ROBOMINERS

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Resilient Bio-inspired Modular Robotic Miners

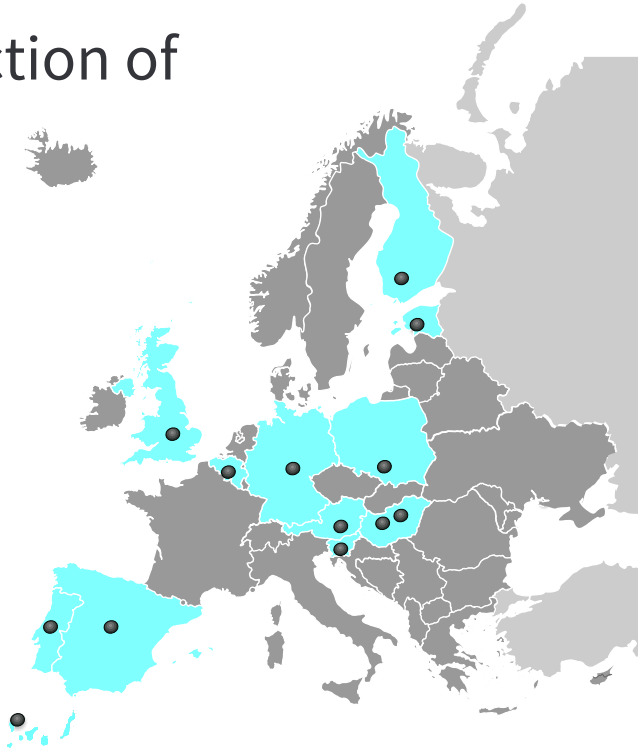
Luís Lopes and ROBOMINERS consortium

EGU 2020: Sharing Geosience Online / Discussion block/live chat: May 5th 2020, 08:30–10:15

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 820971.

Project's quick facts

- *Call Topic:* SC5-09-2018-2019 "New solutions for sustainable production of raw materials" (RIA)
- Project duration: 48 months
- Start date: 1st June 2019
- Project total cost/ EU contribution : 7,4 M€
- Coordinating entity: Universidad Politécnica de Madrid
- Country: Spain
- Project website: *www.robominers.eu*
- 14 partners, 11 European countries
  - Geo-scientific SMEs (LPRC, GEOM, KUTEC, RCI)
  - Academics covering both mining (UNIM, MUL) and robotics (UPM, TALL, TUT)
  - Non-governmental (ASSIM, EFG)
  - Governmental (GeoZS, RBINS, IGSMIE)



Project context and approach

EU is dependent on the import of many mineral raw materials essential for industry, green energy, etc

Enabling EU access to mineral raw materials (including critical/strategic raw materials) from domestic resources is a step recognized under the EU raw materials policy

ROBOMINERS develops a bio-inspired, modular and reconfigurable robot-miner capable of mining underground, underwater, in slurries or above water

Proof of concept will be delivered as a robot designed and constructed as a result of merging technologies from advanced robotics, mechatronics and mining engineering

ROBOMINERS targets abandoned mines, mines at ultra depths and small deposits to be exploitable in a cost-efficient manner

2017 CRMs (27)			
Antimony	Fluorspar	LREEs	Phosphorus
Baryte	Gallium	Magnesium	Scandium
Beryllium	Germanium	Natural graphite	Silicon metal
Bismuth	Hafnium	Natural rubber	Tantalum
Borate	Helium	Niobium	Tungsten
Cobalt	HREEs	PGMs	Vanadium
Coking coal	Indium	Phosphate rock	

EU Critical Raw Materials list 2017

Overall objectives

- To develop a **bio-inspired**, **modular** and **reconfigurable** robot-miner
- For **small** and **difficult to access** deposits
- Equipped with **selective mining** perception and mining tools
- That can be **delivered in modules** to the mineral deposit via a large diameter borehole
- Mining underground, underwater, in slurries or above water

Specific objectives

Build a fully functional modular robot-miner prototype capable of operating, navigating and performing selective mining

Validate all key functions of the robot-miner to a level of TRL-4

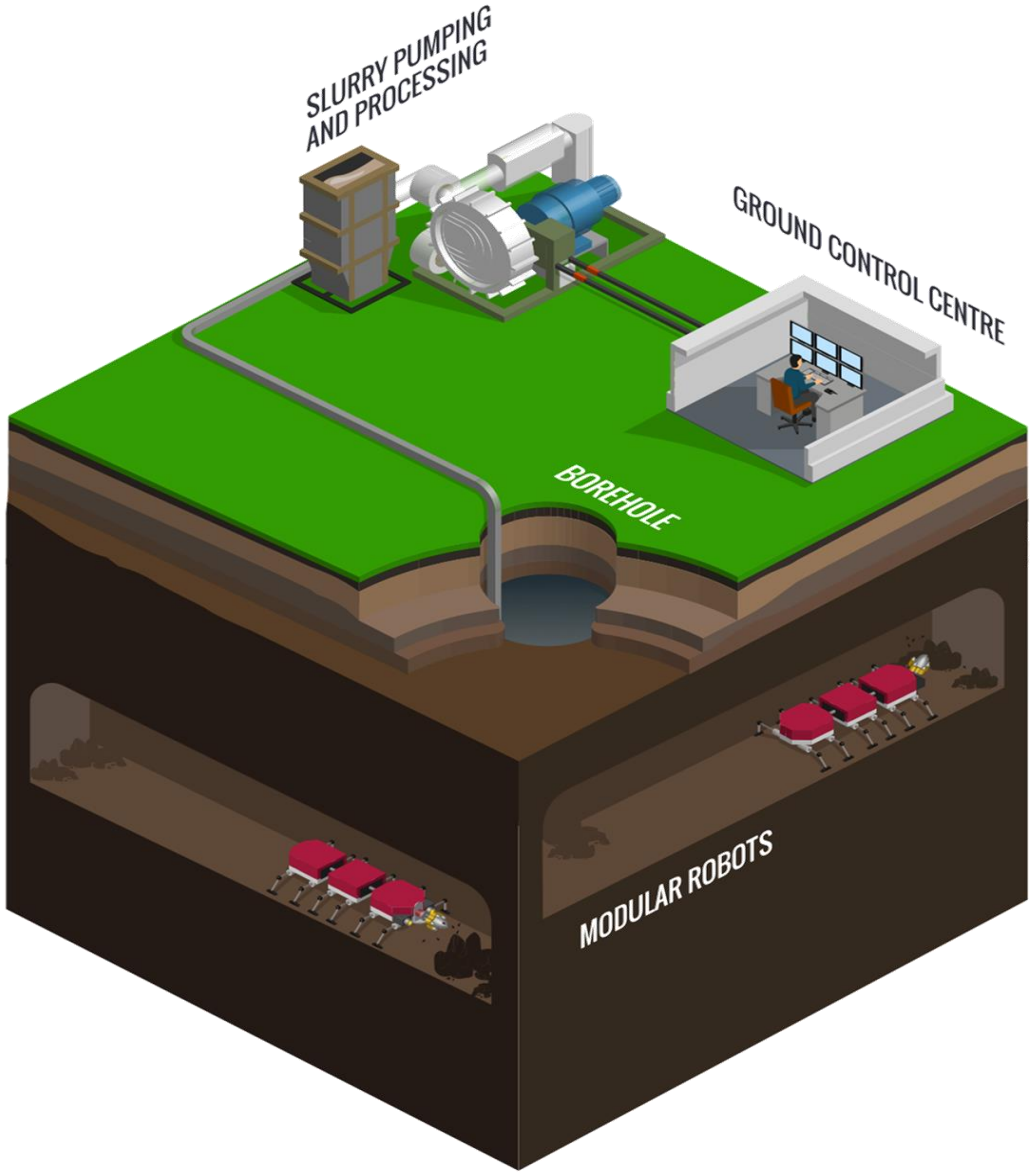
Design a mining system of expected future upstream/downstream raw materials processes via simulations, modelling and virtual prototyping

