DEVELOPING RESILIENT BIO-INSPIRED MODULAR ROBOTIC MINERS

ROBOMINERS

Robotic Miners: A Paradigm Shift in the Mining industry

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With thanks to Vitor Correia @Vitor_EurGeol

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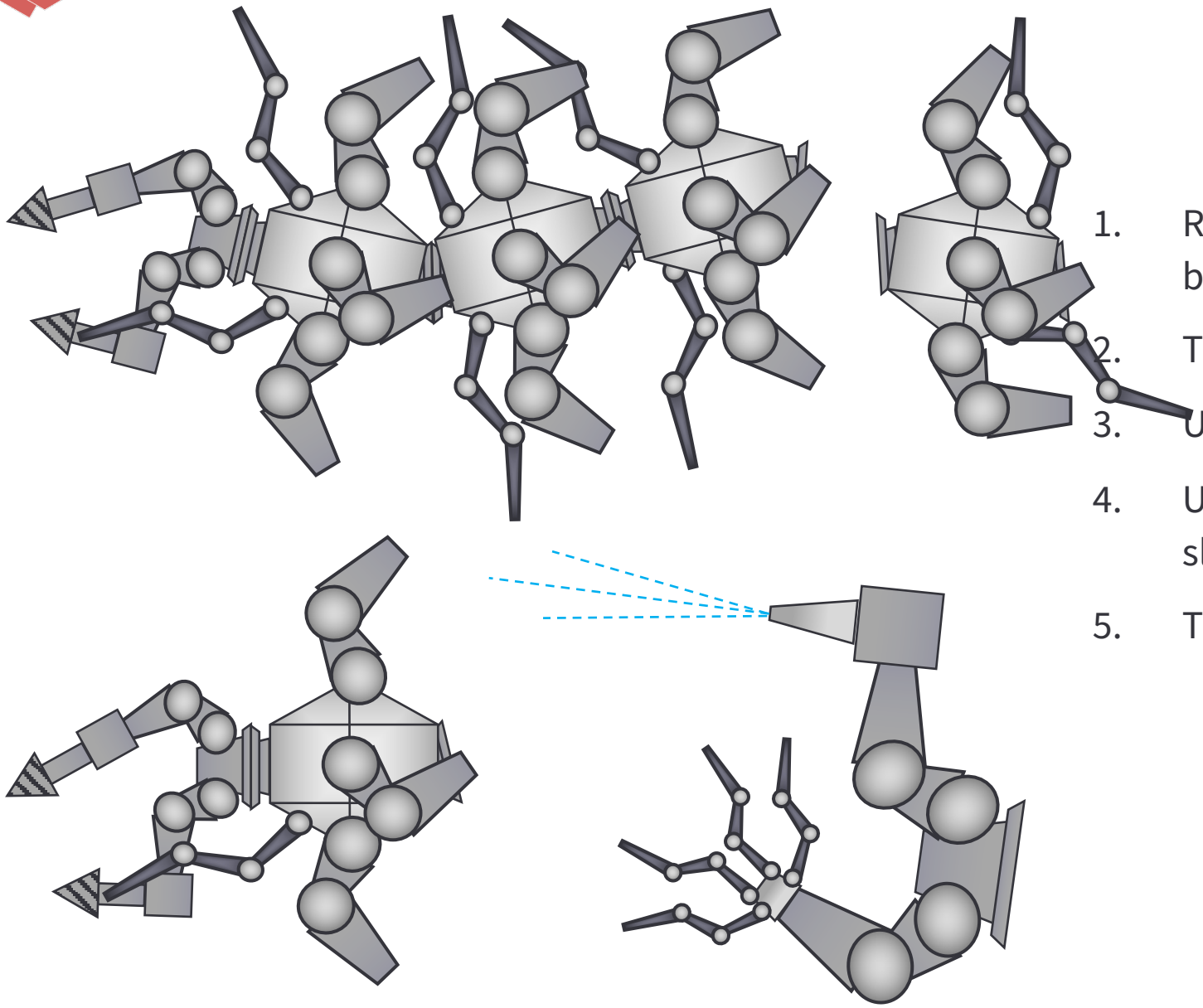
Inspiration

