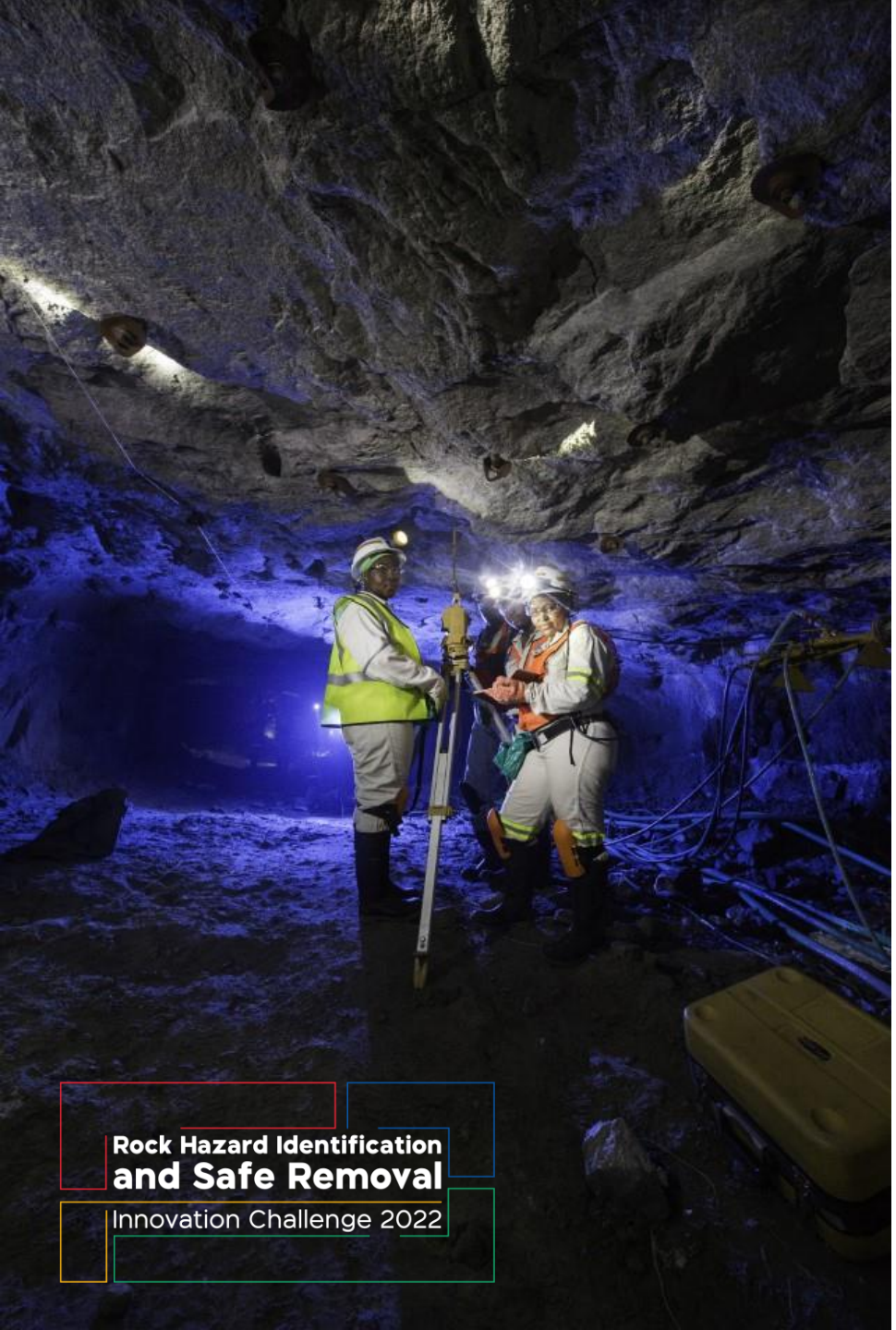


Rock Hazard Identification and Safe Removal

Open Innovation Challenge | Brief

An open innovation challenge to identify high potential innovations for real-time rock hazard identification and loose rock removal in South African Mines.

An initiative by Minerals Council South Africa and the Mandela Mining Precinct, championed by Sibanye-Stillwater and Impala.

MANDELA MINING PRECINCT
MINDS FOR MINES

MINERALS COUNCIL
SOUTH AFRICA

Championed by

we are one
Sibanye Stillwater

IMPALA
Member of the Implats Group

INTRODUCTION

The South African mining industry is currently challenged by a regression in safety performance. A 2021 investigation into the leading causes of fatalities indicated that fall of ground (FOG) related incidents are a key area of concern, accounting for 22 of the 60 overall fatalities for 2020. Falls of Ground (FOGs) have traditionally been the largest single contributor to fatalities and injuries in the mining industry. At present that trend has been cautiously encouraging with a reduction to 3 FOG fatal accidents in 2022 to date. Despite the improvement, one fatality is one too many and it highlights that problem of FOGs still requires attention.

This challenge is an invitation to identify and implement new technology that will enable the development of user-friendly solutions for the South African mining Industry. These innovations must firstly be useful in improving geological confidence at the face and reducing errors in the identification of geological risks. Secondly it must make the underground mining environment safer during the removal of loose rocks after blasting and during cleaning before workers enter the area for drilling.

Partnering for innovations in identification and removal of loose rocks technologies

The Minerals Council South Africa and the Mandela Mining Precinct, and their partners, have dramatically shifted the visibility of innovation in mining in South Africa and aims to continue making progress in the arena, with projects such as this one.

MINERALS COUNCIL SOUTH AFRICA

The Minerals Council's vision is to reposition the South African mining sector as South Africa's foremost industrial sector. The Minerals Council seeks to create, in partnership with key stakeholders, a conducive policy, legislative and operating environment that facilitates doubling real investment in mining by 2030. Part of the Minerals Council strategy is the Elimination of Falls of Ground Action Plan (FOGAP), which aims to make the underground mining environment safe by eliminating Falls of Ground. The Minerals Council's core purpose is to #MakeMiningMatter.

