ROBOMINERS

Vision of the mine of the future

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with contributions from the project members

GeoZS
Geološki zavod Slovenije

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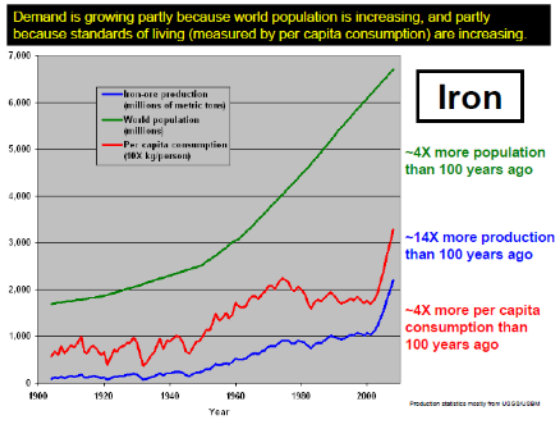
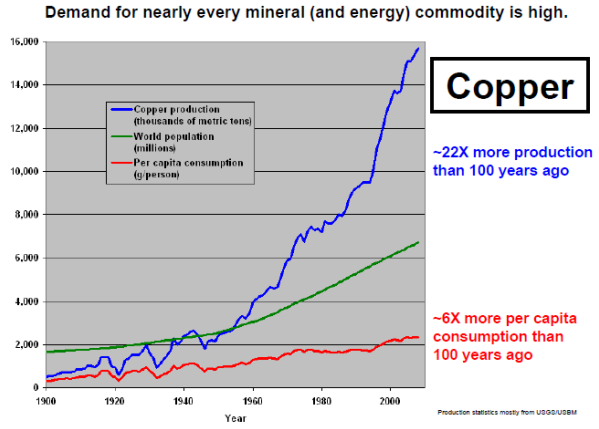
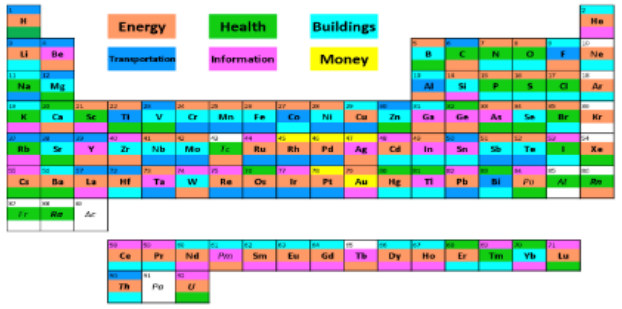
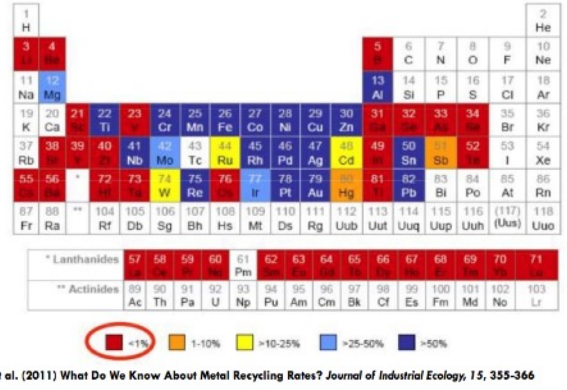
WHY DO WE NEED MINING?

- (1) Global demand for mineral raw materials (and energy) is increasing. Global demand per capita is increasing.
- (2) A variety of resources we use today has increased compared to the number of different materials used in the past.
- (3) Recycling can not meet the demands. Some commodities are even not "recyclable"
- (4) We can not substitute non-renewable resources with renewable ones. Even "green" technologies use significant portion of non-renewable natural resources.
- **Mining will still play a crucial part, if we want to maintain society as it is, and maintain the current living standard.**







