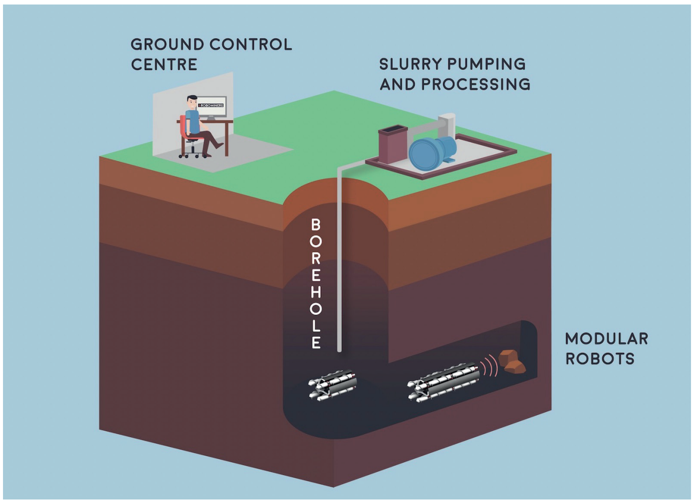
ROBOMINERS | DEVELOPING RESILIENT BIO-INSPIRED MODULAR ROBOTIC MINERS

POLICY BRIEF - SEPTEMBER 2023

INTRODUCTION

The H2020 Resilient Bio-inspired Modular Robotic Miners (ROBOMINERS) project, which started in June 2019 and is set to conclude in November 2023, is creating a prototype of a bio-inspired, modular, and reconfigurable robot-miner. This robotic miner was designed to exploit small and hard-to-reach mineral deposits that are not economically feasible to extract using conventional mining methods.

The ROBOMINERS prototype will operate, navigate, and selectively mine in underground environments. To complement the development of the physical prototype, the ROBOMINERS project is also establishing a mining ecosystem through simulations, modelling, and virtual prototyping. The prototype is being subjected to rigorous testing under various scenarios to evaluate its mining capabilities and resilience, and to demonstrate the potential of this new technology to exploit mineral resources effectively. The key functions of the robot-miner are being validated to a Technology Readiness Level (TRL) of 4, indicating that they have been demonstrated in a laboratory environment.



ROBOMINERS concept.

WHY IS ROBOMINERS RELEVANT?

The mining industry, known for its high number of fatalities and injuries, poses significant dangers to human workers. In addition, the industry often involves heavy equipment used in confined spaces with poor ventilation, high temperatures, water inrushes, and even explosive atmospheres. Due to these inherent risks, the mining industry holds tremendous potential for the adoption of robots. Today, driverless haul trucks and automated drill rigs are already in use in open-cast mines, and the development of robots capable of operating underground and underwater is underway for inspection and testing purposes.

As technology continues to advance, mining robots have the potential to extract minerals from greater depths in the Earth's crust, particularly in environments that are harmful to human workers due to high temperatures and rock stress. These conditions often lead to increased mining costs due to safety and engineering requirements.

Moreover, engineers and geologists can spearhead a paradigm shift in underground mining by using robots. Robots do not require ventilation shafts or drainage tunnels, and the dimension of galleries can be reduced to the diameter of the robot. This transformative shift, initiated by projects like ROBOMINERS, will significantly impact mine design and, more crucially, mining costs. In this future vision, by leveraging robotics and automation, the mining industry can improve safety conditions for workers, increase operational efficiency, and access previously inaccessible mineral resources. Mines would become virtually invisible, since robots will work at big depths, excavating galleries with a size that fits precisely the mineralised areas of an orebody, minimising the excavation of waste rock, and sending to the surface a high-grade, pre-processed, ore. As a result, the ongoing development of mining robots offers immense potential for cost reduction and environmental sustainability.

The development of the ROBOMINERS prototype serves as a foundation for further exploration in robotics, focusing on scalability, resilience, reconfigurability, self-repair, and operation in harsh environments. Additionally, advancements in sensors and artificial intelligence are pursued to address collective behaviour and selective mining processes. The project emphasises the convergence of technologies necessary to establish a comprehensive mining ecosystem, including mine design, ore processing, and mill pumping.

WHY ROBOMINERS BRINGS A PARADIGM SHIFT

In pre-20th century mines, extraction primarily relied on manual methods, leading to limited underground mine excavations that focused on mineralised areas. This historical context explains why mine tunnels during the Roman era up until the pre-industrial revolution were notably narrow. Moreover, the use of child labour was prevalent in mining operations during this period. The small size and agility of children made them suitable for tasks requiring manoeuvring in tight spaces or operating tools in cramped conditions. Until the end of the 19th century, children as young as five or six years old were commonly employed in underground mines, enduring gruelling working hours of up to 12-16 hours a day, six days a week.