MANDELA MINING PRECINCT
MINDS FOR MINES

The Mandela Mining Precinct is a public-private collaboration between the Department of Science and Innovation (DSI) and the Minerals Council South Africa, hosted by the Minerals Council South Africa and the CSIR. It is an initiative aimed at revitalising mining research, development, and innovation in South Africa to ensure the sustainability of the industry. The Mandela Mining Precinct implements the South African Mining Extraction, Research, Development and Innovation (SAMERDI) strategy. This SAMERDI strategy includes the Advanced Orebody knowledge (AOK) programme, which is concerned with the identification of hazardous rock.

Partnership: science & innovation Department: Science and Innovation REPUBLIC OF SOUTH AFRICA · CSIR Touching lives through innovation · MINERALS COUNCIL SOUTH AFRICA

Sources: Minerals Council South Africa (2021) Elimination of Fall of Ground Fatalities Action Plan, DMRE Statistics (2022)

CHAMPION MINING PARTNERS

Sibanye-Stillwater is a multinational mining and metals processing group with a diverse portfolio of mining, processing operations, projects, and investments across five continents. The Group is also one of the foremost global PGM auto catalytic recyclers and has interests in leading mine tailings retreatment operations.

Sibanye-Stillwater has established itself as one of the world's largest primary producers of platinum, palladium, and rhodium and is also a top tier gold producer. It produces other PGMs, such as iridium and ruthenium, along with chrome, copper and nickel as by-products. The Group has recently begun to build and diversify its asset portfolio into battery metals mining and processing and is increasing its presence in the circular economy by growing and diversifying its recycling and tailings reprocessing operations globally.

Impala Rustenburg, member of the Implats Group, has operations on the western limb of the world-renowned Bushveld Complex near Rustenburg in South Africa. This operation comprises a 10-shaft mining complex, three concentrating facilities and three furnaces. The base and precious metal refineries are in Springs, east of Johannesburg.

The Merensky and UG2 reefs are mined concurrently, and the mining method is predominantly conventional breast mining with approximately 9% of their monthly production currently mechanised. The mining width for Merensky Reef is typically about 1.3 meters, while that for UG2 is about 1.1 meters. Panel lengths vary from 15 to 30 metres for both Merensky and UG2 Reefs.

THE PROBLEM

Modernisation to improve safety is a strategic priority for the Minerals Council and its partners, as it is an imperative for the mining industry's growth and ability to contribute positively to society.

South African underground gold and platinum mines mostly extract narrow, tabular orebodies. Intense fracturing often occurs due to high stresses encountered at depth-and the structural complexity of these orebodies. This fracturing is also exacerbated by the drill-and-blast method that is traditionally practiced in hard rock narrow reef mines. The combination of faults, joints and shallow-dipping fractures occurring in tabular stopes can compromise the integrity of the hanging wall (roof rock), resulting in rock mass instabilities. These instabilities, which are typically the target of safe-making and support activities during mining, often result in falls-of-ground (rock falls) which could lead to fatalities, injuries and damage to underground personnel and infrastructure.

The ability to accurately identify and visualise geological structures and hazards on the face by mining personnel is typically limited to in-person visual and physical examination, and the ability to identify hazards and risks ahead of the face are limited.

In the mining cycle, after the "blast" phase, mine workers are extremely exposed and vulnerable to falls of ground due to loose rocks dislodged during or after the blast, new fractures induced by mining and not yet detected, and geological phenomena including faults, joints and fractures. A new, better leading practice is needed for frontline workers in SA hard rock, tabular, underground mining to more accurately identify and visualise hazards relating to rock faults, joints and fractures after blasting, before supporting.

Once unstable and unsafe rocks have been identified, it is crucial to stabilize or remove them safely. Many mine workers have lost their lives or been disabled or seriously injured while attempting to deal with removal of loose rocks. The method of using a pinch bar to sound the rock to establish its integrity and then using it to remove the rock is not safe and physically difficult and often tiring. A new tool to safely remove a loose rock from the rock mass and lower it to the floor of the mining excavation in a controlled manner is necessary to ensure zero harm to those tasked with carrying out making safe operations.

THE PROBLEM

This problem is two-fold, consisting of identifying the rock features that are hazardous and then safely supporting or removing the said unsafe rocks.

Human-made processes taking place….

Entry examination and making safe, usually executed:

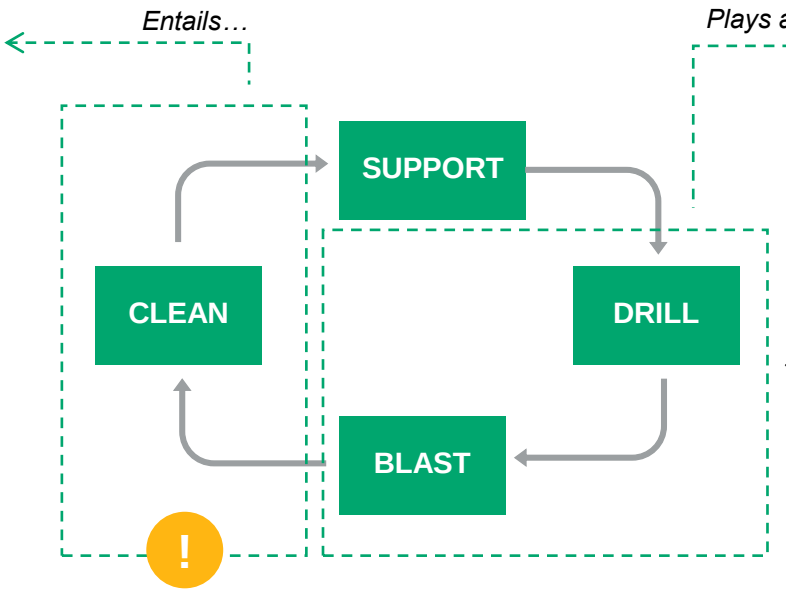
1) Re-entering a pre-worked area,
2) After a passage of time,
3) After a shift change
4) After blasting