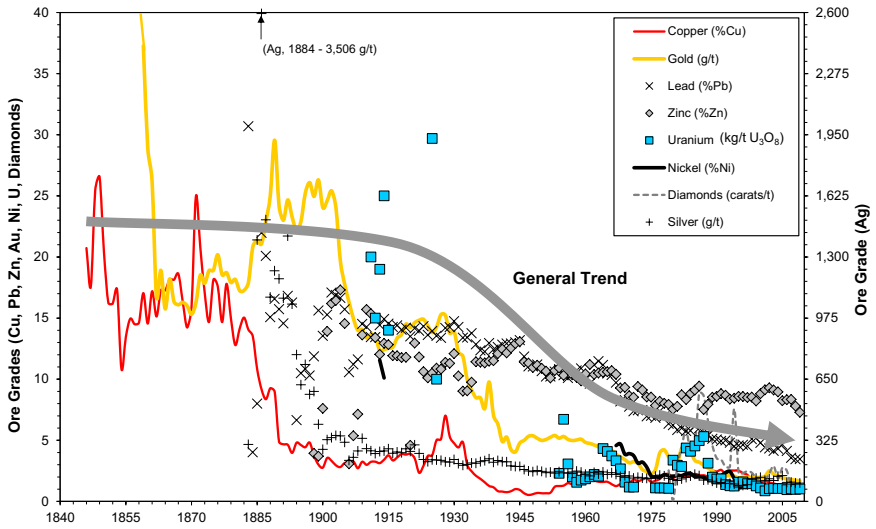


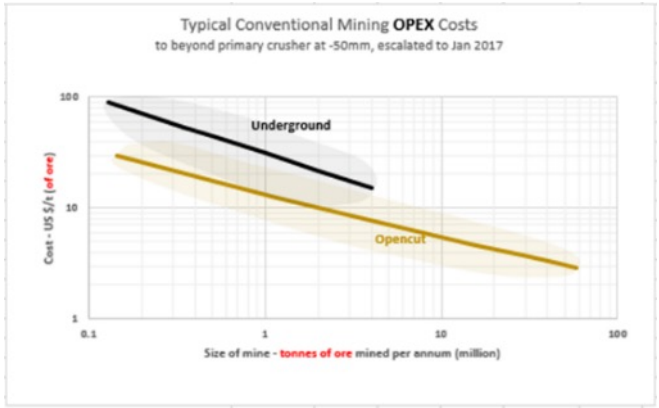
Source: Graedel et al. (2011) What Do We Know About Metal Recycling Rates? *Journal of Industrial Ecology, 15*, 355-366

https://slidetodoc.com/the-importance-of-mineral-resources-in-a-nationalinternational/ USGS data Graedel et al., (2011) J. of ind. Ecol. 15, 355-366

MINING IS THE FUTURE! IF IT' S NOT GROWN, IT MUST BE MINED.

- Only a few accessible high-grade reserves are still left, but there is
  - a lot of inaccessible high-grade resources,
  - accessible low-grade reserves.
- The strategies of mining companies today: Let's mine easily accessible low-grade reserves, and compensate this by increasing annual production (LET'S GO BIG. REALLY BIG!)





iVAMOS! project

various web pages

WHY DO WE NEED ROBOTS IN MINES?

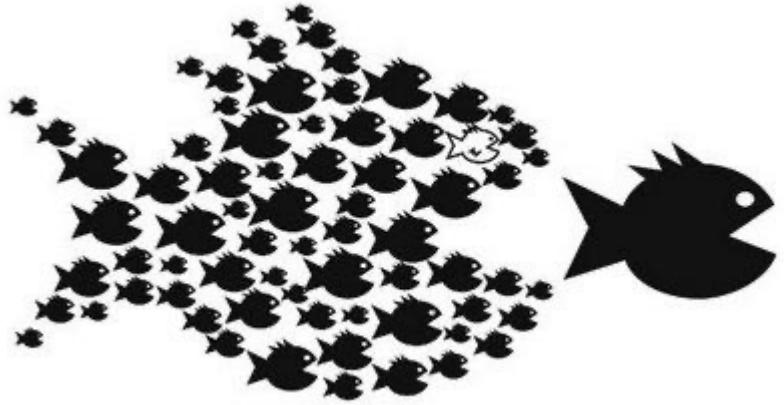
- Easily accessible rich mine deposits are already exploited.
- THERE WILL BE NO DEPLETION OF RESOURCES! The only question is, what will be the cost of extraction of raw materials.
- Mining in the future will also need to occur in areas not suitable for humans (under water, ultra-deep environments, presence of harmful substances, geotechnical instabilities etc.)
- Mining there is costly!
- Using robots in mine could have several advantages:
  - decrease the costs for maintaining safe and healthy working conditions in mines (especially in deep mines, where increased temperature is a big issue);
  - robots can work underwater, there is no need for dewatering (lower costs and environmental impact);
  - robots can work round the clock, no need for traveling to and from underground, rest, vacations etc. (they only need maintenance, repairs and replacements);
  - mining can occurs selectively, with the potential of generation significantly less mine waste;
  - we might need less people to operate the mine, some work can be done remotely;
  - mining can occurs in areas which are not suitable for humans (ocean floor, extraterrestrial bodies, active hydrothermal vents, ultra-deep deposits etc.).

