TOUCHING LIVES THROUGH INNOVATION

The Mining Indaba serves as an opportunity for the CSIR to showcase tailor-made capabilities designed for the modernisation of mining, emphasise the commitment to safety and security in the mining sector, introduce innovation partners to the mining industry at large, and showcase relevant innovations jointly.

The Council for Scientific and is set to engage in Africa's largest investment mining event, the African Mining Indaba Investment Conference, taking place from 3-6 February 2025. The Mining Indaba serves as an opportunity for the CSIR to showcase tailor-made capabilities designed for the modernisation of mining, emphasise the commitment to safety and security in the mining sector, introduce innovation partners to the mining industry at large, and showcase relevant innovations .

science, technology & innovation
Department:
Science, Technology and Innovation
REPUBLIC OF SOUTH AFRICA

CSIR
Touching lives through innovation

FROM CSIR CHIEF EXECUTIVE OFFICER DR THULANI DLAMINI

The mining sector is experiencing a significant transformation, driven by the global response to climate change and the shift towards a clean energy future. This transition has created a growing demand for critical raw materials. However, the industry faces persistent challenges, including rising operational costs, productivity concerns, safety and security issues, and widespread illegal mining in South Africa. These factors have necessitated a reimagining of mining practices to achieve safer, more cost-efficient, and sustainable operations by transitioning from fuel-intensive systems to renewable energy solutions.

The CSIR is committed to supporting competitive industries and building a capable state. Over the years, we have significantly contributed to the industrial and economic growth of South Africa's mining sector by developing specialised, impactful solutions. Our innovations include adapting radar technology for mining applications, establishing deep-level underground mining testing facilities, and advancing rock and geophysics engineering. Additionally, we have played a pivotal role in founding mining technical services and associations such as Coaltech, the Mandela Mining Precinct, and MineRP.

With more than 70% of our staff being qualified experts in science engineering and technology, the CSIR is uniquely positioned to tac' the complex challenges facing the mining industry. Using a sys' approach and multidisciplinary teams, we deliver bespoke, cut edge solutions.

In collaboration with industry stakeholders, the CSIR has recently developed solutions aimed at modernising mines and adopting fit-for-purpose innovations across the mining value chain. These efforts focus on key value drivers, including enhancing safety and health, ensuring environmental sustainability, improving efficiency and productivity, reducing costs, optimising resource utilisation, and ultimately improving quality of life.

We are excited to showcase our expertise at the 2025 Mining Indaba, where a diverse team of CSIR professionals will present a range of specialised capabilities in the following areas:

1. **Safety and health**

- Competency-based training for miners
- Near real-time risk assessment technologies supporting collision prevention
- Compliance testing and advanced safety solutions

2. **Security**

- Cyber range solutions tailored for mining
- Integrated security solutions

3. **Improved efficiencies**

- Additive manufacturing technologies
- Circular laser-based refurbishment services to extend equipment life

4. **Productivity through digitalisation and automation**

- High-resolution geophysical tools for ground stability assessment
- Ore body characterisation and structural mapping

5. **Critical minerals**

- Global competitive assessments for cost-effective mineral extraction

6. **Sustainability**

- Circular economy research and applications
- Advanced technical modelling for bankable studies
- Renewable energy feasibility studies and hydrogen techno-economic analysis in mining
- Water treatment solutions, including acid mine drainage remediation and ecosystem sustainability consultancy

Through our innovative solutions and collaborative efforts, the CSIR is dedicated to enabling the mining industry to overcome its challenges, embrace modernisation, and drive sustainable growth in South Africa and beyond.

SAFETY AND HEALTH

Virtual reality transforms the face of training in the mining industry.

The CSIR has developed an innovative competency-based training framework that provides mining trainees with near-real emergency experiences. The solution uses virtual reality (VR) technology to improve the safety of mineworkers through immersive and experiential training on hazardous scenarios. This training framework uses VR to train mineworkers on how to adequately respond to emergencies such as underground fires and explosions. The approach is set to enhance the trainees' readiness to respond to hazardous underground scenarios such as irrespirable atmospheres, thus contributing to the safety of South Africa's mineworkers.