Most rockfall incidents occur during inspection to stabilise the rock prior to work (re)commencing in the area

Ineffective hazard assessment is a leading cause of FOG accidents for gold and platinum mining

- Current 'making-safe' methods to assess the rock mass condition prior to entering or re-entering typically narrow tabular orebodies involve **critical human interpretation:**
  - **Visual recognition** of geological features distinctive of loose rock and other hazards
  - **Auditory recognition** of acoustic waves generated by striking the rock mass with a steel bar.
- This process is critical to the safety of frontline workers, but also **subject to errors** associated with inexperience, fatigue, physical ability to hear, and time constraints and pressures.

Typical mining cycle



How the rock behaves…

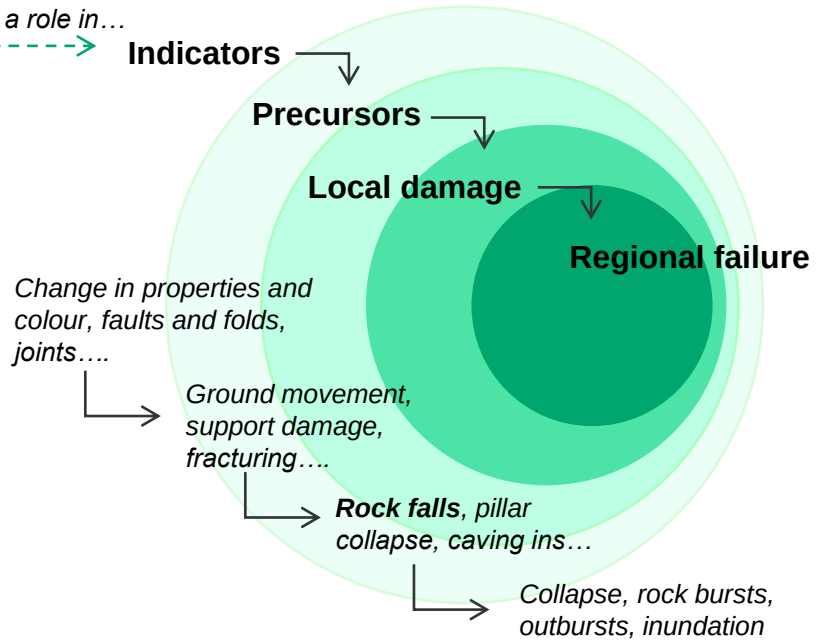


Figure: A sequence of rock mass behaviour leading to regional failure (adapted from Jones, 2020)

THE SOLUTION

The primary goal of this challenge is to demonstrate the feasibility and benefits of a new technology and/or practice aimed at making the underground mining environment safe. This safety will be achieved through improved identification and visualisation of rock hazards on the face, as well as the through the (support or) removal of loose rocks (after blasting and during cleaning) before workers enter the area for drilling.

The innovation developed through this challenge, will need to fit within either, or both, of these two categories. The first category will be concerned with the real-time identification and visualisation of rock hazards on the mining face; and the second category will focus on developing the ability to safely remove lose rocks. Both components of this solution will work together to form one solution that will help make the process of identifying and removing loose rocks in the re-entry process safer.

Rock hazard identification innovations

Demonstrate the feasibility and benefits of a new technology around entry examination in **rock hazard identification and visualisation** after blasting before workers enter the area for drilling.

Loose rock removal innovations

Demonstrate the feasibility and benefits of a new technology to make the underground mining environment safe through **removal of loose rocks after blasting and during cleaning** before workers enter the area for drilling.

THE SOLUTION | Category 1: Rock hazard identification

Advanced Orebody Knowledge: Seeing into the rock and creating a glass rock environment

The focus of the Advanced Orebody Knowledge (AOK) programme, one of 5 research programmes of the South African Mining Extraction, Research, Development, and Innovation (SAMERDI) strategy, is to provide mine planners, rock engineers, geologists and other decision makers with information and knowledge that will contribute to optimal extraction and zero harm objectives. This knowledge is required ahead of mining to adequately inform day-to-day tactical as well as long term strategic decision making.

For the year 2022/23, the AOK programme is focusing on four key project areas:

Smart drill	Technologies ahead of the face	**Technologies on the face**	Geological data

Category one of this challenge, Rock Hazard Identification, is focused on **technologies on the face**. A new, better **leading practice is needed** for frontline workers at the stope - in SA hard rock, tabular, underground mining to identify rock faults, joints and fractures after blasting, before supporting.

THE SOLUTION | Category 1: Rock hazard identification

Several barriers hinder technological adoption for improved real-time rock hazard identification at the rockface

Mobility	Additional workload / inefficiency	Fragility	Costs

Does a solution exist, or can it be developed, which addresses the following needs?

- Provides real-time information on the conditions of the rock face and hanging wall
- Can be used by mining personnel to identify and delineate areas that are problematic or can do so automatically.
- Gives some sort of warning (audible and/or visual) for an area that is assessed to be in danger of imminent failure
- Removes the user's need to touch the rock during examination.
- Is quick and easy to use and interpret, provides 2D or 3D visualisations of the rock features, and potentially incorporates AI analysis to autoanalyse the information.
- Is mobile and practical – whether handheld, wearable or autonomous
- *Preferably:* Allows for quick and easy dissemination of information remotely

User centricity is key: The solution must be seen as a practical, helpful, value-adding tool by the **user,** meaning the mining **workforce.** For this to be the case, it must be lightweight, rugged, easy to use quickly and efficiently, and without requiring additional time effort in existing work processes.