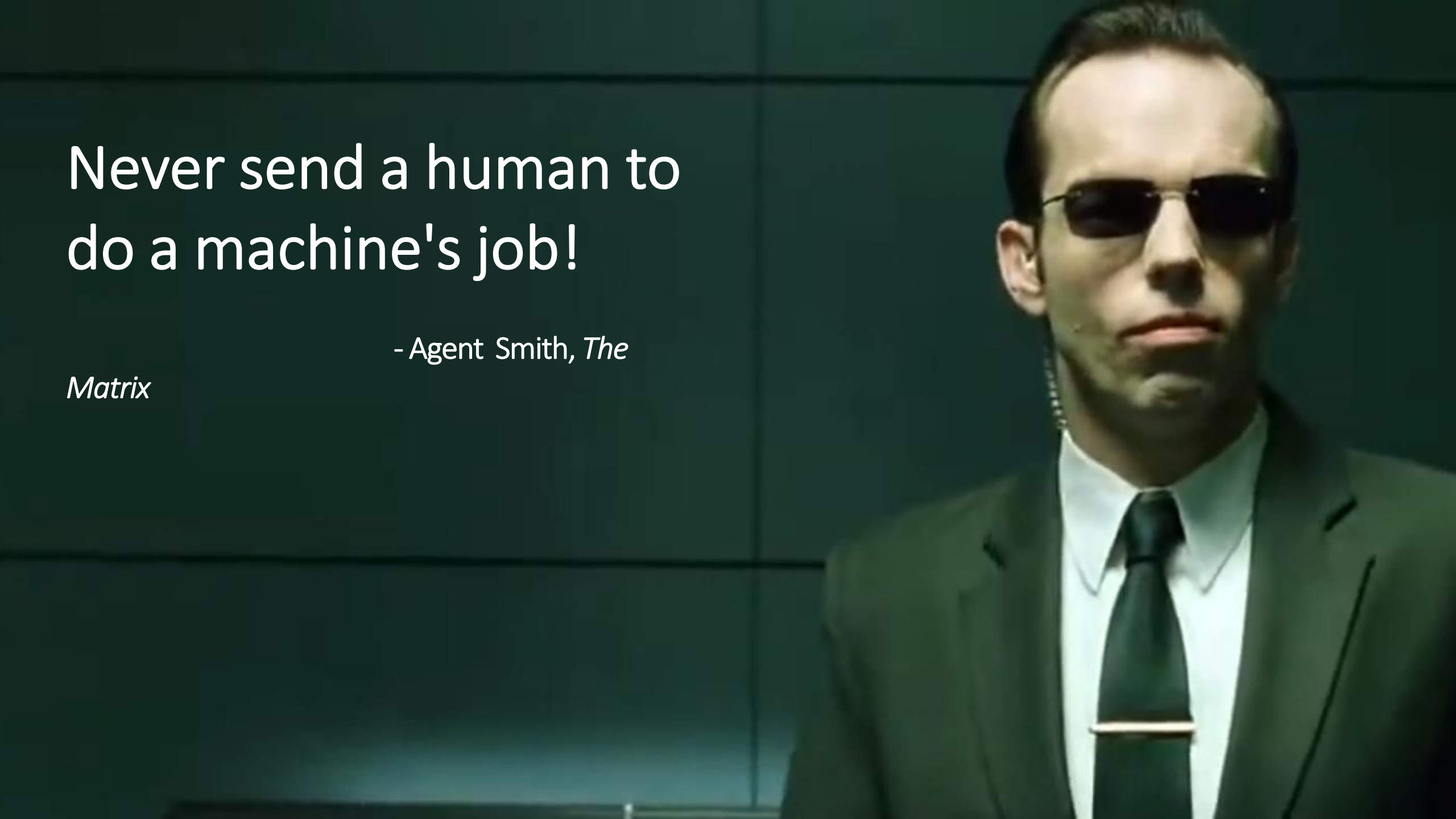
WHAT IF…

We change the paradigm, and let's go small, instead of big!

Thinking about high precission mining with **small autonomous intelligent units** => we reduce many environmental impacts, generate much less waste, better stability etc.

A huge amount of small deposits, which are today regarded uneconomical, might become economically viable for exploitation. Increased social acceptance.