The prevailing phenomenon in mining operations has been workers' inability to adequately respond to the irrespirable atmosphere caused by fires or explosions. The competency-based training thus ensures that the workers are competent in the emergency procedures, which include donning self-contained self-rescuers and proceeding to the nearest place of safety. It also assists workers to know what to expect in instances of emergencies.

The use of VR technology is well established in the mining industry, particularly in the training of machine operators using a VR-enabled simulator of the machine, vehicle or equipment. It is also gaining popularity in training workers in identifying and managing safety risks. The CSIR-developed solution extends the use of VR to include training for emergency response. The utilisation of VR technology contributes positively to productivity and improved safety within the mining sector. The use of an immersive training approach in training for emergency response is a powerful tool to improve preparedness for scenarios that occur infrequently, but with potentially severe consequences.

The CSIR has undertaken roadshows and a pilot programme starting with coal mining operations in 2023 and is extending this to metalliferous mining operations in 2024.

Superior training for the mining industry

Fires in underground mines rapidly create an irrespirable atmosphere due to the release of smoke and toxic gases. This poses a threat to the lives of mine workers, who are unable to self-rescue by following the

designated escape route to a place of safety. For this purpose, mine workers carry an emergency breathing device called a self-contained self-rescuer (SCSR) in the underground workplace. The life-saving potential of the SCSR can only be realised if the worker is adequately trained in its deployment and use and knows what to expect when using the device.

The CSIR has designed the SCSR Expectation Trainer to assist in the training of mine workers in the use of their SCSR. This novel training device reliably offers the user a realistic simulation of breathing from an actual SCSR. Through this innovation, the CSIR seeks to contribute to the quality of training in the donning and use of self-contained self-rescuers.

Most training centres in South African mines do not provide the trainee with a realistic experience of breathing sensations from an actual SCSR. Currently, many of the training facilitators at these training centres only demonstrate the donning procedure to the users using SCSR dummy units during the training sessions. This phenomenon leaves miners insufficiently prepared to deal with a real self-rescue scenario.

The SCSR Expectation Trainer is designed for classroom training and allows the trainee to experience the sensations of heat and breathing resistance commonly experienced when chemical-based SCSRs are activated . Through the application of the Expectation Trainer in regular training, the mining industry can greatly reduce the risk of incorrect use of SCSRs during emergencies.

The SCSR Expectation Trainer unit does not have the inherent risks associated with the chemical-based training units of other original equipment manufacturers (OEMs). Furthermore, the SCSR Expectation Trainer is designed to be connected to OEM training dummy units so that the users can experience a complete donning and use of different SCSR types. The SCSR Expectation Trainer offers a relatively low-cost, reusable option that makes it possible to allow all underground workers to undergo regular experiential training. It is the first of its kind as it combines a realistic user experience with low cost, low risk, and reusability while allowing the trainee the freedom to walk along a simulated escape route. Widespread experiential training translates into more lives saved in an emergency event such as an underground fire.

The SCSR Expectation Trainer is commercially available and may be ordered directly from CSIR or from its licensed manufacturer.

TRACKLESS MOBILE MACHINE SYSTEM TO PREVENT VEHICLE COLLISION.

The CSIR has developed a near-real digital risk tool that predicts the performance of systems in support of the mining industry collision prevention for trackless mobile machines (TMM). In compliance with Chapter 8 of the regulations of the Mine Health and Safety Act of 1996 (Act 29 of 1996), the TMM technology is designed to improve mining safety operations in South Africa.

Through the application of 4IR technologies such as digital twin, artificial intelligence, machine learning, and other data analytic techniques, the TMM technology is well-positioned to support the mining industry's zero-harm and modernisation initiatives. The technology possesses the ability to evaluate vehicle risk interaction and predict optimum scenarios for decision-making in mines. The TMM technology seeks to improve operational efficiency, productivity, safety, cost reduction, and compliance in the sector and supports the mines in implementing overall traffic management strategies.