They faced brutal treatment from mine owners and overseers, who enforced strict discipline through physical punishments and verbal abuse. In the late 19th and early 20th centuries, awareness of the dire conditions faced by child miners began to grow. Efforts were made to improve legislation and labour standards to protect children from exploitation. The emergence of labour unions and advocacy groups played a significant role in raising awareness about child labour abuses and pushing for reforms.

With the advent of new technologies and the Industrial Revolution's transformative impact on various industries, mining also experienced significant changes. Steam-powered drills replaced hand tools, revolutionising the speed and efficiency of drilling and extraction operations. Additionally, pneumatic drills powered by compressed air emerged as a game-changing technology, further enhancing excavation capacity and productivity. Alongside these advancements, the introduction of dynamite as a safer and more powerful explosive replaced black powder. Dynamite proved to be more stable, easier to handle and detonated using a blasting cap or fuse. These technological breakthroughs allowed for the creation of larger tunnels and led to overall improvements in working conditions for miners.

While the creation of larger tunnels improved working conditions, it also resulted in an increase in waste rock production. Waste rock, typically devoid of valuable minerals, accumulated during the access to mineralised zones and within those zones where it mixed with ores, causing dilution that required further processing and resulting in larger volumes of tailings.

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In modern times, mines have transitioned to full mechanisation, with tunnels designed to accommodate heavy equipment such as dumpers and excavators. However, this shift has led to increased amounts of waste rock generation. Additionally, smaller mineralised areas within a deposit are often left behind due to economic considerations, as it may not be viable to extract them. Compounding this challenge, ore grades have been decreasing in many mining operations globally, necessitating the extraction of larger volumes to maintain economic viability. The extraction of such large volumes is only feasible with the use of large machinery, resulting in the production of significant amounts of waste rock and tailings.

ROBOMINERS has the potential to transform this paradigm due to its size.

The ROBOMINERS prototype measures 3 meters in length and boasts a diameter of nearly 1 meter. It possesses the capability to autonomously open tunnels and operate underground without human intervention. This groundbreaking advancement unlocks unprecedented possibilities for the future of mining operations.

One of the key advantages of the ROBOMINERS prototype is its ability to minimise waste rock and tailings generation. With precise excavation techniques, it can extract minerals from small deposits and recover all existing ores, significantly reducing the environmental impact of mining operations. Additionally, ROBOMINERS operates without the requirement for ventilation shafts or the pumping of underground water, streamlining the mining process and minimising operational costs and resource consumption.

ROBOMINERS' capacity to operate at great depths, which are inaccessible to humans due to the Earth's geothermal gradient, unveils a vast potential for mineral extraction. While surface mineral deposits have been extensively exploited, there remains untapped mineral wealth at deeper levels within the Earth's crust. This presents a solution to the increasing demand for raw materials, ensuring a sustainable supply for various industries.

Moreover, the deployment of ROBOMINERS brings the possibility of making mines "invisible." By excavating small tunnels and conducting pre-processing underground, the impact on the surface is greatly reduced. This addresses one of the primary concerns of the public regarding mining, including landscape destruction and environmental consequences. The adoption of ROBOMINERS can help alleviate opposition to mining by mitigating its visible effects.

The ROBOMINERS RM1 prototype. Credit: C. Rossi

DEEP MINING

The main obstacles to the construction of deep mines are, i.e. mines capable of reaching mineral deposits located at depths below 1,000 m, are of three kinds (Correia et al., 2023): physical, geotechnical and economical.

The Earth's geothermal gradient causes the physical constraints. For example, in standard continental crust, a typical geothermal gradient within the first 3 to 5 Km of Earth's surface is about 25°C/km (DiPietro 2013). This means that the temperature of a drift wall at approximately 2 km depth would reach 50°C, which poses risks to workers, such as exhaustion or heatstroke. Such challenges are exemplified in the Mponeng mine in South Africa that operates at depths ranging between 3,160 m and 3,740 m, being the deepest mine in the world, where rock wall temperatures can reach 66 °C (Wadhams 2011). The mine pumps many tons of slurry ice underground every day to cool the tunnel air to below 30 °C.

Geomechanical problems are caused by increased stresses in the in situ rock at greater depths, making strain control more difficult. Therefore, the evaluation of rock mass properties, the mechanisms that control excavations and the resulting support system requirements are critical to mining. Deep-mine designs also require an understanding of rock fracture processes and the development of numerical methods for structural analysis, monitoring of seismic activity, and development of semi-empirical design concepts.

Financially, the implementation of ROBOMINERS offers a more cost-effective approach compared to conventional mining. While operational costs will be constrained by productivity parameters, the initial investment and setup costs are significantly lower than the infrastructure and capital expenses of traditional mines.

In summary, the paradigm shift driven by ROBOMINERS technology will contribute to sustainable prosperity within the European Union. It propels the region towards a future defined by technological advancement, environmental stewardship, and socio-economic progress. By embracing this innovation, the EU can create a mining industry that balances resource extraction with environmental responsibility, paving the way for a more sustainable and prosperous future.

SOURCES

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