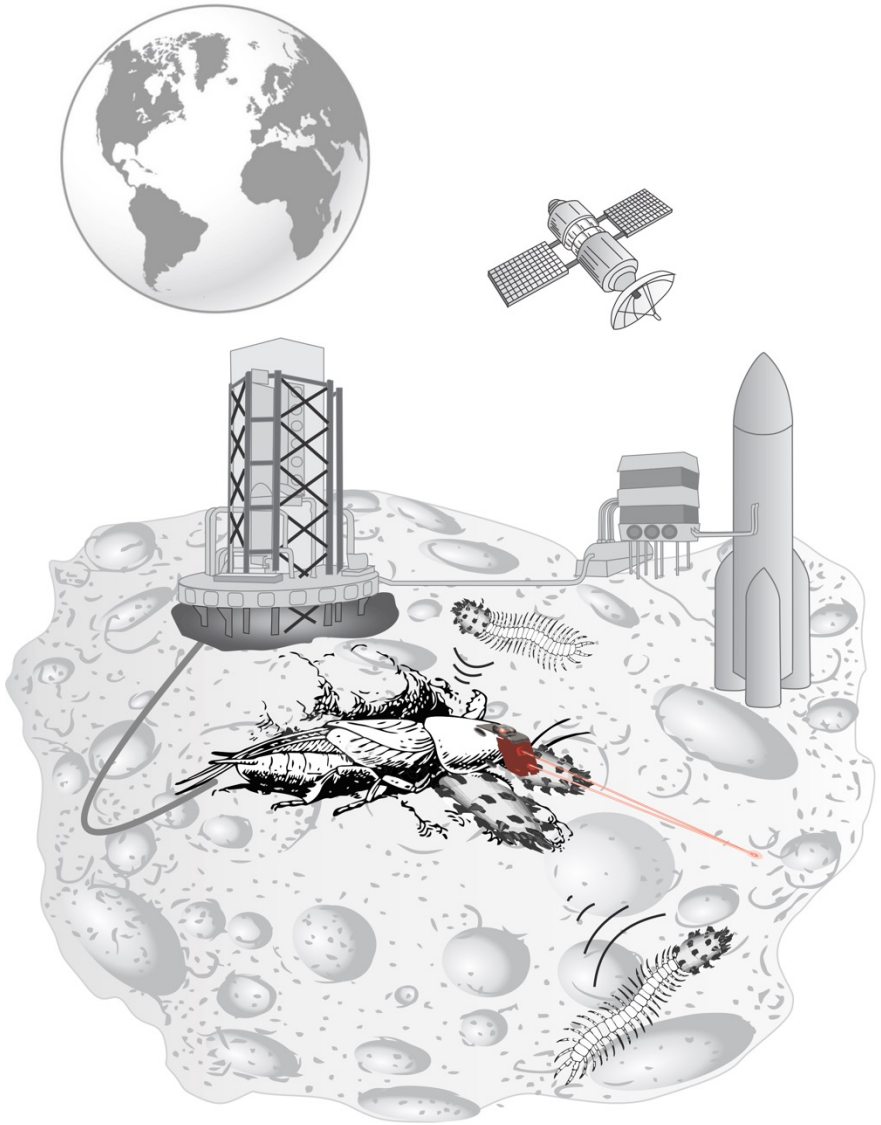



Never send a human to do a machine's job!
- Agent Smith, *The Matrix*

VISION OF THE MINE OF THE FUTURE

MINING:

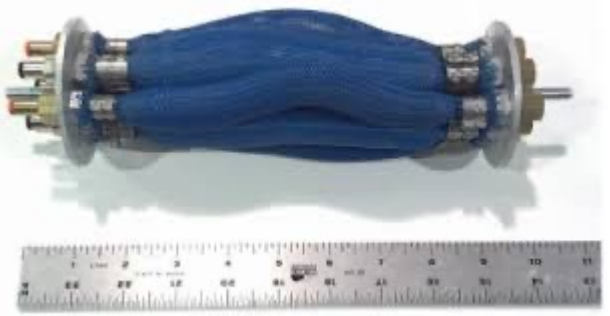
- is completely automated, no humans needed underground; human interventions are needed, but can be done remotely,
- machines are modular, can self-assembly and self disassembly, are able to use various tools and to replace worn-out parts,
- machines are able to distinguish between ore and waste, and are able to make decisions accordingly,
- minerals are extracted precisely, in all 3 directions, with much less waste,
- have complex, or fractal-like mine layout, increased stability,
- mining machines can start digging from the surface, and can operate in various environments, even underwater, in fresh or saline waters, in corrosive environments etc.,
- mineral separation is occurring underground, with in-situ backfilling if needed,
- ore concentrate is transported to the surface,
- downstream industries (concentration, processing, metal extraction) are also automated,
- can operate in extraterrestrial environments (like on the Moon, Mars, asteroids).

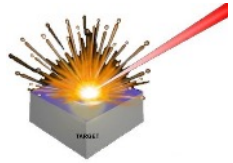


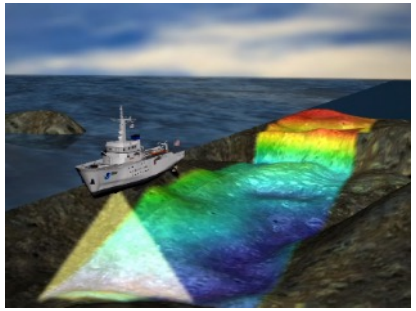
MANY TECHNOLOGICAL CHALLENGES

It could be stated, that underground autonomous mining is bigger challenge than the exploration of extraterrestrial bodies (N. Zajzon)

- energy supply
- motoric and locomotion
- sensing and awareness
- cutting the rock
- ore transportation
- big data handling, communication
- human-machine interaction
- decision making, AI
- robusteness and resistance
- modularity...