Credits: Wikicommons

Concept

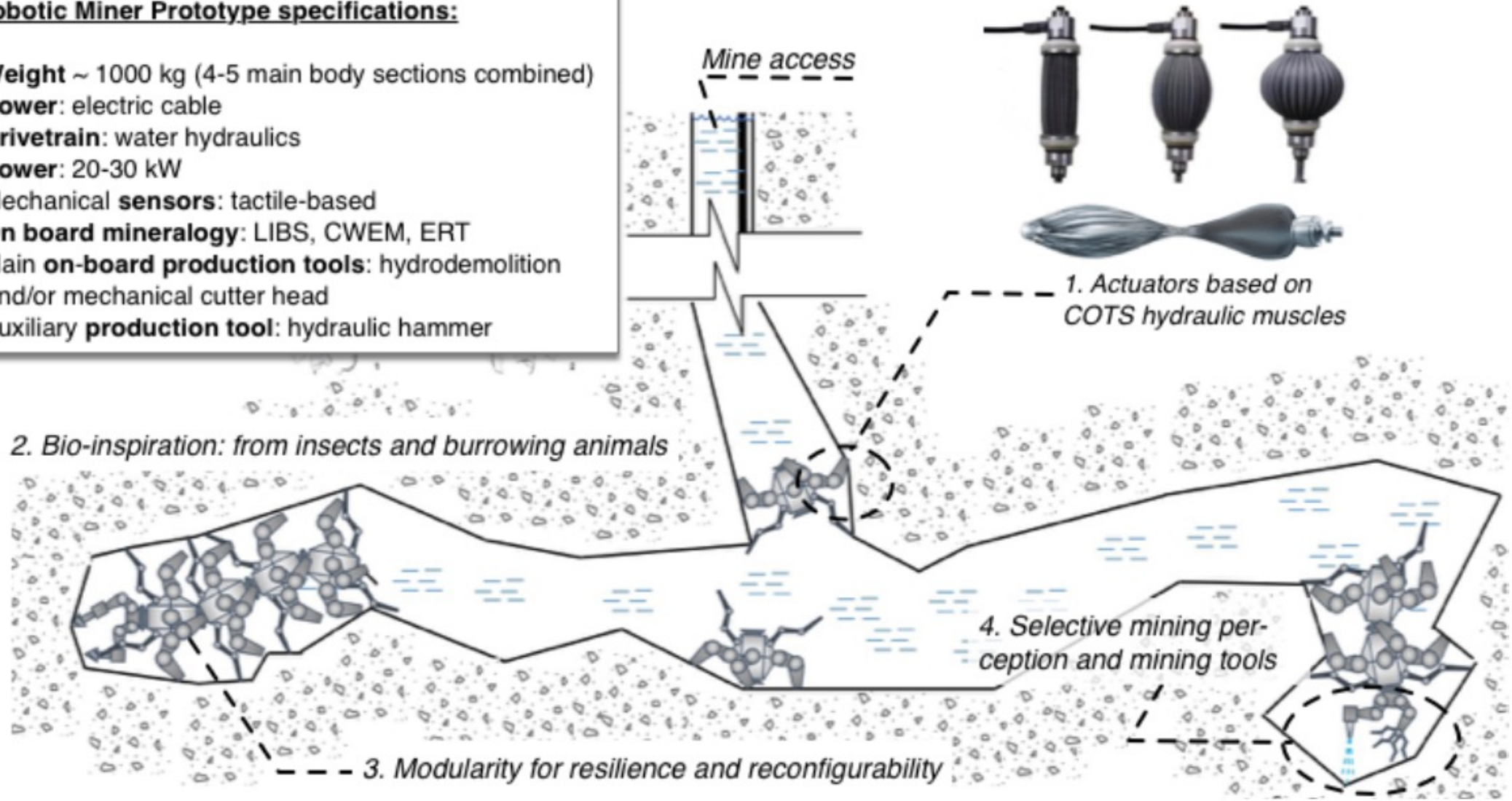


1. Robot parts (modules) are sent underground via a borehole
2. They self-assemble to form a fully functional robot
3. Using specialised sensing devices, they detect ore
4. Using ad-hoc production devices, they produce slurry that is pumped out
5. They can re-configure on-the-fly

Concept

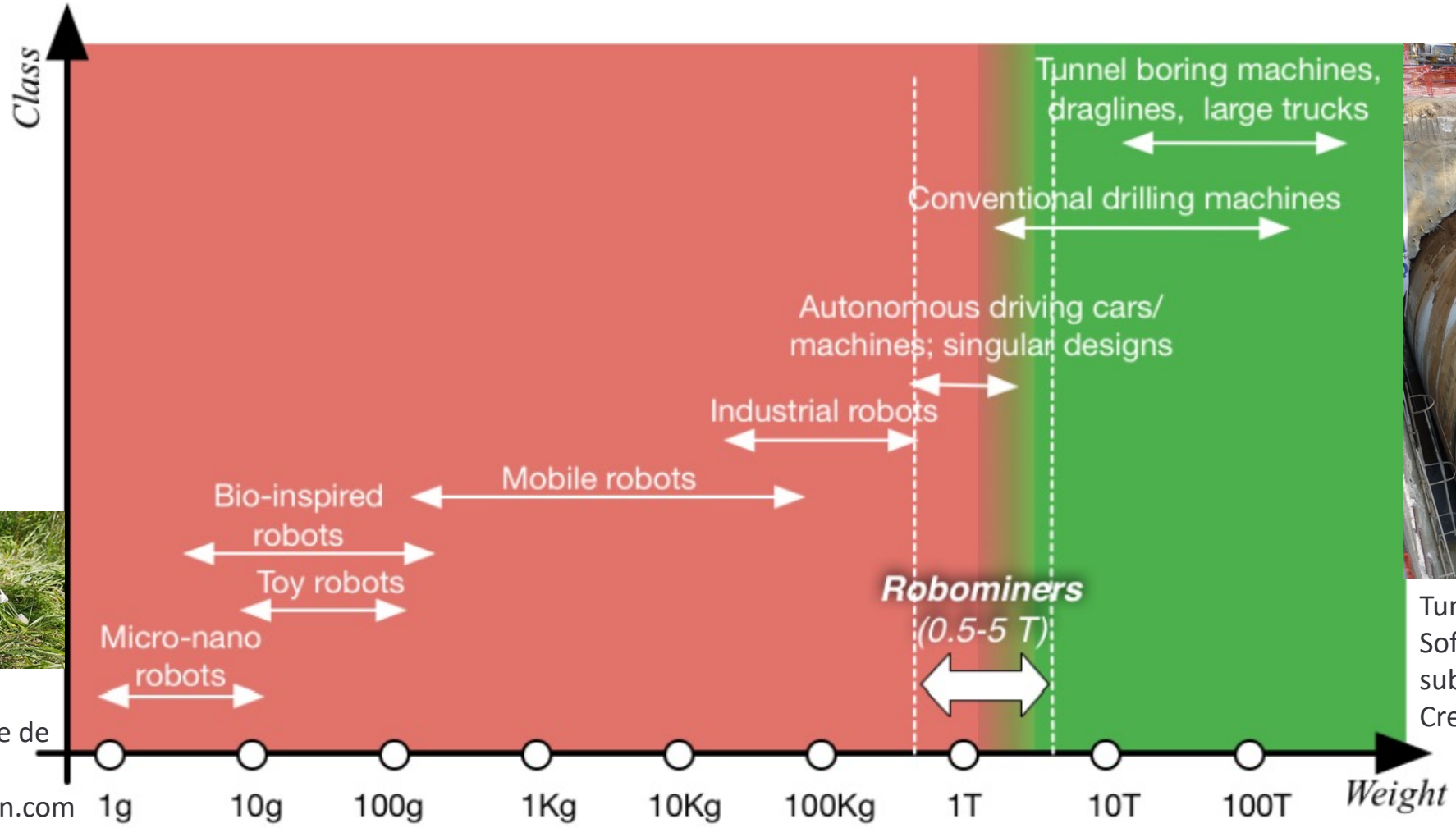
Robotic Miner Prototype specifications:

-**Weight** ~ 1000 kg (4-5 main body sections combined)
-**Power**: electric cable
-**Drivetrain**: water hydraulics
-**Power**: 20-30 kW
-Mechanical **sensors**: tactile-based
-**On board mineralogy**: LIBS, CWEM, ERT
-Main **on-board production tools**: hydrodemolition and/or mechanical cutter head
-Auxiliary **production tool**: hydraulic hammer



Challenges

Pleurobot by École Polytechnique Fédérale de Lausanne.
Credits: MachineDesign.com