The CSIR made significant progress in the mining industry by conducting a pilot study of the technology at a South African open-cast mine. The implementation process of the TMM technology project included the usage of traffic management plans, vehicle logs, and event data to perform data analysis and generate insights. These insights encapsulated event detection for compliance and non-compliance, anomalies, unsafe acts, unsafe conditions, and vehicle interaction. This initial project process formed part of risk identification and management to assist the mine in evidence-based decisions that mitigate risk and subsequently improve safety and productivity.

The TMM solution possesses impeccable benefits for the South African Mining sector. Through its application, national priorities such as industrialisation, localisation, and the re-industrialisation of a modern economy are realised. The CSIR continues to work in collaboration with its main stakeholders, the Department of Science and Technology, the Minerals Council, and the Mandela Mining Precinct.

FORENSIC ENGINEERING

Expert Scientific Analysis for Safety and Efficiency

Forensic engineering involves investigating and analysing failures or accidents related to mining and metallurgical plant operations. This specialised field improves safety and efficiency in the mining and engineering industries by providing critical insights into the causes of incidents or failures of equipment malfunctions, structural collapses, and explosions.

The Council for Scientific and Industrial Research (CSIR) provides expertise in forensic analysis, consulting engineering services and litigation support for a broad spectrum of cases, in mining, metallurgical and chemical engineering, oil and gas industries, legal, and insurance sectors.

The CSIR developed a process for understanding the causes and mechanisms behind the failure of materials, products, or systems, to enhance safety, reliability, and operational performance. The CSIR's investigative approach is fundamentally a problem-solving exercise beginning with understanding the background of the problem, through to the last step of the process. This process of root cause identification and implementing preventive actions reduces the risk of failure, downtime, and loss of production. It increases productivity in industries such as mining, plumbing, oil and gas, and engineering.

The use of state-of-the-art equipment such as Transmission and Scanning Electron Microscopies equipped with Energy Dispersive X-ray Spectroscopy (TEM, SEM, EDX), Electron Backscatter Diffraction (EBSD), and X-ray microscopy (XRM) assist in solving forensic investigations.

Experts in physical, metallurgical engineering, and materials science (PhD, MEng, and MSc) with strong analytical skills, attention to detail, and ability to communicate complex scientific information.

SECURITY

A controlled environment to detect and defend against cybersecurity threats

Cybersecurity is part of the digital age, even in mining operations. The increased threats of data breaches, information sabotage and ransomware attacks are fast becoming prevalent, and organisations have had to find ways to protect themselves against these threats.

The CSIR has developed a controlled and simulated environment for developing cybersecurity skills, as well as for testing. The cyber range provides a platform for individuals and organisations to practice and improve their ability to detect, defend against, and respond to various cyber threats in a secure and isolated setting.

Cybersecurity incidents can have significant consequences, including disruptions to daily operations which can result in financial loss for organisations. A cyber range allows organisations to proactively identify and address vulnerabilities, reducing the risk of downtime and financial losses due to cyberattacks.

A cyber range tailored to the mining sector can simulate scenarios relevant to mining technologies, critical infrastructure, equipment and processes, allowing cybersecurity professionals in the industry to develop specialised skills to deal with industry specific threats. Mining companies can also use the cyber range to train their incident response teams to effectively handle and mitigate incidents.

Situational awareness for mining operations

The CSIR-developed CMORE is an innovative shared awareness and integration platform that addresses the need for situation awareness and collaboration amongst users through the consolidation of information from various sensors and external systems as well as real-time analytics. The South African mining industry faces a myriad of challenges in the safety and security of infrastructure – large and small. Monitoring of operations is becoming an integral part of all operations on site. The seamless integration of tools and systems to share intelligence and knowledge to ensure better decision-making and safety has become imperative.

The web-based platform incorporates information from different sources such as cell phones and sensors into a consolidated view that provides operational response managers with near real-time situational awareness. It is a secure, private cloud-based platform with both mobile and web-based applications which are used to view and contribute information to the system.