Use the prototypes to study and advance future research challenges on

- scalability, resilience, re-configurability, self-repair, collective behavior, operation in harsh environments,
- selective mining,
- production methods,
- necessary converging technologies on an overall mining system level

New mining concept, proven in laboratory conditions, capable of changing the scenario of mineral exploitation

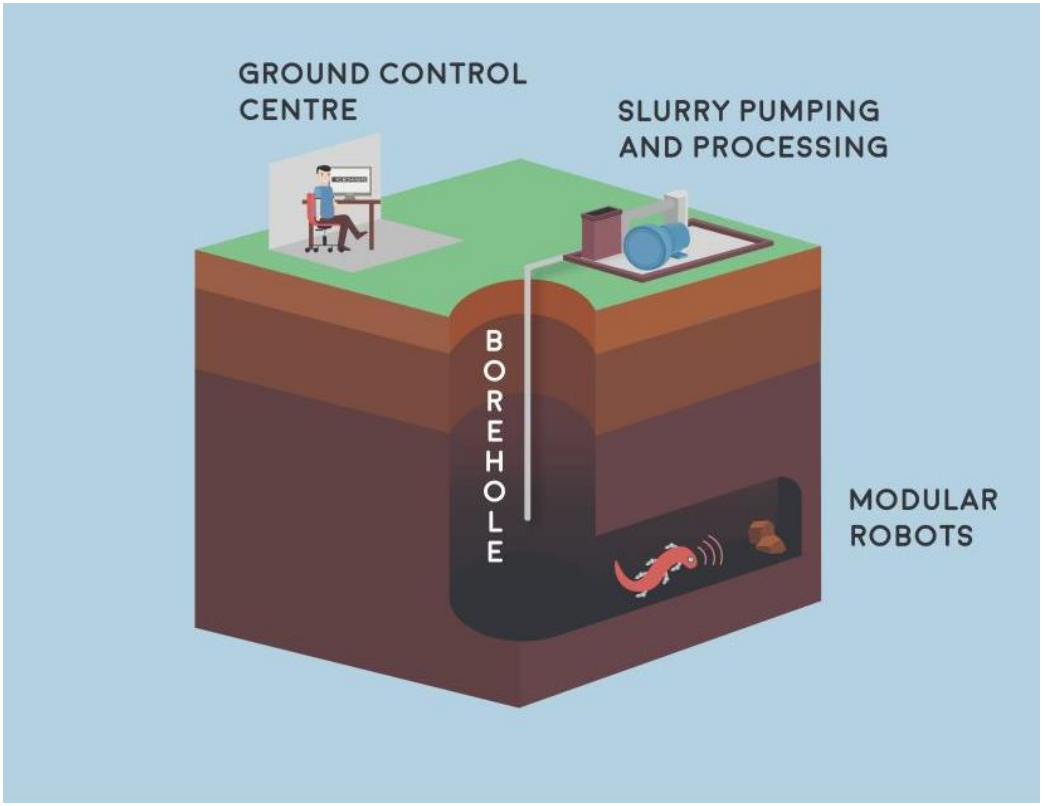
Concept



1. Robot parts (modules) are sent underground via a borehole
2. They self-assemble to form a fully funcional modular 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-job

Mining outline

- Powered by a water hydraulic drivetrain and artificial muscles, the robot will have high power density and environmentally safe operation
- Situational awareness and sensing will be provided by novel body sensors that will merge data in real-time
- Together with specific production tools, they will enable selective mining, optimising the rate of production and selection between different methods
- The produced mineral concentrate slurry is pumped to the surface, where it will be processed
- The waste slurry could then be returned to the mine where it will backfill mined-out areas



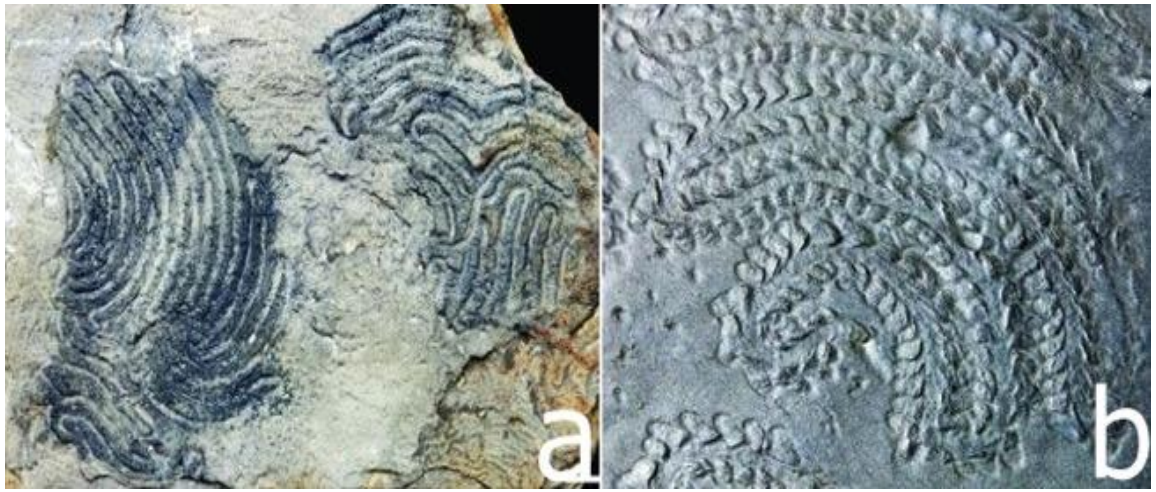
Impacts

- Opening up the possibility to exploit any remaining reserves despite the size and geometry of deposit
- Addressing many of the environmental concerns that are associated with conventional mining
- Positive economic impact in many regions where the potential for developing mining activities exist, contributing directly and indirectly to economical, social and environmental positive impacts
- Create potential for research, innovation, new technology and business development, not just in mining, but also other applications where resilient modular robotics could be important, such as mine rescue, disaster relief or space research