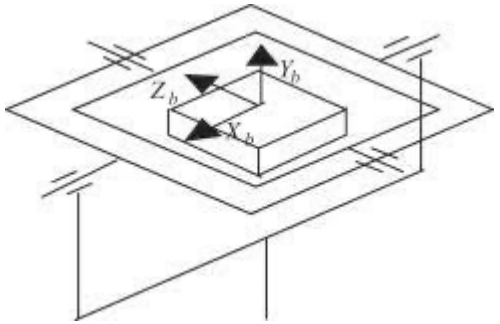


Tunnel boring machine in Sofia - construction of the subway, Line 2.
Credits: Wikicommons

Challenges

Navigation

MotionPak® Multi-Axis Inertial Sensing System



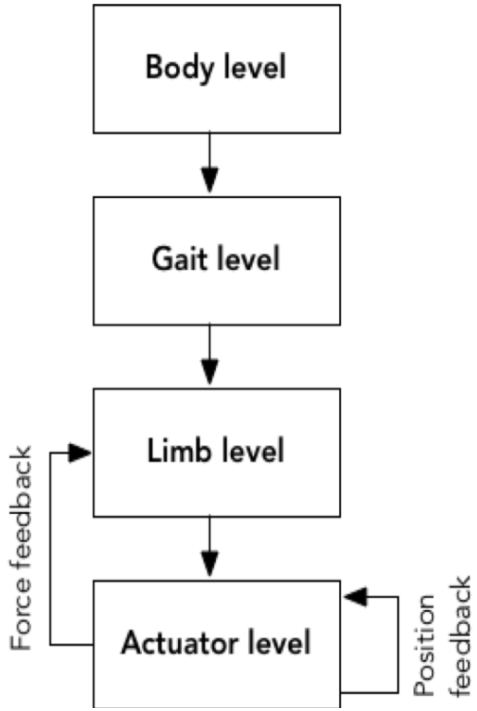
1. Micro inertial measurement unit MotionPak®

Three micromechanical quartz rate sensors and three micromechanical silicon acceleration meters.

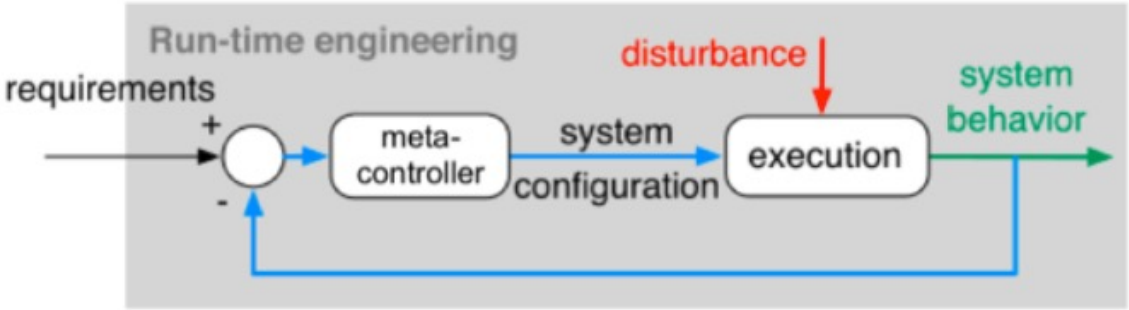
Gyro having a high resolution of 0.004°/s, accelerometer with a resolution of 10 µg. Overall weight 900 g.