THE SOLUTION | Category 2: Loose rock removal

The Fall of Ground Action Plan launched in July 2021 by the Minerals Council and its members, identified the need for a new, safer approach for removal of loose rock under its Research & Development pillar (read more about the Elimination of Fall of Ground Fatalities action plan attached). This technology or solution should remove or distance the worker from the direct hazard area of potential rock falls.

The barring procedure

In order to the reduce the risks of loose rock and to stabilize the excavation site, mine workers carry out the function of barring according to how they have been trained (on) according to each mine's barring procedures.

A need for safer barring

The process of barring is necessary to mitigate the risks of FOG hazards. However, about 60% of FOG incidents were related to the barring procedure[1]. As such, there is a need for a new and safer approach for removing loose rock.

The actual procedures of barring vary from mine to mine but are based on the *13 principles for safe and complaint barring as per the MOSH principles.*

- P.P.E must be available and used at all times.
- Water down to expose bad hanging from a safe and supported area.
- Always have a co-worker with you (Buddy Barring), who observes the barring.
- Use the correct length of pinch-bar, sharp at both ends with a piece of hose covering the sharp end not in use, and a gasket.
- Ensure the area where you are standing is safe, and that you have a clear escape route.
- Ensure that you have firm footing.
- Remove all other persons to a safe area.
- For stoping, bar down from the top of the panel towards the bottom. (From up-dip side).
- Bar for two meters, then turn around and examine for hidden slips.
- Sound test hanging to ensure it is solid/safe.
- On failing to bar down, a second pinch bar must be utilized
- If rock still cannot be barred down, barricade-off or place a guard and report.
- Never work under suspected or loose or suspected hanging and side walls.
- The procedure itself works well as some experts have mentioned, however, the consensus is that manual barring is both physically exhausting and doesn't guarantee the safety of the workers as events such as seismic activities can not be foreseen. Two key focus areas were identified:

Improving safety - Removal of workers from the area of danger
Eliminating fatigue – Modification or replacement of the current dominant tool (pinch bar)

Source: [1]Minerals Council South Africa (2021) Elimination of Fall of Ground Fatalities Action Plan

THE SOLUTION | Category 2: Loose rock removal

The three critical environments identified where the loose rock removal tool would be required are below. It is noted that a solution which is applicable and appropriate for one of these environments may not work for the others – and the challenge owners are open to exploring valuable tools for each of these environments, separately.

	Hard rock reef mining		Bord-and-pillar
	Narrow	Wider	
Commodities	Platinum and gold		Chrome and coal
Type of rocks	Hard rock		Hard and soft rock
Dips	0 to 45 degrees slopes		0 to 25 degrees
Stope width	Ranges from 0.8 m to 1.5 m	1.5 m to 3.0 m normally, 5.0 m for exceptional cases	Ranges from 1.80 m to 3.0 m
Development area dimensions	2.5 m to 3.5 m in height; 3 m to 3.5 m in width		3.0 m to 5.5 m
Face or panel length	10 m to 35 m	10 m to 35 m	5 m to 10 m
Footwall conditions	Very uneven, often with loose broken rock		Even with less broken rock and seldom very steeply inclined (<13 degrees for mechanised)
Roof conditions	Jointed and blocky		Prone to pillar / roof intersection crushing
Primary area of concern	Hanging wall		Hanging wall, roof and pillar sides

*Note: Most mining methods in South Africa are conventional, or mixed (conventional and mechanised)

WHAT'S IN IT FOR YOU?

ACCESS TO FUNDING

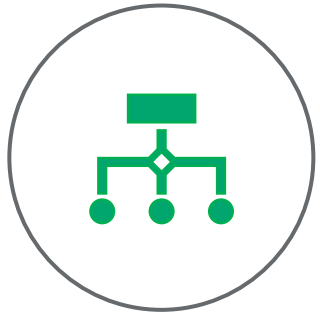
Innovations selected to take part in phase 2 and 3 of this programme will be supported financially with up to ZAR 1m of R&D funding from the Fall of Ground Action Plan R&D fund.

NETWORKING AND FREE MARKETING

If selected as a finalist, you will have the opportunity to showcase your technology publicly and receive significant brand exposure through project and media partners. This showcase aims to focus on community development, and enable collaboration in the South African context, of which your company will be part.

MARKET ACCESS

Finalists will showcase their solutions at a virtual demo-day, helping provide access to key decision makers in the mining industry, enabling market access and a free platform to market your solution to potential clients.



TESTING AND PILOTING

The SAMERDI collaboration initiative, enabled by the Mandela Mining Precinct, allows innovators to test new and/or perfect their existing technologies by using the newly established Maseve test mine. In addition to this test mine, you will be provided access to the champion mines for initial testing and piloting, giving you long term market traction, and a business case to sell to other clients within the mining industry.

ELIGIBLE DEVELOPMENT STAGES

Technology Readiness Levels

TRL 0: Idea. Unproven concept, no testing has been performed.

TRL 1: Basic research. Principles postulated and observed but no experimental proof available.

TRL 2: Technology formulation. Concept and application have been formulated.

TRL 3: Applied research. First laboratory tests completed, proof of concept.

TRL 4: Small scale prototype built in a laboratory environment ("ugly" prototype).

TRL 5: Large scale prototype tested in intended environment.

TRL 6: Prototype system tested in intended environment close to expected performance.

TRL 7: Demonstration system operating in operational environment at pre-commercial scale.

TRL 8: First of a kind commercial system. Manufacturing issues solved.

TRL 9: Full commercial application, technology available for consumers.

Any products that achieve the technical requirements established, and that are between TRL 3-9 will be considered, meaning that there must be proof of concept with viable way forward, or a product that has been tested in a lab or operational environment, with an indication of the effectivity in achieving the desired results.