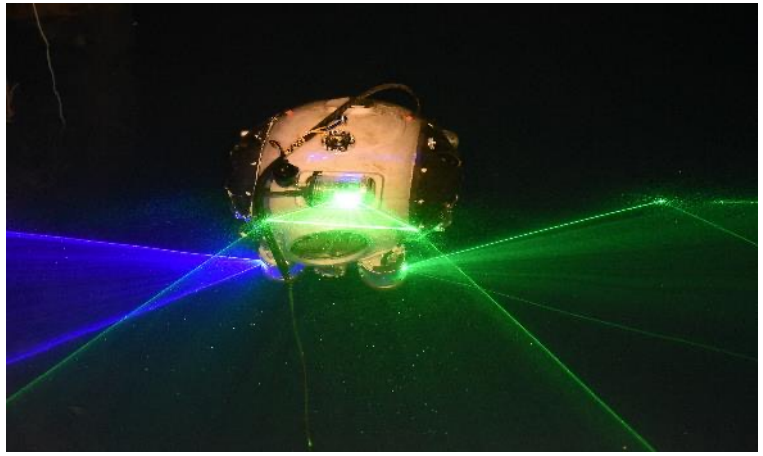




" THE MAN WHO MOVES A MOUNTAIN BEGINS BY CARRYING AWAY SMALL STONES." (CONFUCIUS)

- automatization of tasks, remote control of machines (co-existence of humans and machines)
- sensors, virtual reality environments
- less issues with health and safety of workers

iVAMOS! project



UNEXMIN Georobotics

Sandvik AutoMine

Soil Machine Dynamics

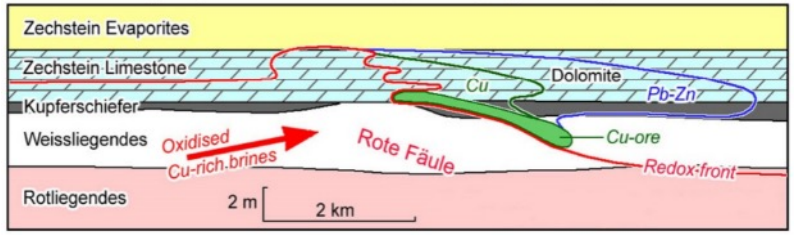
KRISO underwater (mining) machines

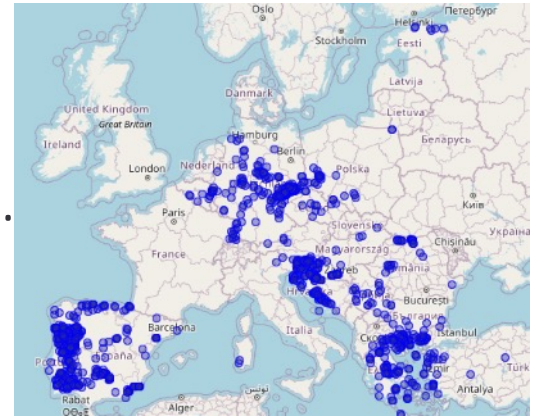
" THE MAN WHO MOVES A MOUNTAIN BEGINS BY CARRYING AWAY SMALL STONES." (CONFUCIUS)

