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Vision of the mine of the future

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Average mined ore grades are constantly decreasing and easily accessible high-grade mineral deposits have already been mined out. Together with the ever-increasing demand for raw materials, a sustainable supply is becoming very challenging for the mining industry. Ores are being exploited in very large operations and in more and more extreme environments. The presence of high temperatures, poisonous gasses or other harmful substances, water, geotechnical instabilities, etc., limits the possibilities for humans to work in such environments, and increases the costs of mining. New paradigm of ore prospection and extraction is needed, and the use of robotics and automation provides a potential solution.

The mid-term vision of mines of the future is that humans would not need to be present at the extraction sites anymore. Mining machinery will become remotely controlled or semi-automated. This would significantly reduce the costs of mining operations and eliminate the risks associated with humans working in life-threatening environments. The main challenges are related to sensing of the surroundings and the presentation of such data in a virtual reality model, the machine-human-machine and machine-machine communication, positioning, energy supply and similar. This technology can transform the mining industry in a similar way as the development of construction machines transformed the construction sector in the last century.

In the long-term vision the mines will be completely automated. Mining machines will be able to sense its environment, allowing them to make decisions autonomously. They will also be able to self-assemble, repair, and perhaps even produce their own copies underground. Robots of the mines of the future will be specialised in a similar way workers are specialised today. Ore processing will be accompanied by an autonomous ore processing system at the site of extraction, which will enable the delivery of concentrate or even ingots to the surface and leave the waste material underground. With such systems highly selective low-environmental impact mining of many currently uneconomical ore bodies could become feasible and would allow mining in ultra-deep environments which are today far beyond our reach. With such mining system, mining of extra-terrestrial bodies could also become a reality, and could even put an end to mining on Earth altogether. Many challenges need to be addressed, including energy supply, locomotion, communications, environmental awareness, big data handling and processing, automated decision-making systems, new rock-cutting technologies, ore transport systems, machine and software maintenance and adaptation, etc.

Humanity is already taking first steps towards this vision. Several international projects have been

funded on the topic of sensing, using remotely controlled machines or autonomous robots to perform dangerous exploration or mining tasks: iVAMOS!, UNEXMIN, ROBOMINERS, AutoFlyMap, ROBUST, RODEO, BADGER, Real-Time Mining, MINERAL EYE and others (funded by the Horizon2020), BlueHarvesting, FIREM-II, HoloMine, UNDRROMEDA and others (funded or co-funded by the EIT RawMaterials), or several industrially-funded projects such as Longwall automation mining, A3R, MSRBOTS, ARIDuA, and many others. Many companies which develop robots or other automatic equipment for mines are also emerging, including Unexmin Georobotics, EXPLORA, Equipois, Sandvik, Superdroid Robots, National Robotics Engineering Center, BROKK and others.