KGHM
POLSKA MIEDŹ

Robotics in mining.

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World Materials Forum 2015; 23rd June 2015; Nancy, France

Content of the presentation.

1. Automation and robotics in current mining activities.
2. European and national programs - automation in mining;
3. SPARC program - safety first in mining operations.
4. Options for robotics - looking for minerals in other areas.
5. Conclusions.

Ten technologies with the power to transform mining (2014).

1. Robotics;
2. Internet of Things;
3. Advanced airborne gravity gradiometer technology for mineral exploration;
4. 3D imaging technologies;
5. Automated drilling;
6. Efficient shaft and tunnel boring system;
7. Autonomous haulage;
8. Plasma technology for increasing precious metal yields;
9. Copper-eating bacteria;
10. Remote operating and monitoring centres.

Source: http://www.mining-technology.com/features/featureten-technologies-with-the-power-to-transform-mining-4211240/

Why Robotics is important to Mining?

1. Probably robots will transform almost every industry and service sector, particularly in the area of mining sector where safety and efficiency are the main issues.

2. The application of robotic technology, although very limited in current mining operations around the world, has far reaching potential for the mining industry.

3. Robotic devices powered by artificial intelligence can perform a wide range of mining operations as well as ore sampling and rescuing trapped miners.

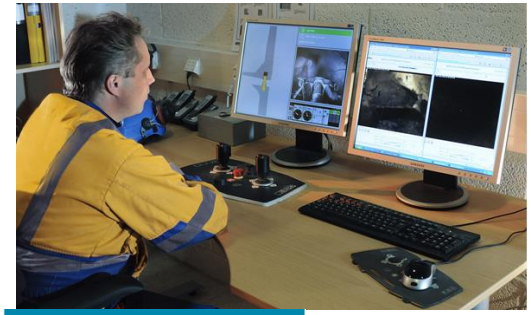
Source: http://www.mining-technology.com/features/featureten-technologies-with-the-power-to-transform-mining-4211240/

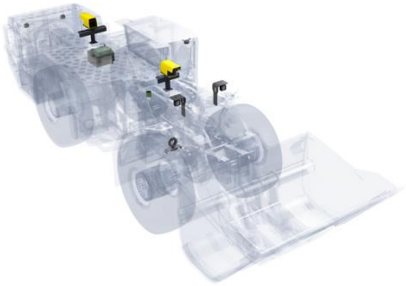
Eamples of commercially available systems for LHD automation.

Underground loaders and trucks: there have been a number of steps towards automation for several years including vehicle monitoring systems, load weighing systems and several remote control systems. **A typical, remotedly steered LHD vehicle is equipped in 150 sensors.**