The miner

- **Bio-inspired**, **modular** and **reconfigurable**

Inspired on insects and burrowing animals



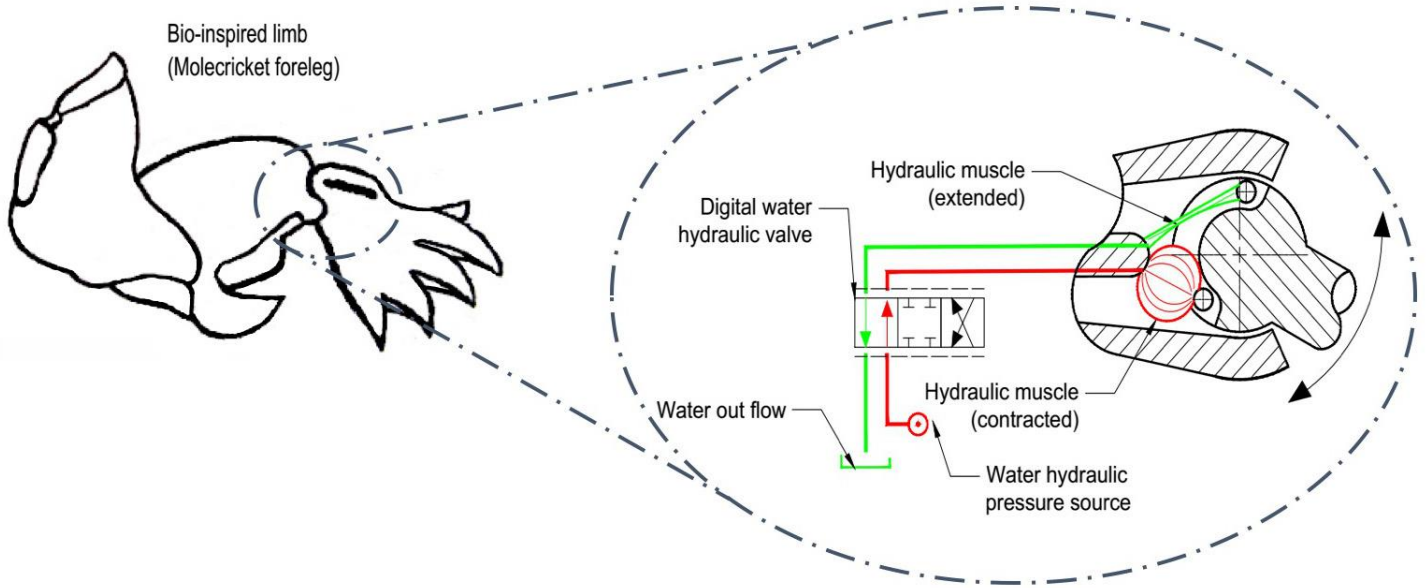
2D and 3D feeding patterns as shown by trace fossils.

The miner

- **Bio-inspired**, **modular** and **reconfigurable**

Tech specs:

- 0.5-1 ton
- 20-30 kW
- Hydraulic
- Tethered



COTS artificial muscles

The miner

- **Bio-inspired**, **modular** and **reconfigurable**

Example:

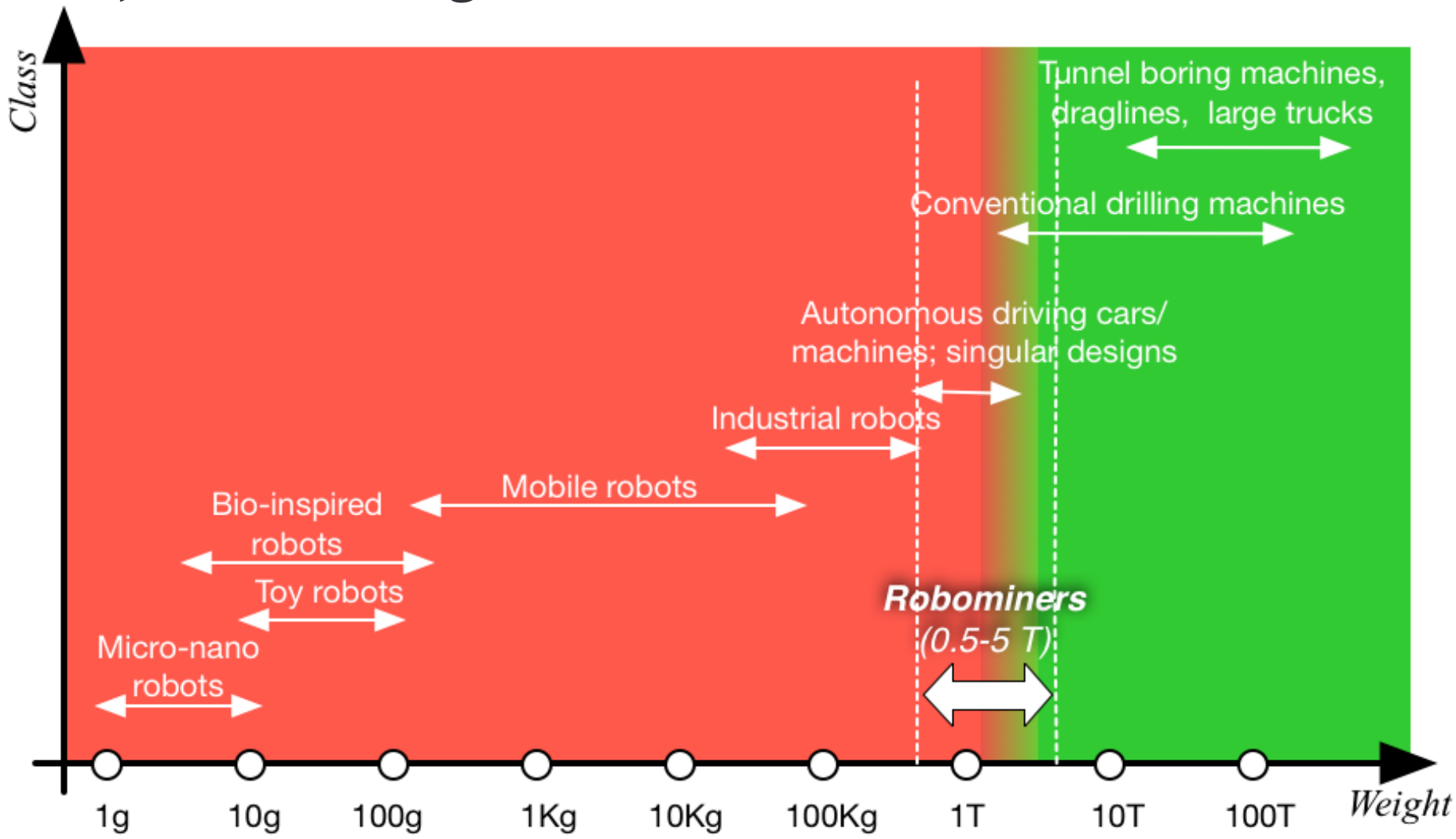
Modular robotic platform.