CMORE provides mine operations monitoring and control teams with situational awareness in a visual format, based on content-rich near real-time state and event information.

CMORE integrates data from various sensors such as cameras, cellphones and seismic sensors. The fusion of these data sources provides a unique capability that allows users to be more responsive to operational, safety and security needs. This enables appropriate responses to be implemented early enough to mitigate negative impacts on safety and productivity.

This consolidated hub presents opportunities to operational managers to make decisions and ensure safety in mining operations.

ENERGY

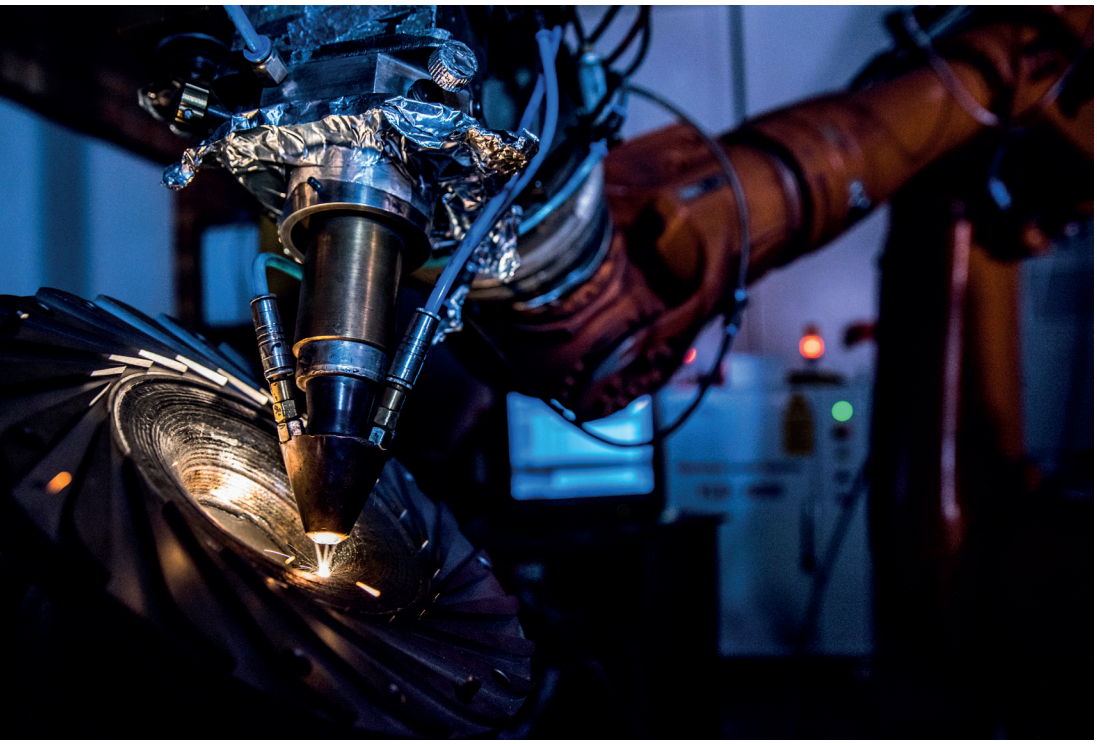
CSIR equips the industry to transition to greener sustainable practices