Challenges

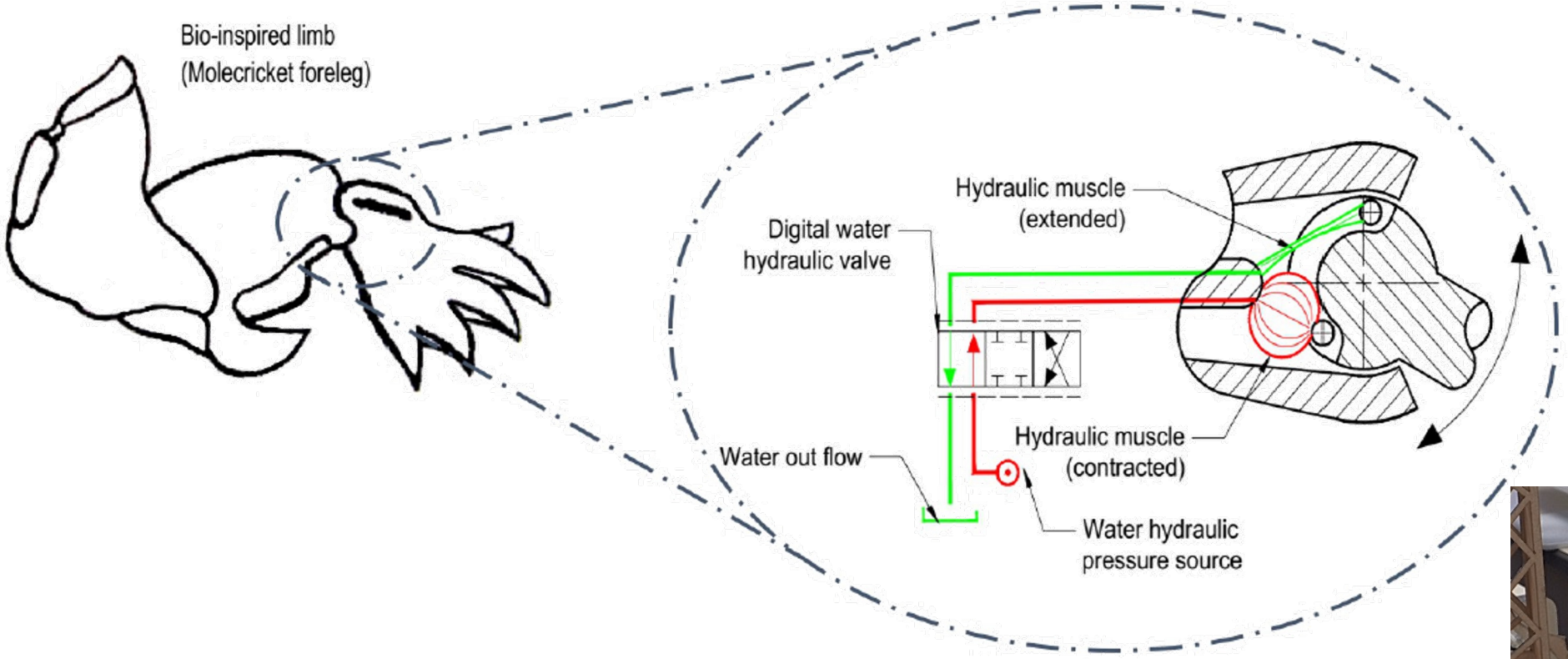
Control

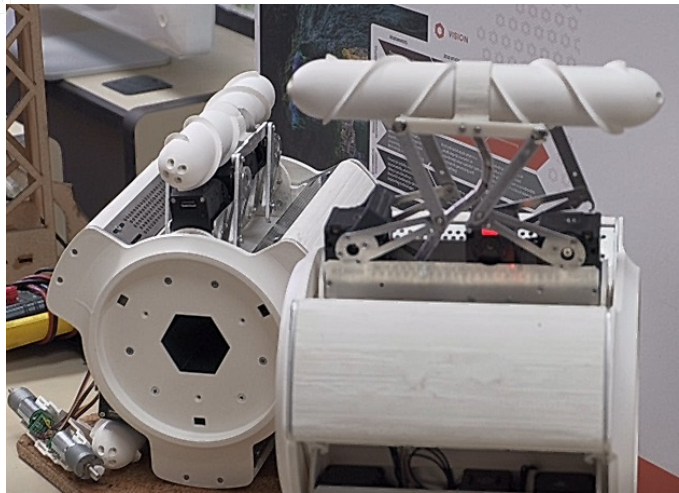


1. Micro inertial measurement unit MotionPak®
2. Combination of low-level reactive control and high level deliberate decision-making and planning (Model-Driven Engineering and Model-Based Cognitive Control)



Mechatronics

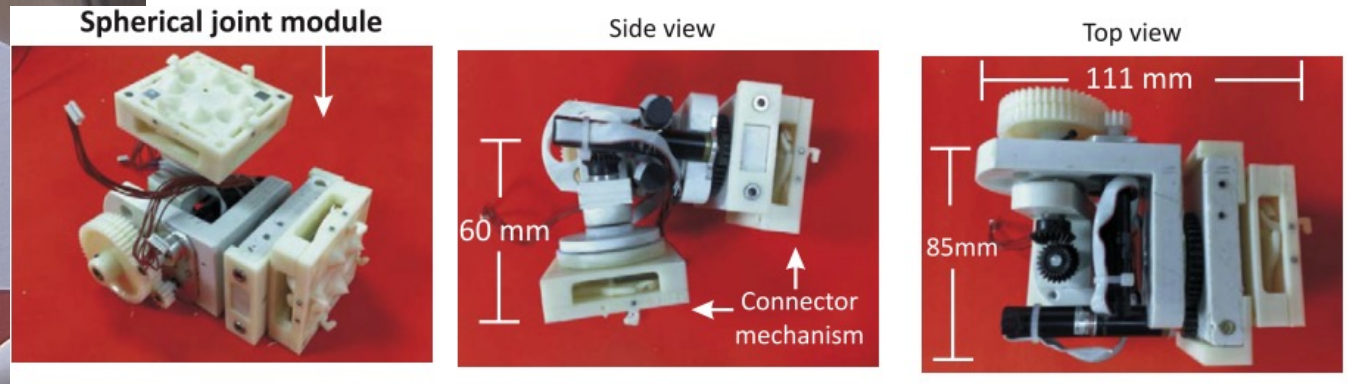


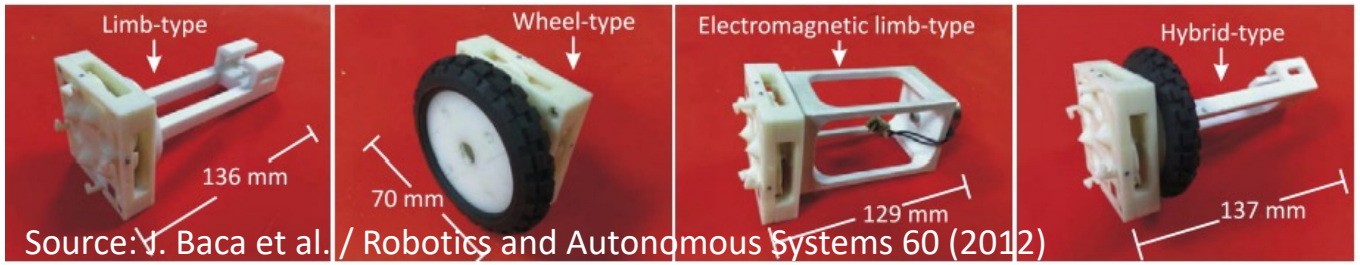


Modularity

Key enabler for ROBOMINERS

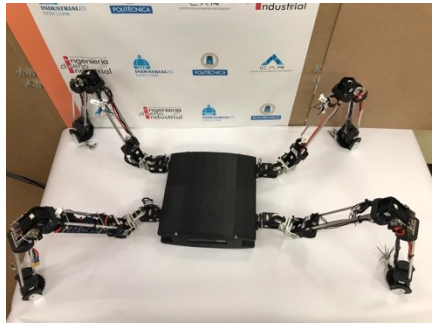
Re-configurability will allow fault tolerance and flexibility to adapt the robot's size, power output and reach to a wide range of geological scenarios.

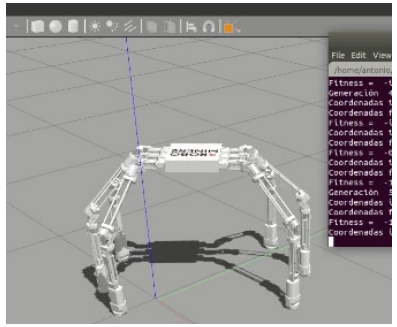


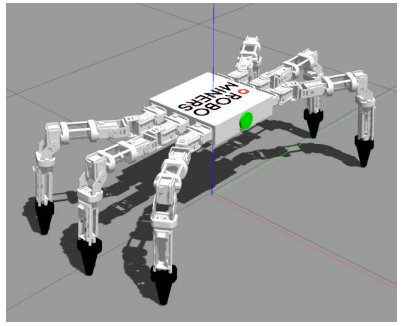


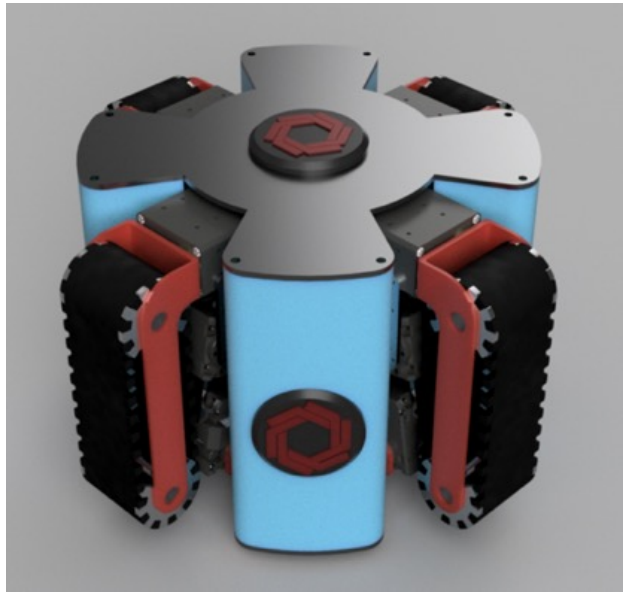
Source: J. Baca et al. / Robotics and Autonomous Systems 60 (2012)