European Commission Standards (https://businesscolumnist.files.wordpress.com/2014/10/trl-eu.jpg)

PROGRAMME TIMELINE

FRIDAY 12 AUG 2022

Challenge goes live!
Submissions for challenge open

MONDAY 12 OCT 2022 10H00 (SAST)

Deadline for submissions
Submissions close and evaluation and shortlisting commences

MONDAY 31 OCT 2022

Finalists announcement
After shortlisting has taken place from 12 to 28 October, selected submissions will be contacted, with further guidance and detailed expectations for final pitching and demo.

31 OCT – 25 NOV 2022

Engagement and clarification
Finalists will engage with judging panel and receive any clarifications

FIRST WEEK DEC 2022

Innovation Showcase
Finalists will get to showcase their innovations in a virtual or hybrid event, to industry and panel of judges. Final pitching round will take place with judges.

DEC 2022

Announcement of winners for next steps
Winners will be announced, and arrangements for seed funding and R&D support, prototyping, practical testing and piloting will kick off.

Notes:

- All announcements will be made with enough time to accommodate for planning.
- Should you have any questions or queries, please do not hesitate to contact us via the communications portal.

JUDGING CRITERIA | Category 1 – Rock hazard identification

CRITERIA	DESCRIPTION
TRL	• Current solution's TRL
Operational success	• Has the solution been tested in situ on hard rock / soft rock and how successful was the trial?
Current Status	• Time required to develop a deployable system
Worker safety	• User at safe distance from the rock • Removes the user's need to touch the rock • Equipment aligned to the mine health and safety requirements which ensures that the equipment is intrinsically safe (see more details in appendix)
Effectiveness at identifying rock hazards	• Can physically delineate all problematic areas in the rock and visualise these in 2D / 3D on a screen • The solution has robust data management capabilities which includes data storage of gathered information • Solution can operate in typical and difficult underground mining conditions such as low-light, fog, dust, humid and variations in temperature • Loose rocks are identified at varying depths and high penetration rate into the rock, independent of rock type • Identifies and delineates loose rocks at varying depths and orientations of discontinuity, independent of rock types
User friendliness	• The solution easily integrates results into other information systems (data interoperability) • Is mobile and practical in the underground mining environment– whether handheld, wearable or autonomous • Use of the equipment requires little to no training • Results easily interpreted with little to no technical training • Solution is reusable in multiple shifts • Solution integrates well with existing workflow and infrastructure in the working area • Maintenance is easy and affordable • Solution is durable (due to the high corrosive nature of underground mining environment)
Business criteria	• Proof of track record: Proof of market traction, previous projects and clients, and years of experience in industry. • Feasibility of solution: Demonstrates sound evidence and applicability within its intended environment. • Viability of solution: The proposal must include an estimated measurement of impact and cost effectiveness. • Team capability: The team is passionate and dedicated to the solution; and can solve problems effectively and adapt to the needs of the user requirements • Preferably, the solution is or can be manufactured in South Africa

See Appendix 1 for detailed criteria

JUDGING CRITERIA | Category 2 – Loose rock removal

CRITERIA	DESCRIPTION
TRL	• Current solution's TRL
Operational success	• Was the system tested and how successful was the trial?
Current Status	• Time required to develop a deployable system
Effectiveness in removing loose rocks	• How well can it remove loose rock without destabilising surrounding 'secure' rocks • Removed rock size sufficient to allow normal cleaning procedure • Adaptability to different rock strengths and conditions (solid, fractured, scaling
Worker safety	• To what extent can the system operate independently of a human operator • Does it distance the miner from the area being barred, enough to remain under supported areas at all times? • Does the machine's movement affect safety in the working area? • Environmental conditions created (noise, dust, fumes) by solution are tolerable • Equipment aligned to the mine health and safety requirements which ensures that the equipment is intrinsically safe (see more details in annex)
Compactness	• Ease of transport down existing shafts / tunnels to different working areas • Machine dimensions, modularity and weight appropriate for both the stoping and development areas in the hard rock narrow and wide reef mining environment as well as bord-and-pillar
Mobility	• Ability to navigate within the panel with minimal human intervention / minimal disruption to the rest of the mining activities • Able to operate on very uneven surfaces (on top of barred down rock/blasted rock) • Able to navigate comfortably on dips between 18 to 45 degrees

See Appendix 2 for detailed criteria

JUDGING CRITERIA | Category 2 – Loose rock removal

CRITERIA	DESCRIPTION
User friendliness	• Simplicity of implementation (does the system require radical or incremental changes to systems, layout, workers, etc.) • How easily can the solution be deployed with minimal operation disruption to accommodate it • Operator requirements / skill level • How easily can the solution evolve as requirements evolve, can it be used in various geological setups/across commodities (hard rock narrow reef, conventional mining and bord-and-pillar) • Minimal effort needed for assembly, setting up and dismantling to go to the next working area • The tool to (1) weigh less than the heaviest pinch bar if it is to be operated manually OR (2) loosen the rock via a mechanical process independent of human intervention. • Can operate in working conditions such as low visibility, high noise levels, high amounts of dust and humidity as well as high temperatures • Solution is durable • Maintenance is easy and affordable • The solution easily integrates results into other information systems (data interoperability)
Business criteria	• Proof of track record: Proof of market traction, previous projects and clients, and years of experience in industry. • Feasibility of solution: Demonstrates sound evidence and applicability within its intended environment. • Viability of solution: The proposal must include an estimated measurement of impact and cost effectiveness. • Team capability: The team is passionate and dedicated to the solution; and can solve problems effectively and adapt to the needs of the user requirements • Country manufactured in: The solution needs to be manufactured in South Africa

See Appendix 2 for detailed criteria

SUBMISSION CHECKLIST

Confirm you are submitting all relevant information:

Organisation overview	❑ Company name ❑ Website URL ❑ Location – City, Region, Country ❑ Ownership details (if South African-based, BEE status)
Solution	❑ Type of technology put forward ❑ Description of your product ❑ Stage of development (by Technology Readiness Level, see slide 12) ❑ Indication around IP ownership of product (if applicable) ❑ How it works (without going into details that may put IP at risk) ❑ Approach followed ❑ Business model overview (revenue model) ❑ Supporting hardware or software needed for development
Market traction	❑ Track record of previous clients, sales, projects, or years of experience ❑ Plans for scaling solution ❑ Images, videos, links of your product in market
Team	❑ Names of team members ❑ Qualifications ❑ Skill-sets and proficiencies ❑ Related experience

DISCLAIMER | INTELLECTUAL PROPERTY

The intention of this challenge is to identify promising technological innovations that could be implemented in the mining industry.