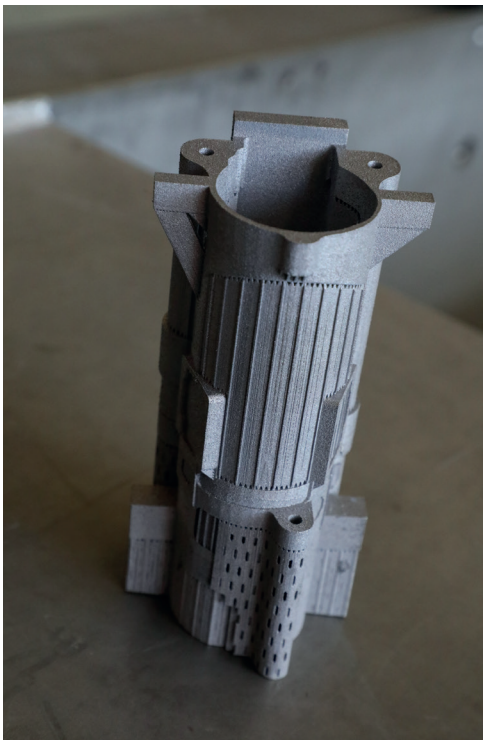
South African mining entities have made commitments to making significant advances towards NetZero targets by 2030 and to be carbon neutral by 2050. As part of transitioning towards this target, the CSIR is in the process of developing a solution in the hydrogen space, particularly focused on the deployment of dual-fuel hydrogen internal combustion engines for the South African Mining Industry (SAMI). This hybrid approach ensures operational continuity while gradually integrating hydrogen as a fuel source, simultaneously reducing emissions, and cost-effectively reskilling the workforce.

The mining industry faces the need to decarbonise and the CSIR is geared towards addressing this within the industry. This process aims to ensure compliance with international environmental standards such as the Carbon Board Adjustment Mechanism and facilitate the adoption of hydrogen technology while taking into careful account the financial implications of such a transition. This is crucial for mining companies facing financial constraints and needing to balance economic viability with environmental responsibilities.

This technology has the potential to contribute to the economic and social sustainability of the mining sector by ensuring that the move towards greener technologies. The solution offers support to individuals and communities who are dependent on mining for their livelihoods.

To accelerate the adoption of hydrogen technologies in SAMI, the CSIR is undertaking a detailed study that is intended to serve as a roadmap for the SAMI's transition to hydrogen technologies and is at the forefront of developing a dedicated laboratory for hydrogen internal combustion engines.





SUSTAINABILITY

Efficiency and Cost-saving Across Industries

Laser-based Surface Engineering

The Council for Scientific and Industrial Research (CSIR) has a diverse and specialised portfolio of laser-based technologies to support various industries such as manufacturing, mining, defence, transport, energy, etc. Designing novel technologies and enhanced processing approaches, these services typically reduce costs, saving time by limiting downtime, reducing wastage, and improving performance.

Laser Cladding

This is a process of laser refurbishment used to restore worn, damaged, or faulty components. Applications of laser cladding involve repairing various items, such as moulds, shafts, compressor screws, turbine blades, continuous casting rolls, and sealing cracks, among others.

Mobile Laser-based Refurbishment System

The CSIR developed a strong competence in laser-based refurbishment, based on laser cladding technology. The system was designed for on-site welding. This capability is invaluable for the refurbishment of large and high-value components with faster response times and significant cost savings to industry.

3D Laser Cutting and 3D Pipe Cutting

The 5-axis, 5kW CO2 laser system is designed for cutting three-dimensional parts and tubes. Its applications encompass a variety of tasks including the laser cutting of welding preparations on tubes, the precise cutting of square tubes, the shaping of formed body parts, and the fabrication of automotive body components.

Laser Hardening

Laser transformation hardening is used on carbon steels that contain between 0.3% and 1.5% carbon, including cast iron. This technique finds applications in various areas such as repairing gears, press tools, components in automotive steering pumps, forming tools and moulds, piston ring grooves in heavy-duty engines, and turbine blades, among others.

Laser Welding

Laser welding involves joining components by utilising a laser source, which may or may not require additional filler material. This technique is applied in various areas, such as welding automotive body panels, creating lightweight structures, manufacturing stainless steel tubing, and fixing gears to shafts, among others.

Metal 3D printing offers cost-effective solutions for critical parts, reducing downtime and inventory costs

Metal additive manufacturing, commonly known as 3D printing, involves creating parts layer by layer from digital models, enabling unprecedented flexibility and precision to manufacture difficult-to-machine parts on demand.