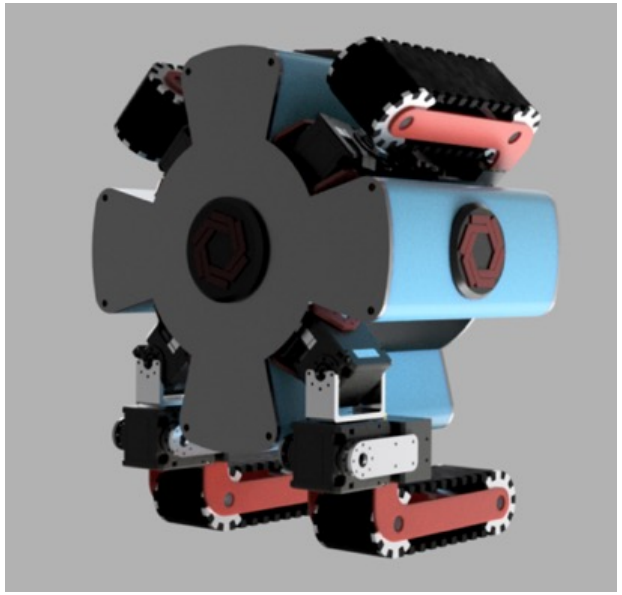
Autonomy and resilience







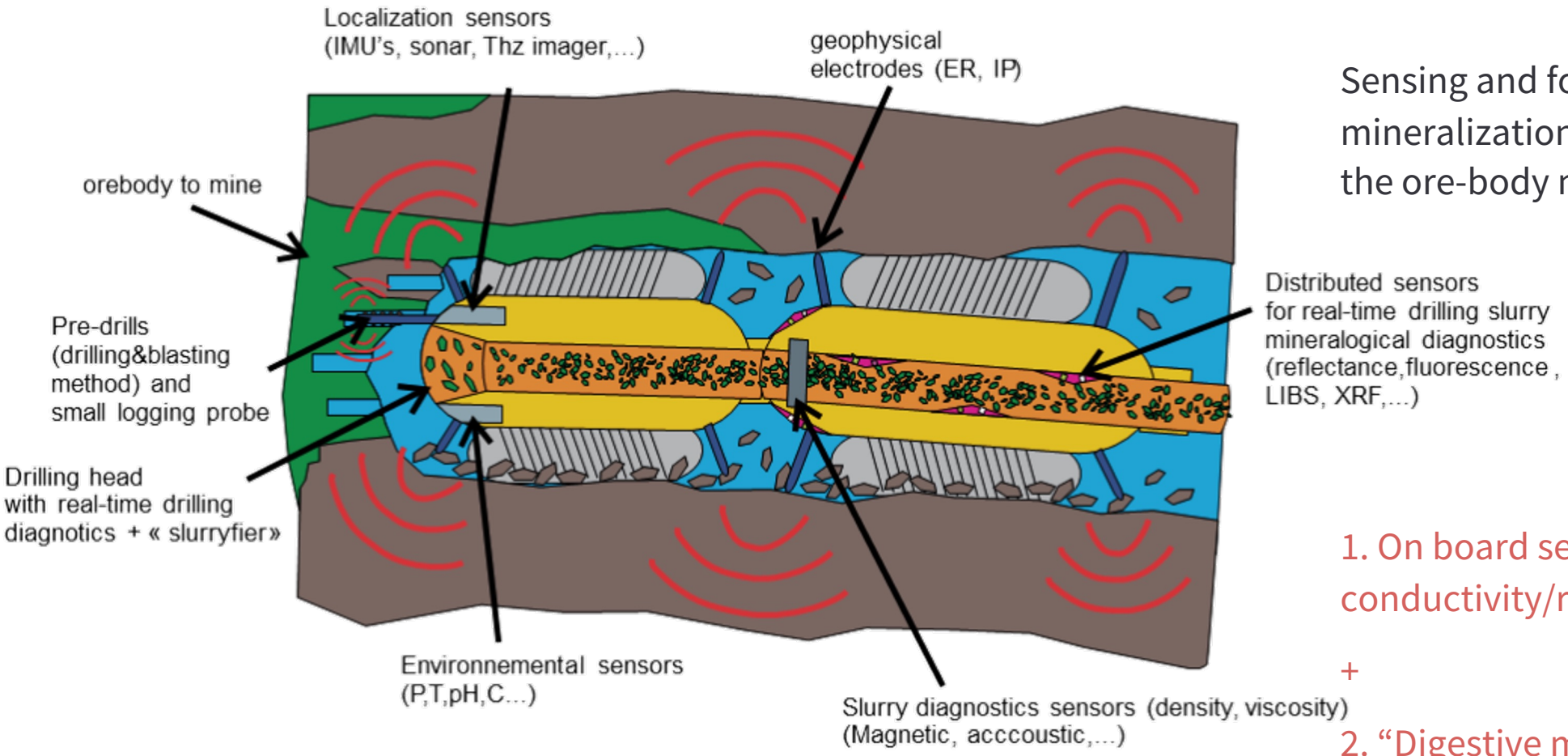




Resilience based on four pillars: redundancy, physical reconfiguration, adaptive behaviour and system reconfiguration

Re-configurability will allow fault tolerance and flexibility to adapt the robot’s size, power output and reach to a wide range of geological scenarios

Selective mining



Sensing and following main mineralization directions, while refining the ore-body model in real-time