MINEGEM™

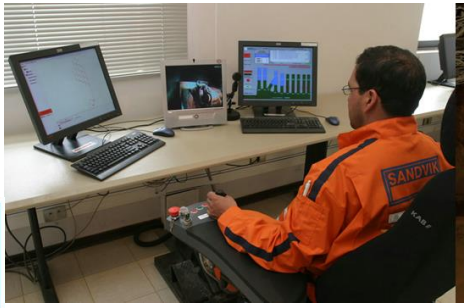
CATERPILLAR®





Atlas Copco

Scooptram Automation

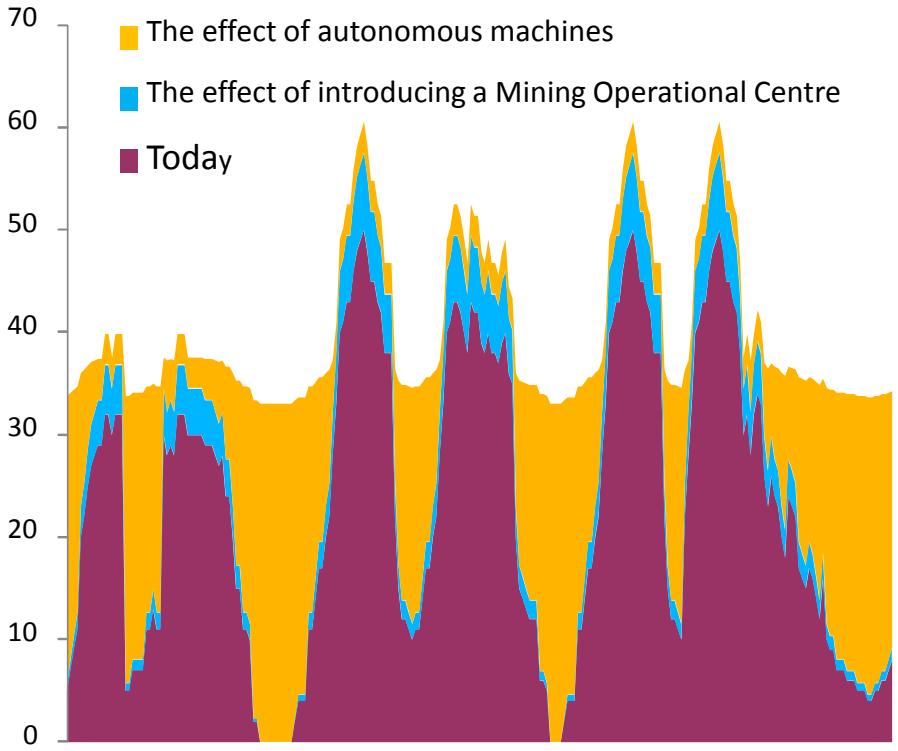


AutoMine™

SANDVIK

source: Prof. Håkan Schunnesson, LTU, Sweden, Mine Automation Key Research & Development Partners: Universities, Research Institutes and Companies

Main Target – increased effciency by mining activities during 24 hours.



Improvement potential: Autonomous Machines 40-80%
Mining Operational Centre 10-20%

- It is not unusual that the face utilization in underground mines is typical 25%. This usually due to reasons such as:
  - Blast ventilation, machine breakdowns, shift changes, lunch breaks and travel time
  - The complex sequencing of mine operation
- Mine Automation makes it possible to run a underground mine 24/7 and enhance the face utilization.
- Autonomous Machines enables huge improvements but requires huge investments and takes time to implement

Source: Hans Wahlquist; Director Business Development| Mobilaris AB; Sweden

mobilaris

Challenges for future metal mining operations.

BASIC PRE-CONDITIONS FOR AUTOMATION

- ✓ *Rock Mass Characterisation*
- ✓ *Predictive Maintenance*
- ✓ *Condition Monitoring of ZEPA vehicle*

BASIC TECHNOLOGIES FOR AUTOMATION

- ✓ *Communication*
- ✓ *Localisation systems*
- ✓ *Road and Traffic Management*

REPLACING HUMANS IN ZERO ENTRY PRODUCTION AREAS (ZEPA)

- ✓ *Human in Automated systems*
- ✓ *Augmented Reality*
- ✓ *Automated Inspection and Image Analysis*
- ✓ *Autonomous Patrolling Robots*

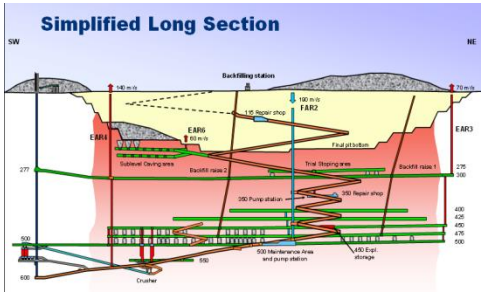
APPLICATIONS

- ✓ ***Continuous mining***
- ✓ *Automated drilling*
- ✓ *Automation of Loading and Transportation*
- ✓ *Automation of Charging*
- ✓ *Automation of Scaling and Reinforcement*
- ✓ *Automation of Media Installation*

After Prof. Håkan Schunnesson; *Division of Mining and Geotechnical Engineering, LTU, Sweden*

EU and national programs - automation in mining

1. Intelligent Mine" project. Helsinki University of Technology, Kemi mine Finland (1992-1997).



2. RWTH Aachen initiative (2008)

Inteligent Deep Mine – arranging the consortium and preparing project in the EU FP7 program.

3. Nordic Rock Tech Centre AB (RTC, Sweden) established a consortium for the conceptual study to develop a common vision for future deep mining (2009-2012).

4. I²Mine – FP7 UE funded project

Innovative solutions for safe extraction of deep laying mineral deposits in Europe (2011-2015).