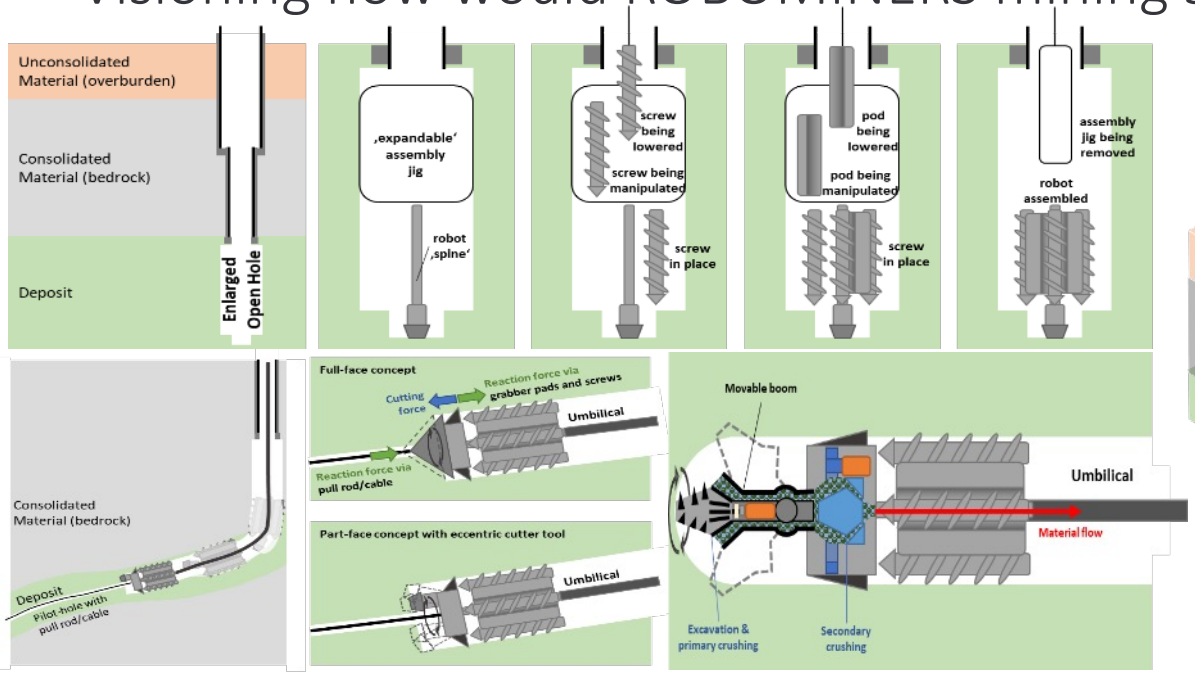
ROBOMINERS

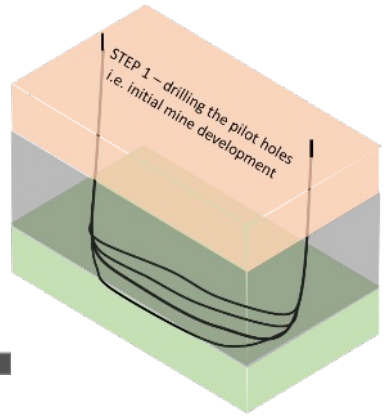
GEOLOGY IN ROBOMINERS

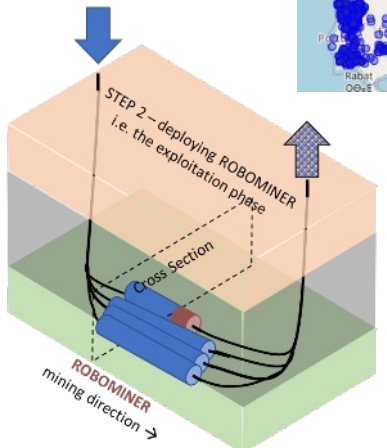
- Determination of ROBOMINER scenarios:
  - operational or abandoned mines with known resources (but difficult to access)
  - ultra-depth
  - small deposits uneconomical for traditional mining
- Database of European ore deposits relevant to ROBOMINERS.
- Visioning how would ROBOMINERS mining system looks like in practice.