It is important that no confidential intellectual property or information is disclosed through this process. This may include pre-existing software, processes, systems or market research that is not publicly available.

By submitting a response, you represent that your response does not, and will not be deemed to, contain any confidential information of any kind whatsoever. Minerals Council South Africa, Mandela Mining Precinct, Department of Science and Innovation and its project partners will not be held liable for the loss of any intellectual property.

In the event that your solution is selected, if required, a partner agreement will be signed to protect intellectual property.

APPENDIX 1
DETAILED JUDGING CRITERIA
CATEGORY 1 – ROCK HAZARD IDENTIFICATION

JUDGING CRITERIA | Category 1 – Rock hazard identification

		SCORE				
CRITERIA	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5**
TRL	Current solution's TRL	Below TRL 3		TRL 3-5		TRL >5
Operational success	Was the system tested and how successful was the trial?	No		Solution was tested with success using modelled underground mining environment (Insert details of mining environment modelled)	Solution was tested with success in underground mining environment in other geography (Insert geography & mining environment/commodity)	Solution was tested with success in South African underground mining environment (Insert RSA mining environment, where possible operation name)
Current Status	Time required to develop a deployable system	>5 years	3-5 years	2-3 years	1 year	<1 year
Worker safety	User at safe distance from the rock	Highest worker exposure to hazardous area (x<1m from the rock)	High worker exposure to hazardous area (x<0.5m from the rock)	Some worker exposure to hazardous area (1m from the rock)	Minimal worker exposure to hazardous area (x>1m from the rock)	Removes worker from the area (operated remotely)
	Removes the user's need to touch the rock	The user touches the rock excessively while performing RHID	The user touches the rock in an unacceptable rate while performing RHID	The user touches the rock at an acceptable rate and with minimum need for force while performing RHID	The user has very little need to touch the rock and when they do, is with the slightest force while performing RHID	The user does not need to touch the rock at all while performing RHID
	Equipment aligned to the mine health and safety requirements which ensures that the equipment is intrinsically safe, as per local and international standards.	No - Not compliant				Yes - Intrinsic safety standards met

JUDGING CRITERIA | Category 1 – Rock hazard identification

		SCORE				
CRITERIA	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5**
Effectiveness at identifying rock hazards	Can physically delineate all problematic areas in the rock and visualise these in 2D / 3D on a screen	Cannot delineate any problematic areas	Fails to delineate most key problematic areas including key features	The solution successfully delineates some problematic areas	Successfully delineates most problematic areas including key features	Successfully delineate all problematic areas
	The solution has robust data management capabilities which includes data storage of gathered information	Unable to store any gathered information	Has limited data management capabilities	Can be adapted to effectively store information to also be retrieved at any time	Stores specific gathered information and can be retrieved at any time	Effectively stores the gathered information and can be retrieved at any time
	Solution can operate in typical and difficult underground mining conditions such as low-light, fog, dust, humid and variations in temperature	Equipment performance is affected by all of the physical conditions	Equipment performance affected by 2 or more of the physical conditions, including any limitations due to lighting	Equipment performance affected by 2 or more of the physical conditions, excluding lighting	Equipment performance not affected by most of the physical conditions, including lighting and dust accumulation on rock surface	Equipment can perform optimally under all underground conditions
	Loose rocks are identified at varying depths and high penetration rate into the rock, independent of rock type	<10 cm into rock Specific rock type only	<10 cm into rock Any rock type	Identifies loose rocks only to a limited extent into the rock and depths: <1m into rock, independent of rock types	Identifies loose rocks at an ideal extent into the rock. but at specific depths (≥1m into rock | mine depth of up to 3.84 km)	Identifies loose rocks at varying depths and see beyond 2m (penetration rate) into the rock across all rock types, independent of mine depth
	Identifies and delineates loose rocks at varying depths and orientations of discontinuity, independent of rock types	Cannot identify and delineate any loose rocks	Can identify loose rocks only for a specific rock type only	Can identify and delineate loose rocks for specific orientations across the rock	Can identify and delineate loose rocks up to 3.84 km depth into the mine and for all orientations across the rock	Can identify and delineate loose rocks independent of mine depth and for all orientations across the rock

JUDGING CRITERIA | Category 1 – Rock hazard identification

		SCORE				
CRITERIA	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5**
Effectiveness at identifying rock hazards (continued)	Solution provides rock falls risk profiling and gives warning (audible and/or visual) for an area that is assessed to be in danger of imminent failure in real space and time	Cannot perform risk profiling and warning for any assessed area		Can be adapted to perform risk profiling and warning for an area that is assessed		Can perform risk profiling and warning for an area that is assessed to be in imminent failure in real space and time
	Solution is suitable for all stoping heights and length within conventional underground mines *(Stope heights between 0.8m – 2.5m, average panel length 15 – 30 m)*	Not suitable for any of the South African environments	Suitable for one specific working environment only	Can be adapted to meet minimum conditions to work in most areas	Meets minimum conditions to work in most areas	Applicable across all environments
	The solution provides real-time information on the conditions of the rock surrounding the excavation	No		Provides conditions of the rock surrounding the excavation in an acceptable timeframe (less than 30min)	Yes – almost immediate (Less than 5 min)	Yes – immediate
	The solution has data management capabilities, incorporating data volume, velocity and data formats / structures	No data management capabilities	Has limited data management capabilities	Can be adapted to incorporate scalable data management capabilities	Has some data management capabilities	Has big data management capabilities
User friendliness	The solution easily integrates results into other information systems (data interoperability)	No		Integrates results with some information systems used in mine operations		Yes – all or most standard systems
	Is mobile and practical in the underground mining environment– whether handheld, wearable or autonomous	No		Equipment a bit cumbersome, but somewhat practical in the intended environment		Equipment easily handheld, wearable and/or easily operation practical in the intended environment