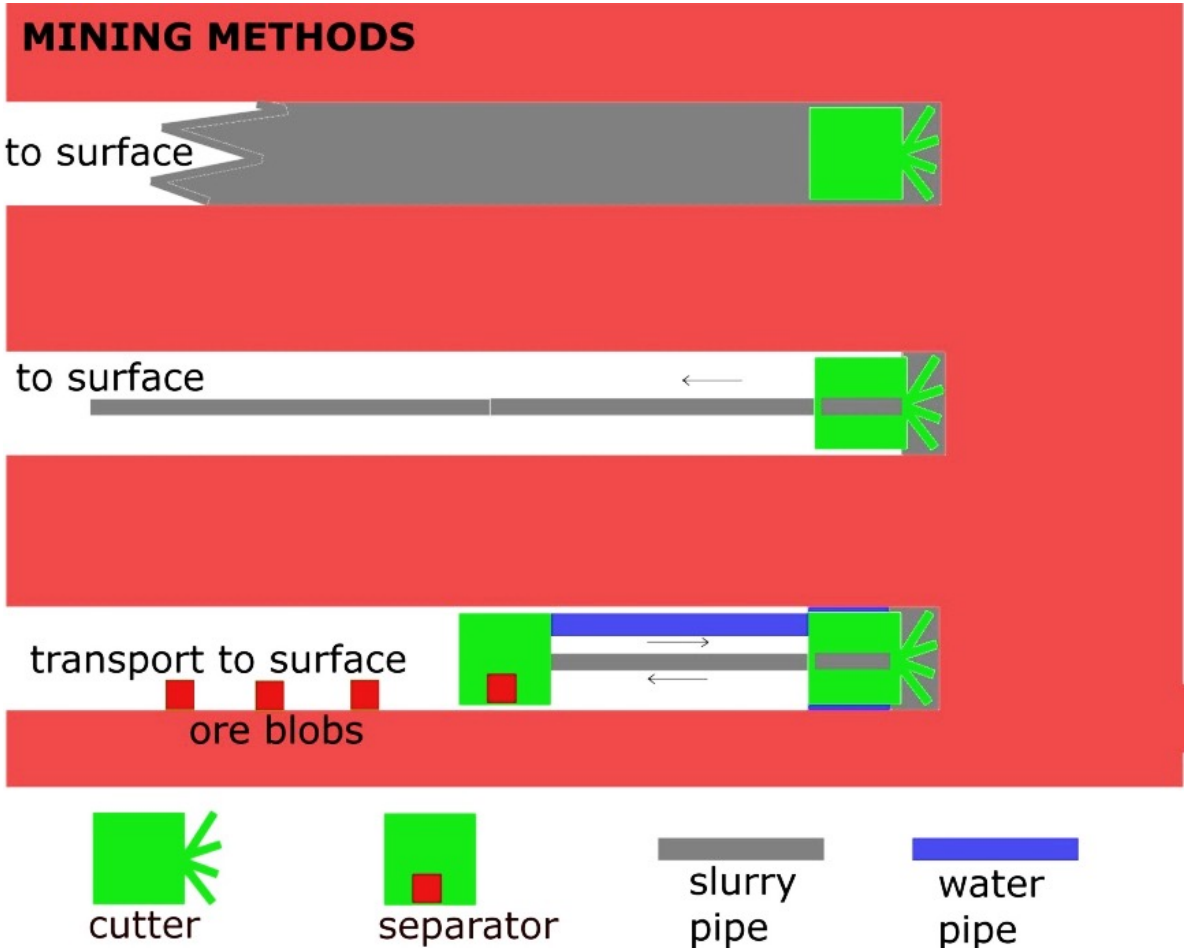
1. On board sensors (rock hardness, conductivity/resistivity, electrochemistry)

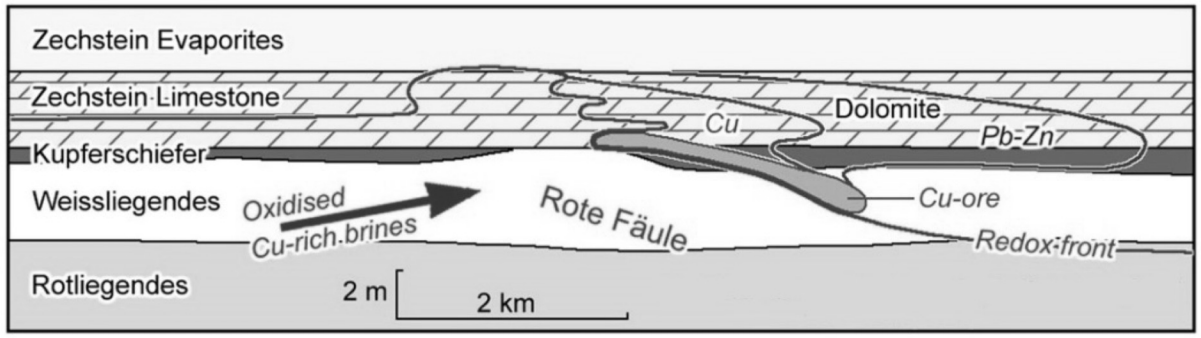
+

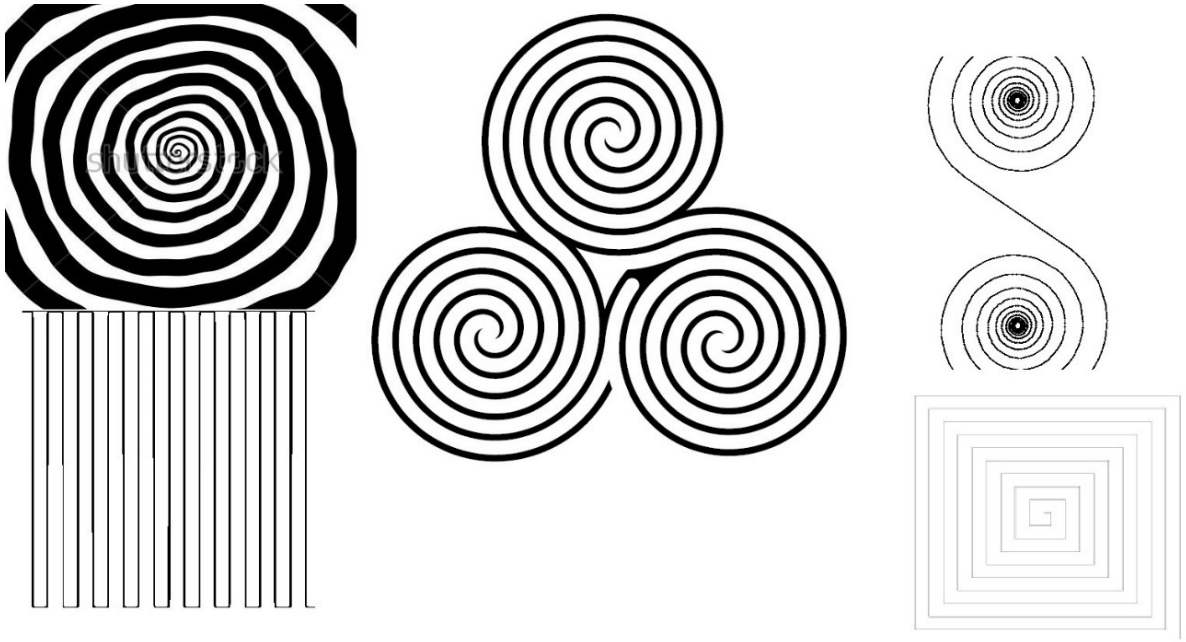
2. "Digestive mineralogy"