Many of the critical parts that fail in the mining industry cannot be repaired. To avoid this, companies need to keep large inventories of extremely expensive parts to reduce downtime. In many cases where inventory is not kept, plants and production lines can be shut down for weeks while replacement parts are sourced from original equipment manufacturers (OEMs) costing mining companies millions of dollars a day in lost revenue.

Technologies like metal 3D printing are now so cost-effective that it is possible to apply them to the supply chain in the form of digital distribution of spare parts. The CSIR has numerous large metal 3D printers (up to 600 x 600 x 700 mm3) to print critical, large metal parts in a fraction of the time it would normally take to ship them from OEMs. These machines promise to drastically reduce inventory costs and downtime over the next decade (especially in remote operations).

PRODUCTIVITY THROUGH DIGITAL AUTOMATION

Hot Isostatic Pressing

For Improved Material Performance

Hot Isostatic Pressing (HIP) is a specialised manufacturing process employed in industrial sectors to eliminate internal defects in components that occur during the initial manufacturing process. This is achieved by subjecting components to a blend of high temperature and high gas pressure (approx. 2000 bar) within a regulated environment.

The Council for Scientific and Industrial Research houses state-of-the-art HIP technology with the ability to perform HIPing, quenching, and heat treatment in one cycle. This integrated approach results in reduced costs and increased productivity. The facility's operations are supported by specialised non-destructive testing (NDT) and metrology laboratories that uphold standards of quality and precision.

Pre-HIPing assessments and measurements are crucial for establishing a material's initial condition. These include density measurement, dimensional analysis and mechanical property testing. Metrological analysis such as surface profilometry provide high-resolution data for analysing surface finish and geometrical accuracy. Pre and post-NDT, such as ultrasonic testing or radiography, is typically performed to identify existing defects or irregularities like cracks or voids.

Applications:

- Casting densification
- Additive manufacturing
- Powder metallurgy
- Metal injection moulding
- Introduce compressive residual stresses in parts to improve fatigue performance.

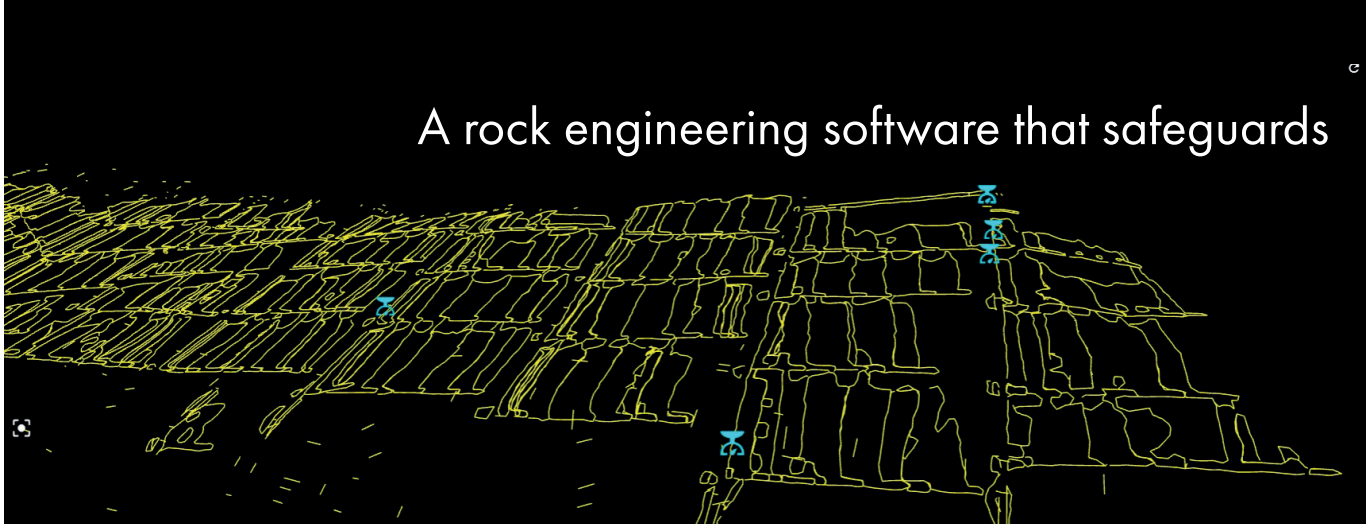
Materials:

- Steel
- Titanium
- Aluminium
- Magnesium
- Nickel superalloys.