JUDGING CRITERIA | Category 1 – Rock hazard identification

		SCORE				
CRITERIA	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5**
User friendliness (continued)	Use of the equipment requires little to no training	Extensive training and/or specific expertise required	There is a moderate to significant amount of training required	Minimal training required	Mostly intuitive	Zero training required - very intuitive
	Results easily interpreted with little to no technical training	Technical expertise and training is needed	There is a moderate to significant amount of training required	Minimal training and digital literacy required	Mostly intuitive, some digital literacy required	Zero training required - very intuitive
	Solution is reusable in multiple shifts	No		Yes - but wears out quickly		Yes - long duration
	Solution integrates well with existing workflow and infrastructure in the working area	Complicated, extra steps required		Extra steps are required		Very simple and no extra steps required
	Maintenance is easy and affordable	Complex and expensive maintenance		Complex OR expensive maintenance		Easy to maintain
	Solution is durable (due to the high corrosive nature of underground mining environment)	No evidence provided around durability of equipment indicated	Evidence provided around durability: [Durability <6 months]	Evidence provided around durability: [Durability 6-12 months]	Evidence provided around durability: [Durability 12-24 months]	Evidence provided around durability: [Durability >24 months]

JUDGING CRITERIA | Category 1 – Rock hazard identification

		SCORE				
CRITERIA	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5**
Business criteria	Proof of track record: Proof of market traction, previous projects and clients, and years of experience in industry.	No track record in market shown	1-2 projects / clients in market described OR 1-3 years	3-5 projects / clients in market described OR 3-5 years	More than 5 projects / clients in market described OR 5-10 years	Over 10 projects implemented successfully described OR more than 10 years
	Feasibility of solution: Demonstrates sound evidence and applicability within its intended environment.	Not feasible	Has potential to be feasible	Feasible, with fair obstacles	Feasible, with minimal potential obstacles	Fully feasible as product currently is
	Viability of solution: The proposal must include an estimated measurement of impact and cost effectiveness.	Not viable (clear financial loss)	Has potential to be viable	Can be viable with additional funding	Solution is financially sustainable	Solution demonstrates and quantifies a promising level of cost effectiveness
	Team capability: The team is passionate and dedicated to the solution; and can solve problems effectively and adapt to the needs of the user requirements	No passion or want to solve problems	Team has little interest/ capacity	Team has passion, but other priorities	Team has passion and few other priorities	Team is fully dedicated to solution
	Country manufactured in: Preferably, the solution is or can be manufactured in South Africa	The solution is not manufactured in South Africa ,	The solution is not manufactured in South Africa, but has provision within the next 5 years	Team willing to make provision for manufacturing in South Africa within the next 2 years	Parts of the solution manufactured in South Africa	The solution manufactured in South Africa

APPENDIX 2
DETAILED JUDGING CRITERIA
CATEGORY 2 – LOOSE ROCK REMOVAL

JUDGING CRITERIA | Category 2 – Loose rock removal

		SCORE				
CRITERIA	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5**
Technology maturity	Current solution's TRL?	Below TRL 3		TRL 3-5		TRL >5
Operational success	Has the solution been tested in situ on hard rock / soft rock and how successful was the trial? (provide details of mining environment modelled, mining environment, geography and commodity tested, and if in South Africa – place and operation if possible)	No		Solution was tested with success using modelled underground mining environment	Solution was tested with success in underground mining environment in other geography	Solution was tested with success in South African underground mining environment
Stage of development	How much time is required to develop a deployable system?	More research needed to validate concept > 5 years	Development of working prototype 3-5 years	Additional development on an existing prototype 2-3 years	Slight modifications 1 year	<1 year
Effectiveness in removing loose rocks	How well can it remove loose rock without destabilising surrounding 'secure' rocks	Does not remove loose rock	Destabilises more rocks than it removes	Removes most loose rock but significantly destabilises surrounding rock	Removes most loose rock but destabilises surrounding rock to a negligible degree	Removes all loose rock without destabilising surrounding rock
	Removed rock size sufficient to allow normal cleaning procedure	Size of fragmentation makes it impossible to clean in conventional ways, requires additional tools / equipment	Size of fragmentation makes it very difficult to clean in conventional ways, requires additional tools / equipment	Size of fragmentation requires significant modification to cleaning process / tools used	Size of fragmentation requires slight modification to cleaning process / tools used	Standard size of fragmentation sufficient to clean in conventional way
	Adaptability to different rock strengths and conditions (solid, fractured, scaling	Can only remove soft rock, not strong enough to remove hard rock but limited adaptability to different rock conditions	Can only remove soft rock, not strong enough to remove hard rock but can adapt to most rock conditions	Can only remove hard rock, too strong for softer rock but can adapt to most rock conditions	Can remove all rock types and can adapt to most rock conditions	Can remove all rock types and can adapt to all rock conditions