Each leg is a completely autonomous robot, equipped with CPU, batteries and comms.

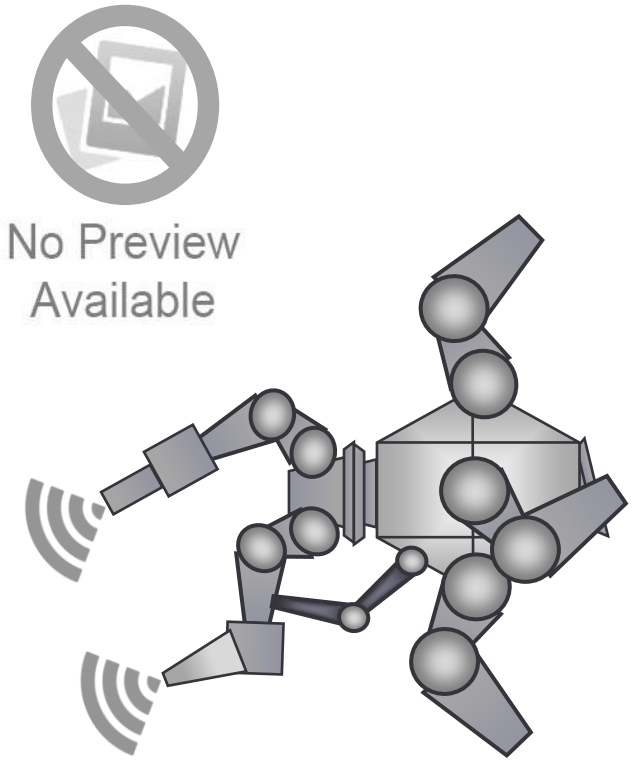
The end-effector is changeable.

(Source: M. Hernando, UPM)

- **Big robot, small mining machine**



Selective mining/1: sensing



Instrumentation strategies for **in-stream** elemental analysis:

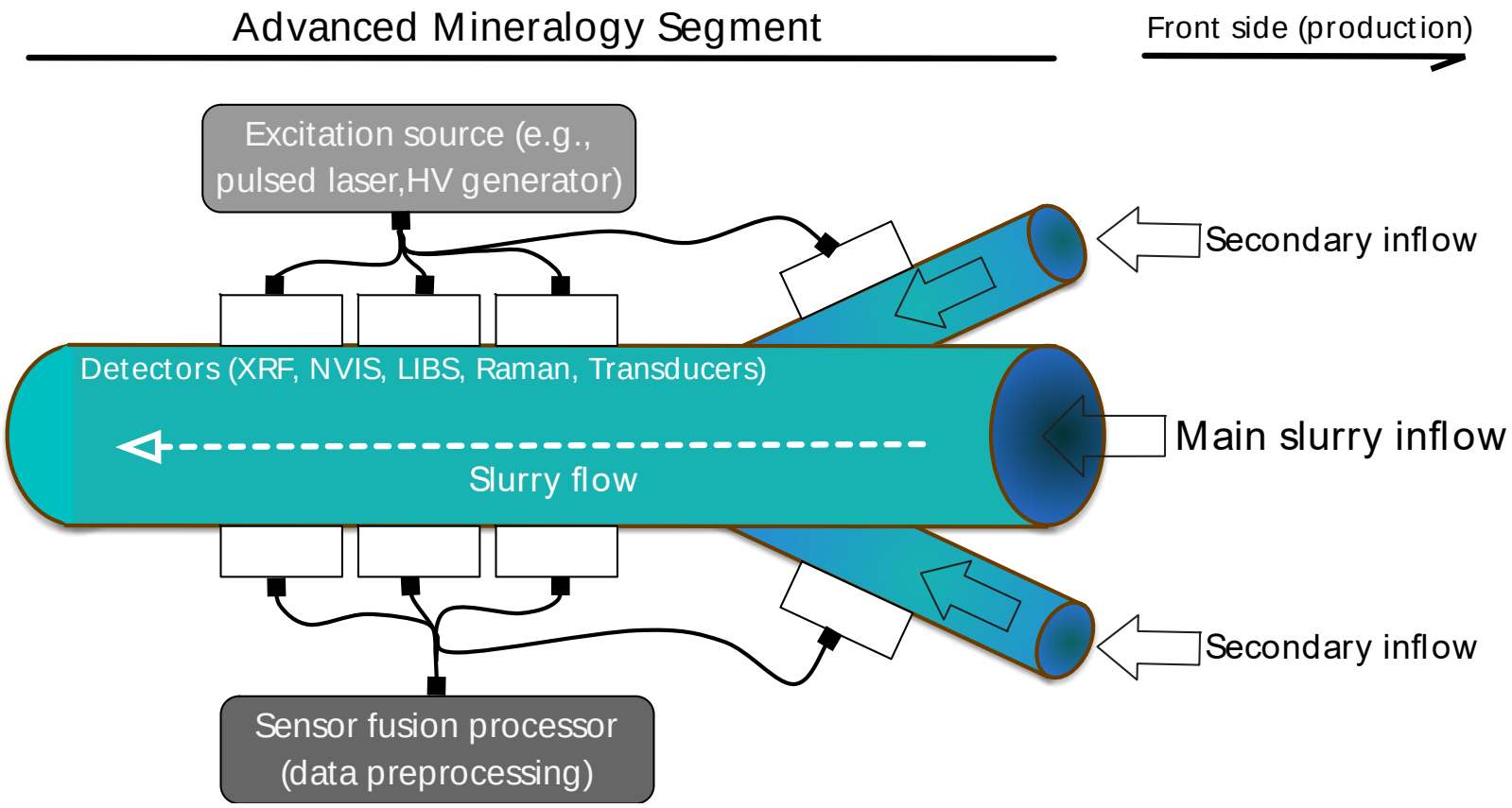
- high sensitivity solid state XRF spectrometer / LIBS spectrometer and Gamma-Ray spectrometer

Instrumentation strategies for **in-stream** molecular analysis:

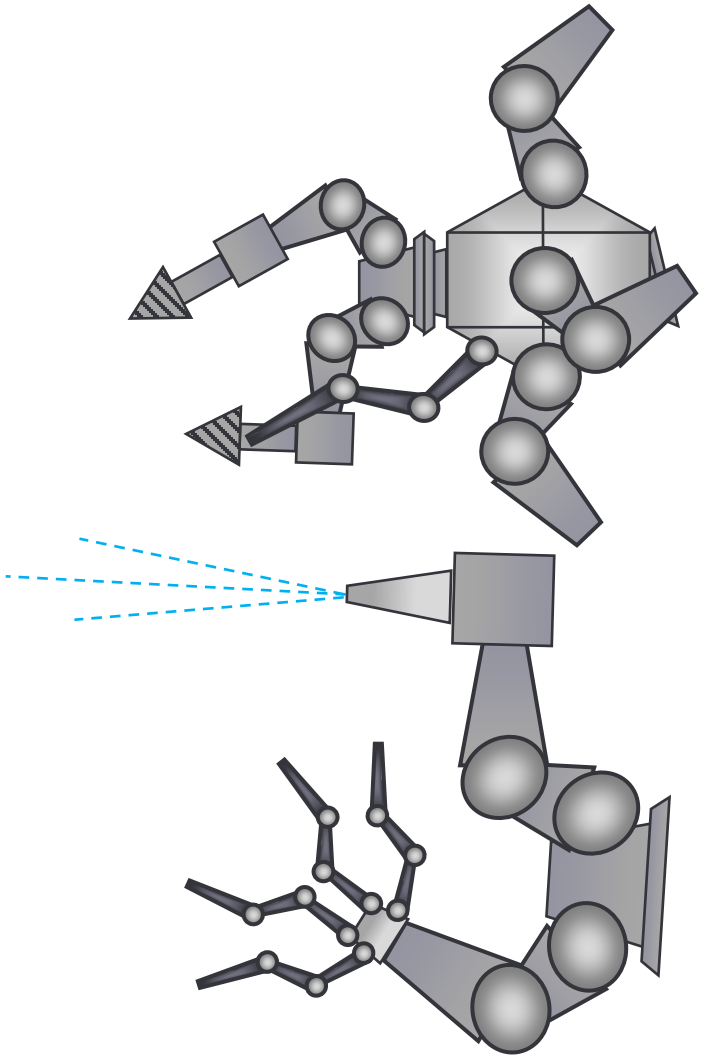
- Optical UV-VIR-NIR techniques, including Resonance UV Raman spectroscopy, time resolved VIS Raman spectroscopy, NIR absorption spectroscopy and LINF spectroscopy

Selective mining/1: sensing

- **“Digestive” mineralogy**



Selective mining/2: production

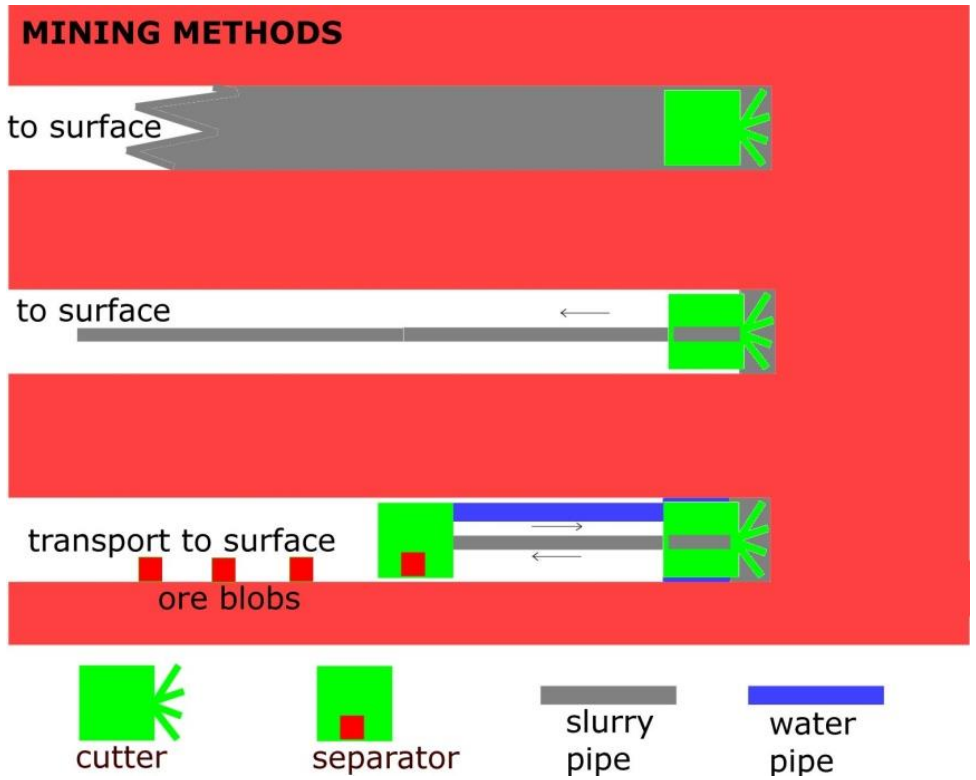


Production tools

- Drilling: eg. Tricone drill bit
- Cutterhead machines: Full-fase cutter head
- Micro-blasting
- Waterjet cutting
- Hydraulic breaking
- Diamond wire

Mining system

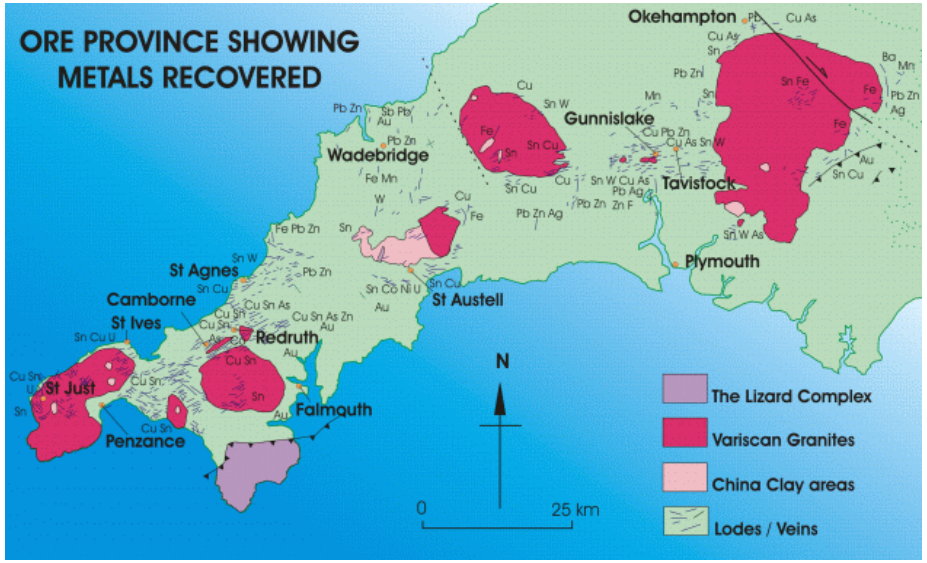
- Need of a **new approach to mining strategy and mine design**
- Studying and simulating the various systems components in future mining scenarios
- Creating a **simulated environment for the entire mining operation,** considering
  - drilling methods
  - mineral exploration
  - minerals processing and transport options
  - power supply scenarios
  - mine design and mine geometry
- Micro and macroeconomics studies
- Inventory of relevant deposits