Challenges

The mine design







Impact

Mining capability	0,5 ton/hour (0,2 m^3 /hour)
Pumping capability	0,2 m3 /hour of rock
Excavation capability	Capability to excavate 250 MPa hard rock

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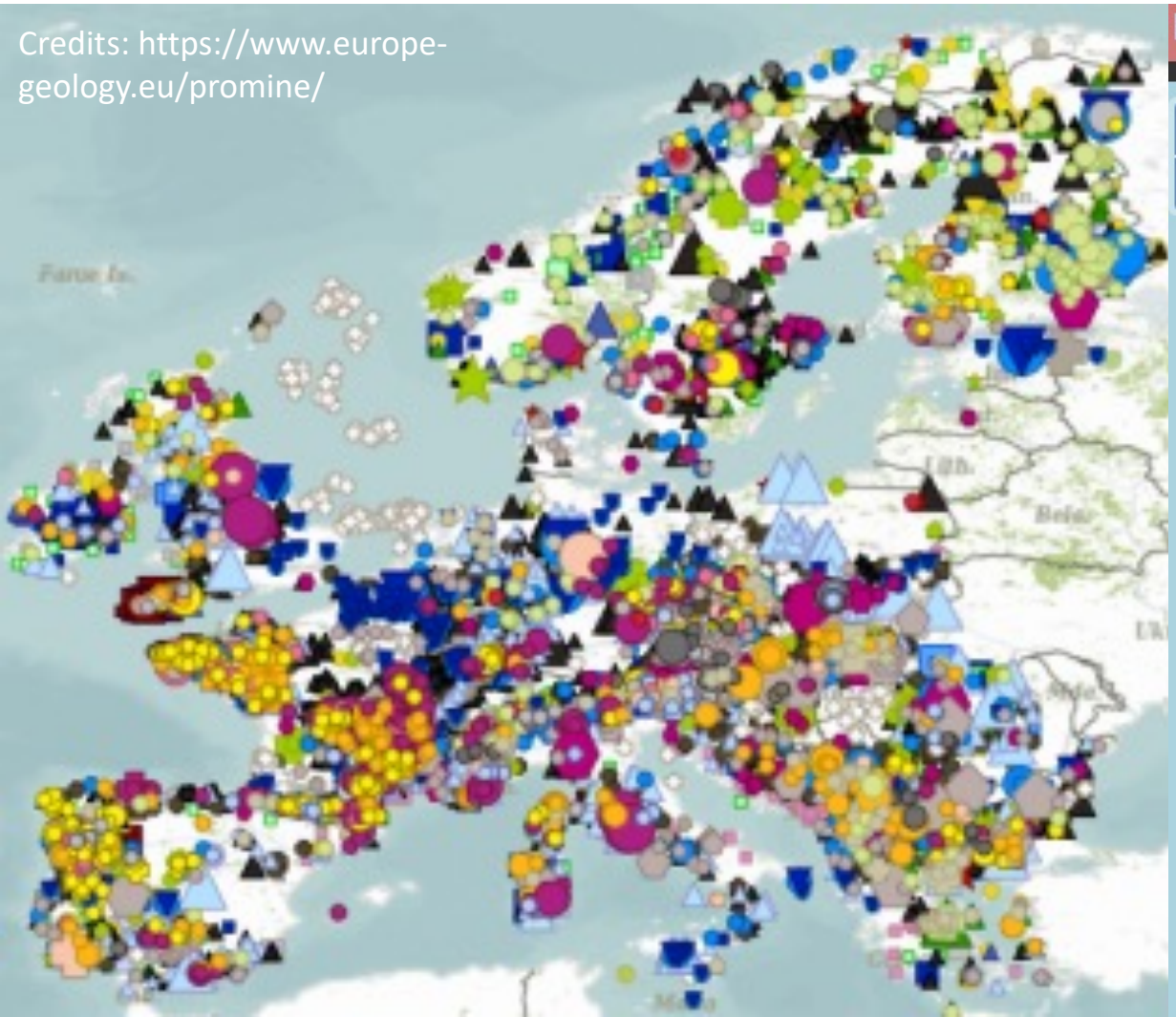