JUDGING CRITERIA | Category 2 – Loose rock removal

		SCORE				
CRITERIA	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5**
Worker safety	To what extent can the system operate independently of a human operator	Needs to be manually operated by a person next to it	Needs to be operated by a person < 2m away	Remotely controlled from < 4m away	Remotely controlled from > 4m away	Autonomous, no need for worker presence
	Does it distance the miner from the area being barred, enough to remain under supported areas at all times?	Operator under unsupported area at all times	Operator under unsupported area most of the time	Operator exposed to unsupported area during inspection only	Operator under supported area most of the time	Operator under supported area at all times
	Does the machine's movement affect safety in the working area?	Needs manual collision avoidance and many loose parts exposed	Needs manual collision avoidance and a few loose parts exposed	Needs operator to avoid collisions remotely but no minimal loose parts	Needs operator to avoid collisions remotely but no loose parts	Has automatic collision avoidance functionality and minimal loose parts exposed
	Environmental conditions created (noise, dust, fumes) by solution are tolerable	Extremely hazardous, workers would need additional PPE		Creates a tolerable amount of hazards but no need for additional PPE		Does not create any additional hazards
	Equipment aligned to the mine health and safety requirements which ensures that the equipment is intrinsically safe. (Equipment meets international & South African underground mining standards on Intrinsic safety)	No - Not compliant				Yes - Intrinsic safety standards met

JUDGING CRITERIA | Category 2 – Loose rock removal

		SCORE				
CRITERIA	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5**
Compactness	Ease of transport down existing shafts / tunnels to different working areas	Requires significant changes to current transport system	Minimally compact	Moderately compact	Mostly compact	Very compact
	Machine dimensions, modularity and weight appropriate for both the stoping and development areas in the hard rock narrow and wide reef mining environment as well as bord-and-pillar	Cannot fit in low areas	Can fit in areas with heights < 1.4m	Can fit in areas with heights < 1.2m	Can fit in areas with heights < 1.0m	Can fit in areas with heights < 0.8m
		Cannot reach in high areas	Can only reach areas with heights <2m	Can only reach in areas with heights <2.5m	Can only reach areas with heights <3.0m	Can reach in areas with heights >3.0m
Mobility	Ability to navigate within the panel with minimal human intervention / minimal disruption to the rest of the mining activities	Cannot manage without human intervention and disrupts the rest of the mining activities	Struggles without human intervention and disrupts the rest of the mining activities	Can navigate with minimal human intervention and slight disruption to the rest of the mining activities	Can navigate without human intervention and slight disruption the rest of the mining activities in the working area	Can navigate without human intervention without affecting the rest of the mining activities in the working area
	Able to operate on very uneven surfaces (on top of barred down rock/blasted rock)	Cannot manage on very uneven ground		Has limited ability to navigate on top of rocks on the ground		Can easily navigate on top of blasted/barred down rock
	Able to navigate comfortably on dips between 18 to 45 degrees	Can not manage in steep areas	Can only manage up to 15-degree dips	Can only manage up to 25-degree dips	Can only manage up to 35-degree dips	Can navigate up 45-degree dips comfortably

JUDGING CRITERIA | Category 2 – Loose rock removal

		SCORE				
CRITERIA	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5**
User friendliness	Simplicity of implementation (does the system require radical or incremental changes to systems, layout, workers, etc.)	Requires complete redesign of current systems	Requires a significant change to current systems	Requires incremental change to current systems	Requires very small changes to current systems	Requires no change in current systems
	How easily can the solution be deployed with minimal operation disruption to accommodate it	Complete disruption of operations	Significant disruption to operations	Minimal disruption to operations	Insignificant disruption to operations	No operational disruption / makes the process quicker and easier
	Operator requirements / skill level	Special skills required; extensive formal training needed	Additional skills required; some formal training needed	Skills can easily be acquired through quick informal training	Solution is intuitive, easy to learn with informal training	No special skills required
	How easily can the solution evolve as requirements evolve, can it be used in various geological setups/across commodities (hard rock narrow reef, conventional mining and bord-and-pillar)	Cannot be used in environments other than the one it was built for		Can operate in more than one environment with slight modifications		Can operate in multiple environments without modifications
	Minimal effort needed for assembly, setting up and dismantling to go to the next working area	Extensive effort to set up, needs to be carried / driven to next working area	Significant effort in set up, needs to be carried / driven to the next working area	Simple set up, needs some physical assistance to move to the next working area	No set up needed, needs minor physical assistance to move to next working area	No set up needed, can move to the next area without any physical assistance
	The tool to (1) weigh less than the heaviest pinch bar if it is to be operated manually **OR** (2) loosen the rock via a mechanical process independent of human intervention.	Needs more than one person to operate	Can be operated by one person with significant physical strain	Can be comfortably operated by one person	Minimal human effort needed	No human intervention needed

JUDGING CRITERIA | Category 2 – Loose rock removal

		SCORE				
CRITERIA	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5**
User friendliness	Can operate in working conditions such as low visibility, high noise levels, high amounts of dust and humidity as well as high temperatures	Cannot operate in most working conditions	Can operate in some working conditions with significant performance changes	Can operate in most working conditions with slight performance changes	Can operate in most working conditions with no effect on its performance	Can operate in all working conditions with no effect on its performance
	Solution is durable	Solution is durable (due to the high corrosive nature of underground mining environment)	No evidence provided around durability of equipment indicated	Evidence provided around durability: [Durability <6 months]	Evidence provided around durability: [Durability 6-12 months]	Evidence provided around durability: [Durability 12-24 months]
	Maintenance is easy and affordable	Complex and expensive maintenance		Complex OR expensive maintenance		Easy to maintain
	The solution easily integrates results into other information systems (data interoperability)	No		The solution integrates results with specific information systems used in the mine operations		Can be integrated easily (Plug-and-Play)

JUDGING CRITERIA | Category 2 – Loose rock removal

		SCORE				
CRITERIA	**DESCRIPTION**	**1**	**2**	**3**	**4**	**5**
Business criteria	Proof of track record: Proof of market traction, previous projects and clients, and years of experience in industry.	No track record in market shown	1-2 projects / clients in market described OR 1-3 years	3-5 projects / clients in market described OR 3-5 years	More than 5 projects / clients in market described OR 5-10 years	Over 10 projects implemented successfully described OR more than 10 years
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