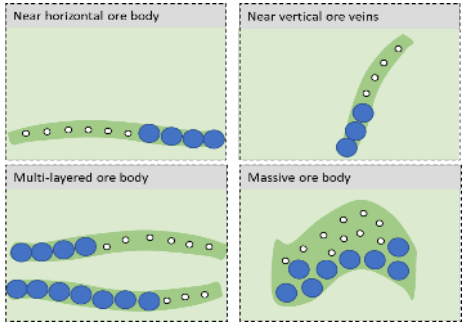






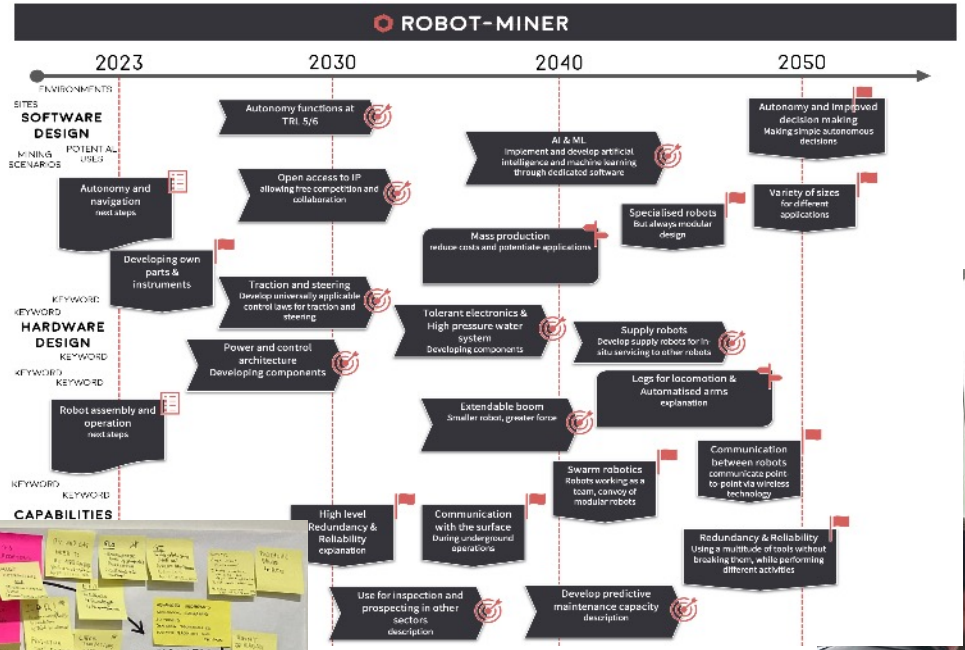


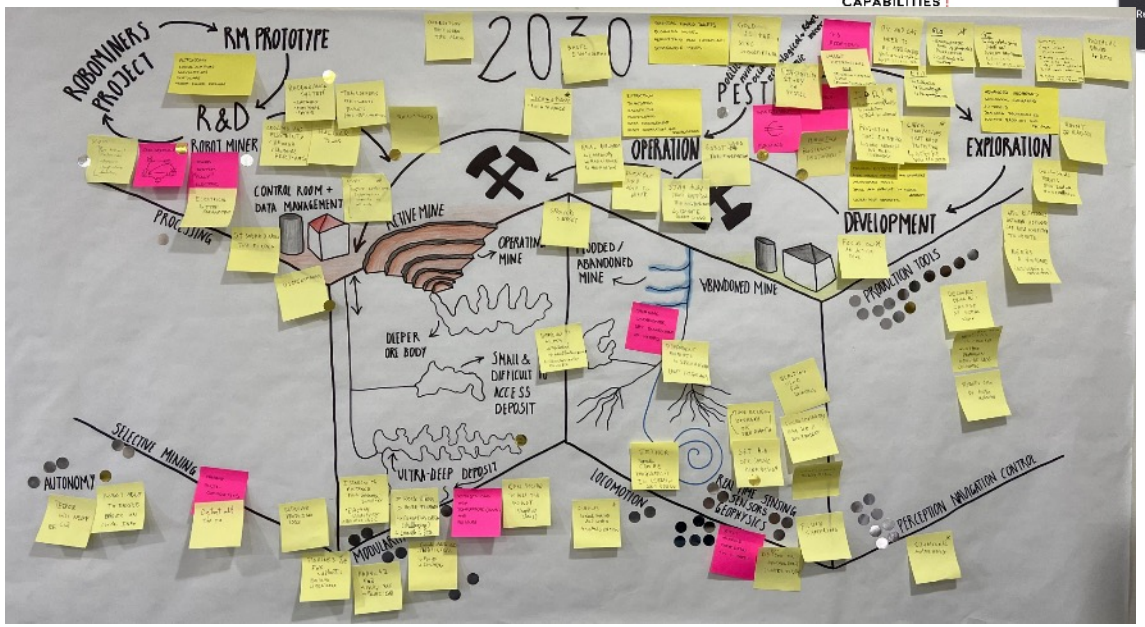




ROADMAPS

- Roadmapping
- Clustering
- Preparation for pilots at higher TRL levels



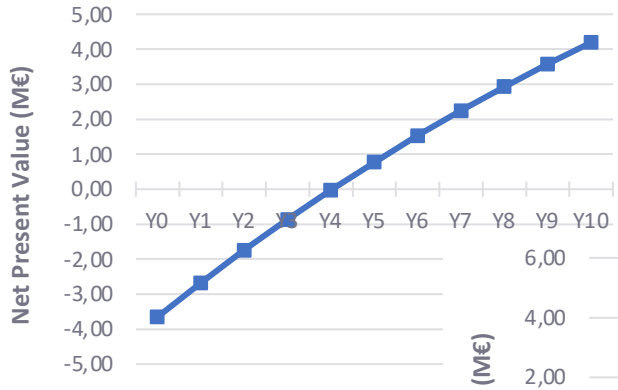


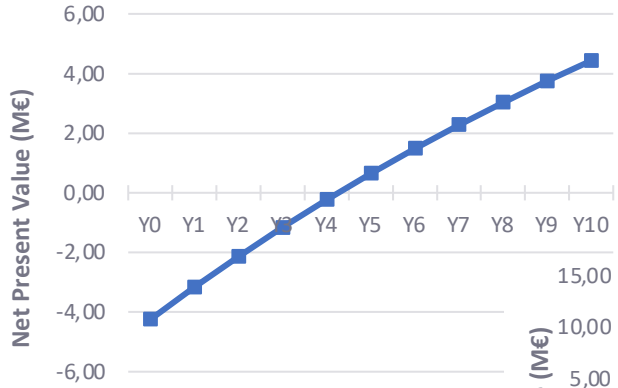
INTEGRATED SUSTAINABILITY ASSESSMENT

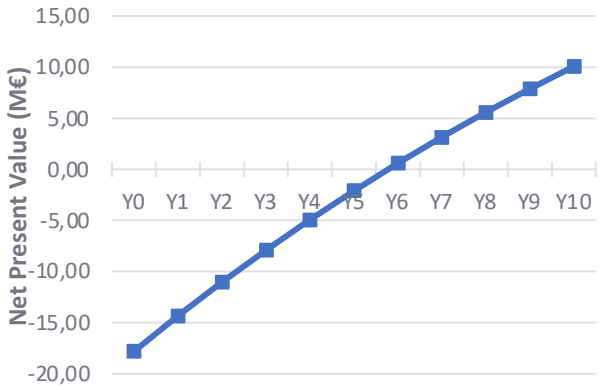
MACROECONOMIC investigations (general level). three scenarios:

- Cu mining (ultra-deep)
- Pb-Zn-Ag mining (MVT)
- Au mining (orogenic gold)

Critical parameters: price of ore, productivity, uptime, initial investment costs







SITE SPECIFIC economic investigation

Features common for all 3 scenarios:

- Access works relatively quick
- Lack of ore dilution and waste generation
- Noise, dust and gases emission – marginal
- Lack of influence on climate

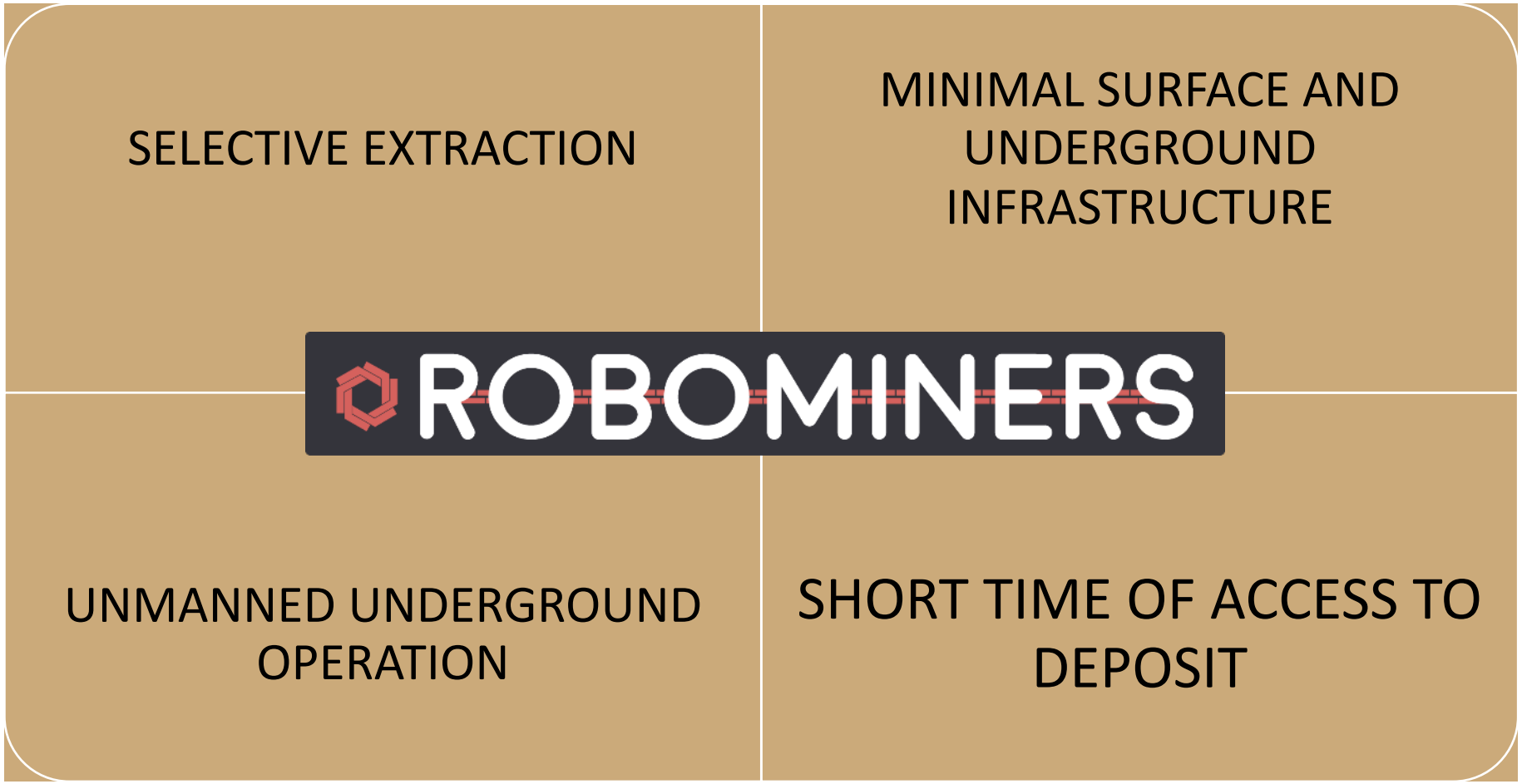
Feature specific for each scenario:

- Operating mines: VMS Zn-Pb-Cu-Sn deposit, Portugal
- Ultradepth deposit: SSC Cu-Ag in Kupferschiefer, Poland
- Abandoned small mine: epithermal Au-Cu, Hungary

critical parameter - cost for borehole
critical parameter - cost of gold
critical parameter - price of metals

ROBOMINERS VS. TRADITIONAL MINING

Advantages of Robominers technology to be promoted towards societal stakeholders

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