SIMIO simulation, by RCI

Targeted mines

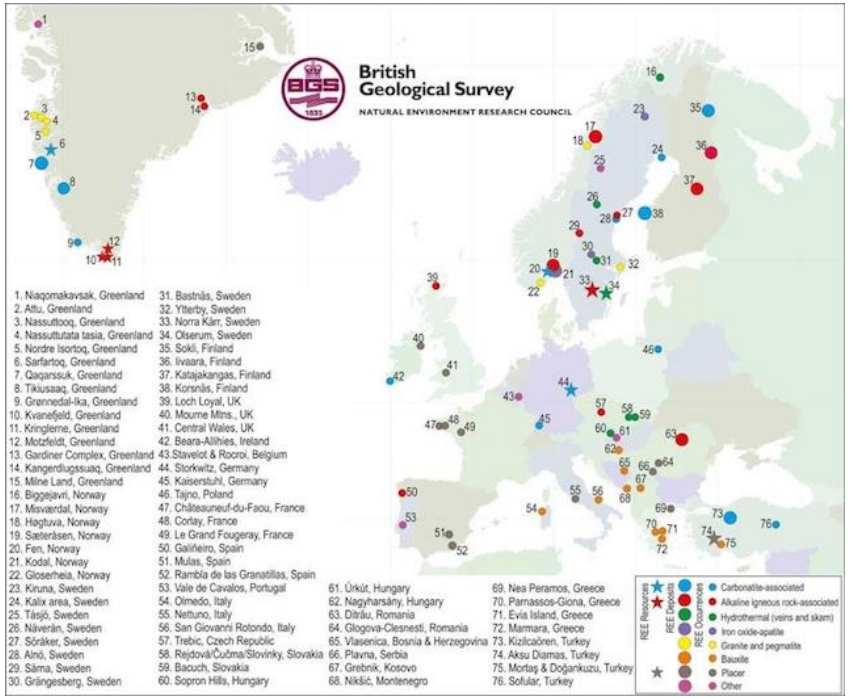
- **Abandoned mines.** ROBOMINERS presents a solution for reopening many of Europe's abandoned underground mines, **without the need for a full recommissioning and in particular without the need to dewater the mine**.



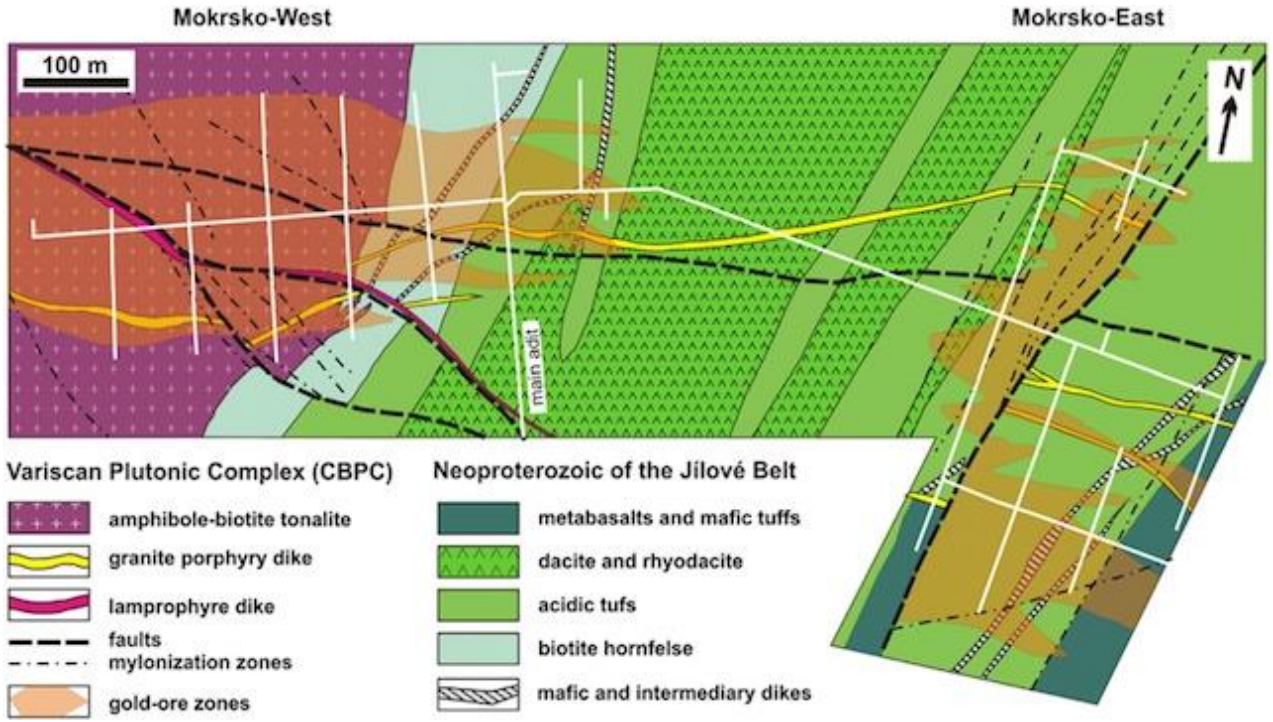
Left: Metals mined from the Cornwall mineralised belt. Right: Ruins of the abandoned Botallack Mine in Cornwall. Operating from the 1500s to 1895, Botallack was once one of the greatest copper and tin mines in England

Targeted mines

- **Small but high grade mineral deposits.** *The proposed technology does not require the development of any mine infrastructure and even very small deposits can be mined.*