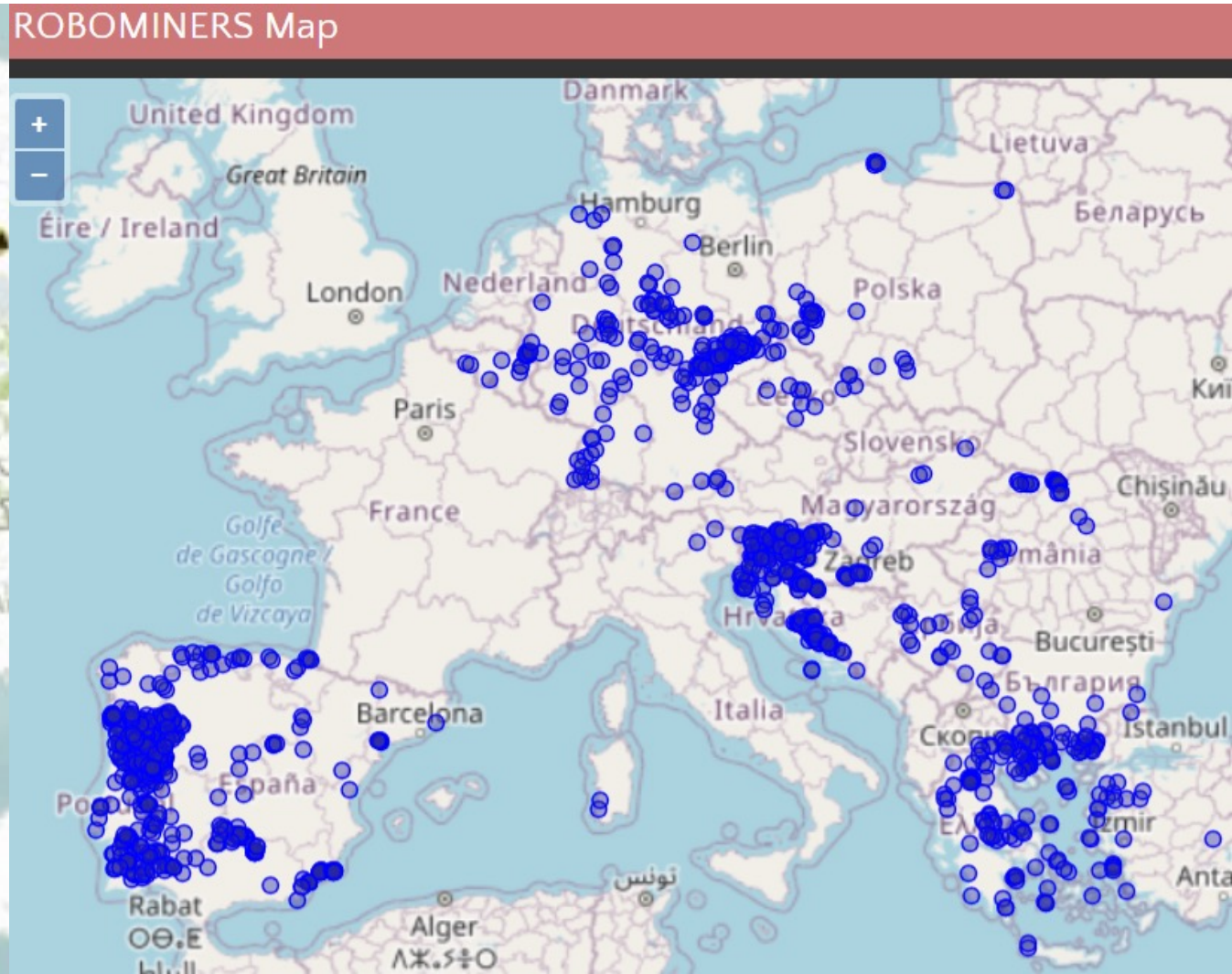

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Credits: Diavik Diamond Mine via https://www.gia.edu/gems-gemology/summer-2016-diamonds-canadian-arctic-diavik-mine/

Drilling works at Mponeng mine.
Credits: Graeme Williams/The New York Times/Redux, via https://www.wsj.com/articles/SB10001424052702304854804579236640793042718

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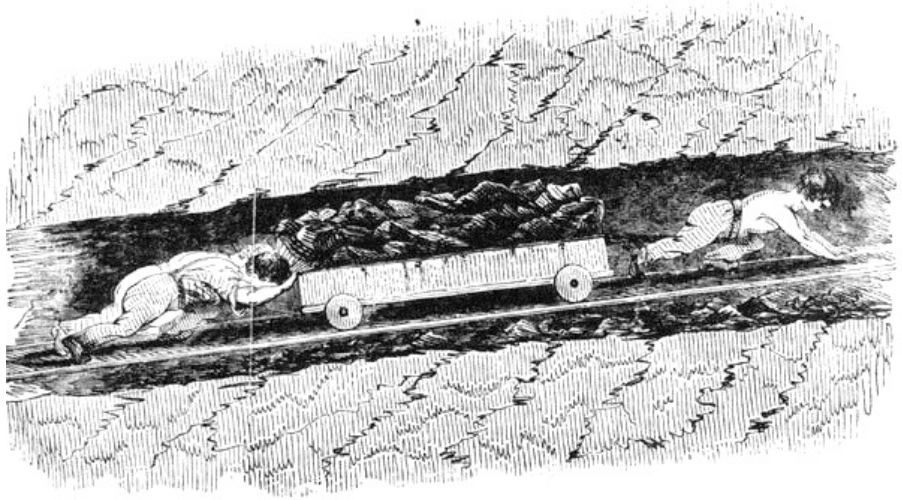

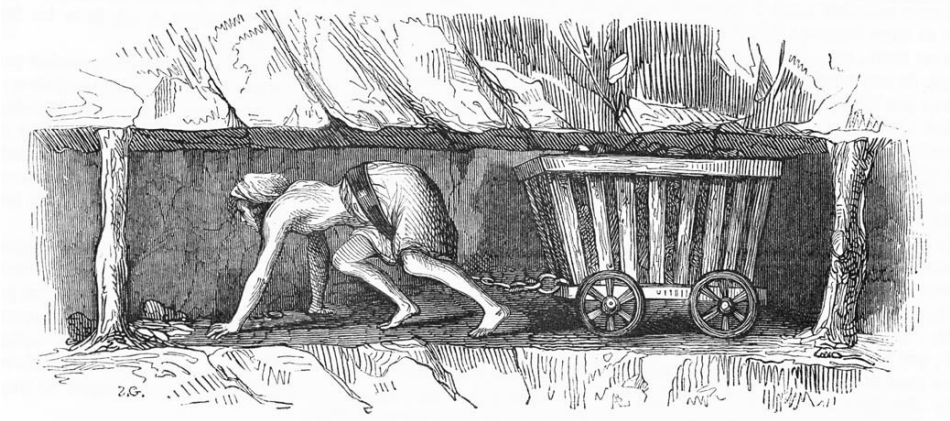

Dimension of galleries can be reduced to the diameter of the robot, and there's no need to create ventilation shafts or drainage tunnels

Potential to extract minerals from bigger depths in the Earth's crust, in harmful environments for humans

5 takeaways for a new paradigm

VISION: mines would become virtually invisible, since robots will work at big depths, excavating galleries with a size that fits precisely the mineralised areas of a ore-body, minimising the excavation of waste rock, and sending to the surface a high-grade, pre-processed, ore.

1. No personnel in the mine
2. Reduction of necessary groundworks and access routes both on the surface and underground
3. No dewatering costs and associated environmental impacts
4. Less waste, so that the cost of removing and managing waste rocks is minimal
5. Cheaper capital cost than an underground mine, quicker set up and closure

Advancing the ROBOMINERS vision encompasses the creation of a completely new mining ecosystem, where the mine design is in line with the deposit characteristics and the robot requirements, including power supply, drilling methods and paths for slurry transport to the surface. Extraction of small and difficult to reach (deep) mineral deposits becomes economically feasible.

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Thank you for your attention

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