Industries:

- Aerospace
- Automotive
- Mining
- Industrial
- Oil and gas
- Power generation.

SCAN ME
for Technology Equipment Specifications



A rock engineering software that safeguards the integrity of data in mines

Increasingly, rock engineering in South Africa's mining industry relies on the collection and analysis of data.

Data is traditionally gathered on rock mass quality, rock sample strength, actual support installation quality, and stope conditions and is captured in spreadsheets. This manual system limits the availability of data to other personnel, on and off-site, creates risk for data loss , and is not conducive for good data analysis.

The CSIR has developed a state-of-the-art Rock Engineering Assistant digital platform that safeguards data by running a secure cloud platform. The platform provides an opportunity to secure and analyse the data without replacing current general or rock engineering-specific software codes. With this application, the data is hosted within database formats that allow basic searching and exporting of results for additional analyses if required.

Current applications include amongst others, a computer-based support design code that also acts as a database for support testing results and allows access to analysed testing data to execute a support design currently executed manually, computer-based access to historical research reports created in the industry, or at a mine, tablet-based execution of rock mass quality and stope audits, saving the results into a database which can be analysed later.

The Rock Engineering Assistant platform will also allow the user to display application findings in real-time on a mine plan displayed on the screen, enabling the user to access specific data from the mine plan and make well-informed decisions by considering all the available data during decision-making. Several other computer-based applications have been identified and will be added continuously to improve the platform.

Currently, the REA platform supports underground mining operations but plans to expand its application to surface mines are in place.

The Learning Factory for Modernisation and Sustainability of Mines

The mining industry is undergoing a significant transformation driven by the Fourth Industrial Revolution (4IR), characterised by technologies like artificial intelligence, robotics, and automation. This presents both challenges and opportunities for the sector. To thrive in this evolving landscape, the mining industry requires a highly skilled workforce capable of adapting to new technologies and embracing innovative practices.

Recognising this critical need, the Council for Scientific and Industrial Research (CSIR) has developed the "Future Skills Learning Factory," a collaborative initiative with mining companies aimed at addressing the skills gap and driving the modernization and sustainability of the mining sector.

The Future Skills Learning Factory will serve as a hub for developing the skills required for the future of mining. 4IR-driven training solutions, such as virtual reality simulations and online learning platforms, will play a crucial role in equipping the workforce with the necessary competencies. These technologies will enable miners to gain hands-on experience operating and maintaining advanced equipment, analysing data for predictive maintenance, and implementing safety protocols in a digitized environment. By focusing on these critical areas, the Learning Factory will empower the mining industry to achieve its goal of Zero Harm Production while embracing the opportunities presented by technological advancements.

The Future Skills Learning Factory will prioritise a collaborative approach, bringing together industry, academia, and government to ensure that training programs align with the evolving needs of the sector and national development goals. It will leverage practical learning environments, such as maker spaces and mobile learning factories, to provide hands-on training experiences and facilitate the development of in-demand skills. By focusing on local needs and national priorities, the Learning Factory aims to create a sustainable and impactful platform for skills development and innovation across the mining sector and related industries.

Furthermore, the Learning Factory will play a crucial role in promoting inclusivity and community development. It will provide opportunities for youth and local communities to engage with emerging technologies and explore potential career paths within the mining sector. Collaborations with educational institutions will focus on developing and training individuals in new energy-related skills, while supporting the growth of Small and Medium Enterprises by providing training programs to modernise their offerings and enhance their competitiveness.

By fostering a culture of continuous learning and embracing the potential of 4IR technologies, the Future Skills Learning Factory will empower the mining industry to achieve its goals of modernisation, sustainability, and Zero Harm Production, while ensuring that the workforce is equipped with the skills and knowledge to thrive in the future of work.

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