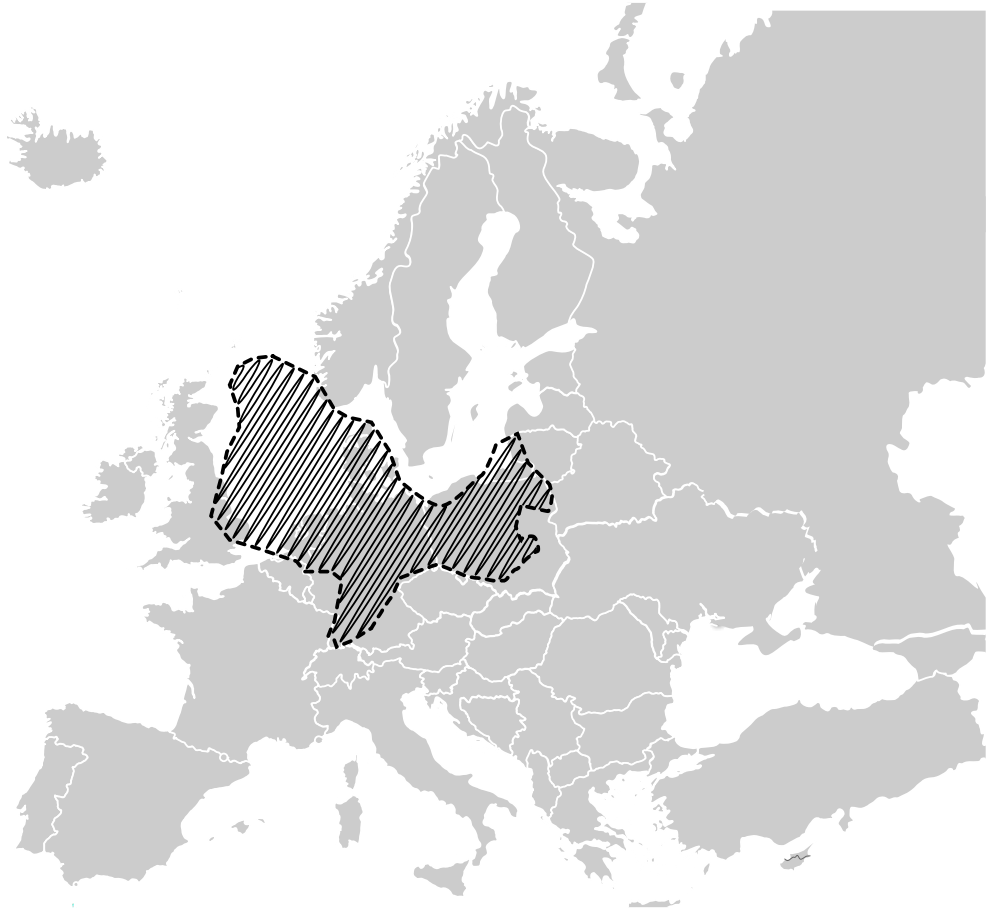
Locations of the enrichments of rare earth elements in Europe.



Geological map of the Mokrsko-West and Mokrsko-East deposits (horizontal section at ca. 300 m a.s.l.)

Targeted mines

- **Ultra depth.** *Under this application scenario a large diameter borehole will be drilled from the surface to the deep-seated deposit.*



Extension of the Kupferschiefer Formation

Possible geological and mining scenarios

- Suitability of ore deposits for the ROBOMINERS technology is based on:
  - specific metal value of the ore and other market conditions
  - favourable geotechnical properties
  - commercial technologies to extract and refine metals from ores
- Possible scenarios to apply ROBOMINERS technology include:
  - operating and abandoned mines or mine-sections with known remaining resources
  - unexplored or explored non-economic occurrences by conventional methods
  - not accessible and hazardous environments
  - mining in areas requiring minimum surface footprint

Magmatic deposits

- e.g. Carbonatite-alkaline intrusion, Orthomagmatic Cu-Ni-Fe-Pt deposits

Magmatic-hydrothermal deposits

- e.g. Pegmatite deposits, Epithermal deposits, Skarn

Hydrothermal deposits

- e.g. Vein association deposits, Orogenic gold deposits

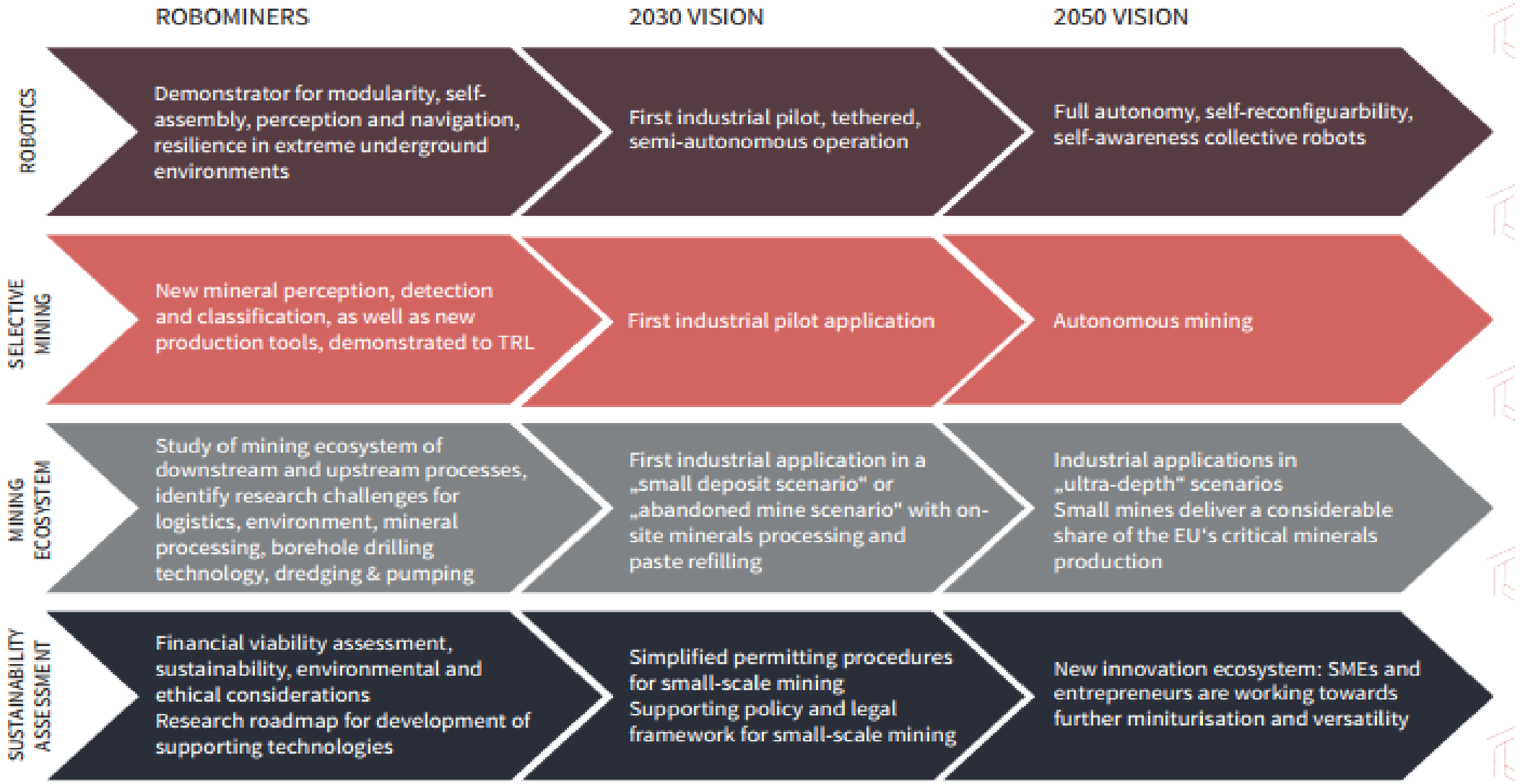
Sedimentary deposits

- e.g. Bauxite deposits

ROBOMINERS technology needs for different deposit types

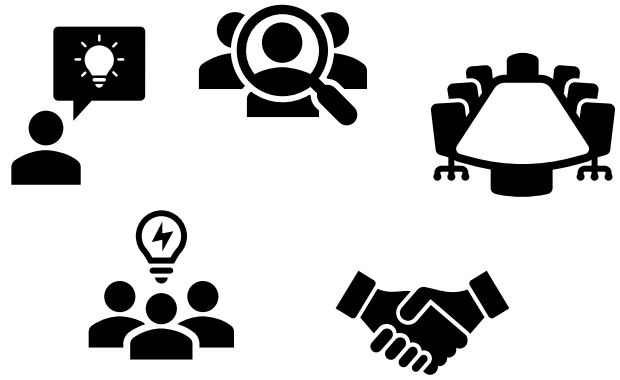
- Required capabilities include:
  - advance directional drilling (cm to m ahead) to identify continuation direction of an ore body
  - real-time chemical analysis for multiple target elements
  - real-time mineralogical analysis
  - underwater operational capability (for deep vein and stratiform deposits)
  - video camera(s) for hazard detection
  - first-stage mineral processing to separate a concentrate feed from waste rock
  - capability to move vertically as well as horizontally
  - slurry pumping system to bring mineral concentrates to surface & waste rock slurry to a backfill
  - rock-bolting or other tunnel stabilisation system to maintain structural integrity of the mine
  - battery recharge system
  - location method in the absence of GPS
  - communication system between the robots and the surface control room

Vision


ROBOMINERS
2030 VISION
2050 VISION
ROBOTICS
Demonstrator for modularity, self-assembly, perception and navigation, resilience in extreme underground environments
First industrial pilot, tethered, semi-autonomous operation
Full autonomy, self-reconfiguarbility, self-awareness collective robots
SELECTIVE MINING
New mineral perception, detection and classification, as well as new production tools, demonstrated to TRL
First industrial pilot application
Autonomous mining
MINING ECOSYSTEM
Study of mining ecosystem of downstream and upstream processes, identify research challenges for logistics, environment, mineral processing, borehole drilling technology, dredging & pumping
First industrial application in a „small deposit scenario" or „abandoned mine scenario" with on-site minerals processing and paste refilling
Industrial applications in „ultra-depth" scenarios
Small mines deliver a considerable share of the EU's critical minerals production
SUSTAINABILITY ASSESSMENT
Financial viability assessment, sustainability, environmental and ethical considerations
Research roadmap for development of supporting technologies
Simplified permitting procedures for small-scale mining
Supporting policy and legal framework for small-scale mining
New innovation ecosystem: SMEs and entrepreneurs are working towards further miniturisation and versatility

Getting involved in ROBOMINERS development

- Clustering
  - With other EU projects
  - With European initiatives on Robotics and Raw Materials
  - With international projects
- Technology foresight tasks
  - Focus groups meetings
  - Delphi survey online
  - Visioning workshops
  - Roadmapping workshops

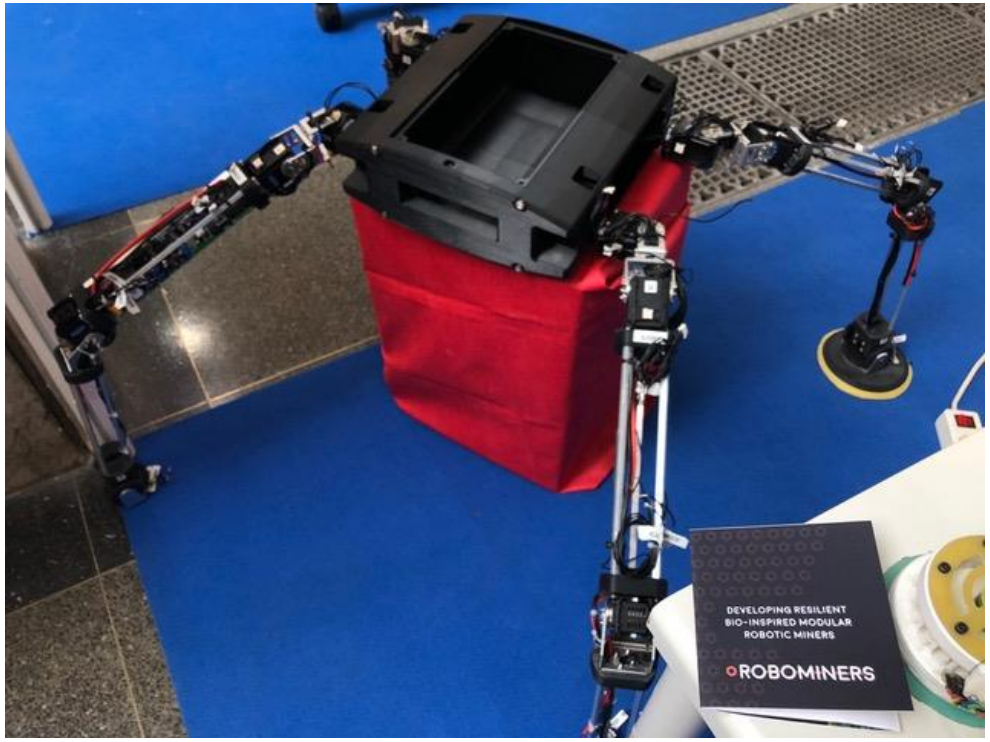


Want to get involved in the project's activities and participate in workshops and online discussions on ROBOMINERS, raw materials and robotics?

Contact Luís Lopes
luislopes@lapalmacentre.eu

Learn more and stay tuned

- **Website:** https://robominers.eu/
- **Twitter:** @robominers
- **Facebook:** @robominers
- **LinkedIn:** @ROBOMINERSproject
- **YouTube:** ROBOMINERS Project
  - Video: https://www.youtube.com/watch?v=BIcnObHfCyA



Thank you !