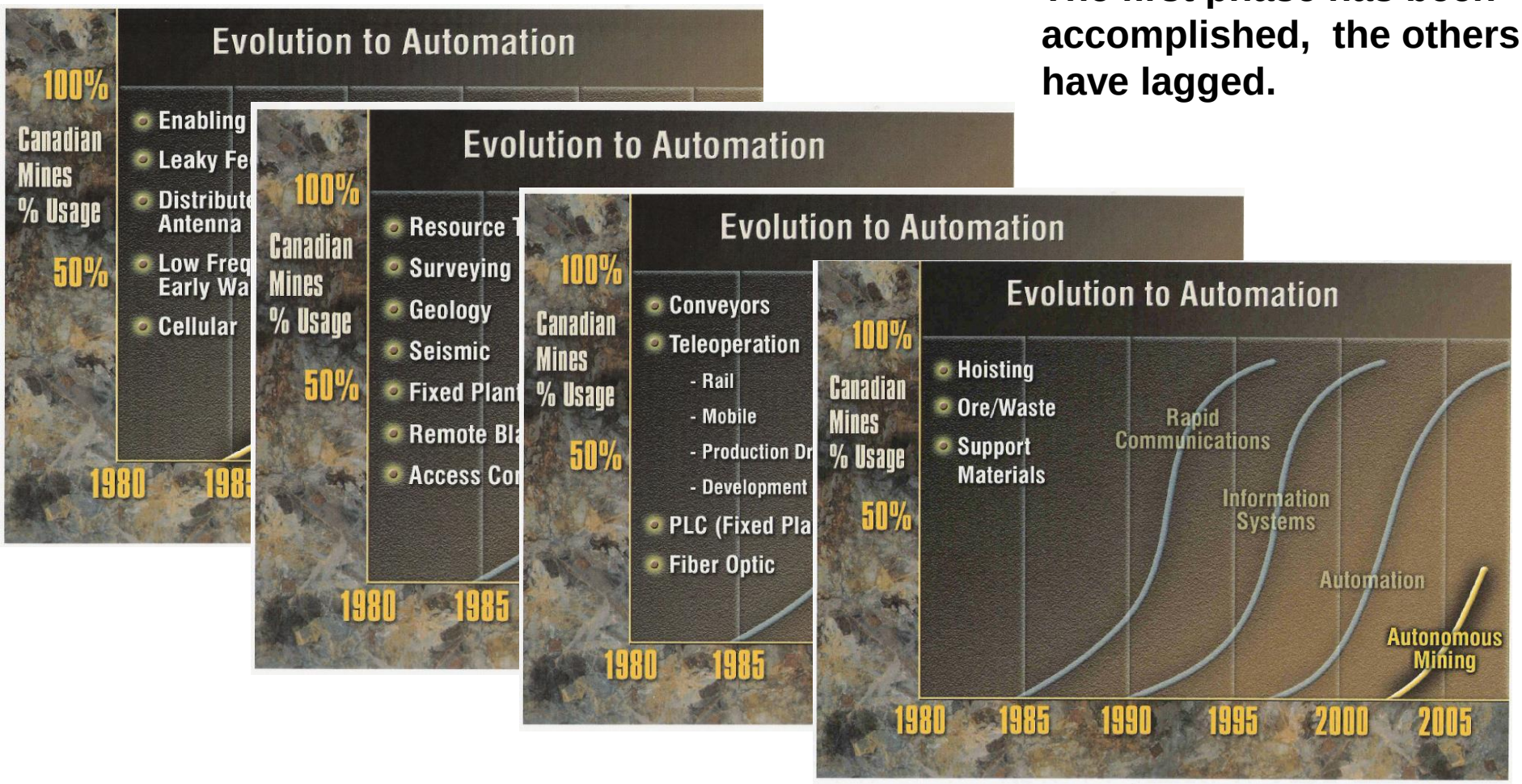
World RTD centers active in automation and robotics in mining operations.

source: Prof. Håkan Schunnesson, LTU, Sweden, Mine Automation Key Research and Development Partners: Universities, Research Institutes and Companies

The “Robolution” in mining – the Canadian example.

During a couple of last decades the quick process of mechanisation in mining sector has been followed by implementation of embedded systems, board computers and establishing IT network for mining operations.

The first phase has been accomplished, the others have lagged.



source: Mining and Robotics; Bill Fox; Presentation to the Northwest Mining Association Dec. 10, 2004.

New knowledge and mobilization of existing competence should contribute to:

- **Safer mines through remote control and automation**
  - No Human Exposure to Production Faces (Short term goal)
  - No Humans in the Mine (Long term goal)
  - No Accidents
- **Productivity improvements, which require significant adjustments including changes to mine plans, reassessment of mining methods, changes to equipment fleet and configuration, and increasing automation.**

Top 10 risks

2014

01	Productivity improvement
02	Capital dilemmas – allocation and access
03	Social license to operate (SLTO)
04	Resource nationalism
05	Capital projects
06	Price and currency volatility
07	Infrastructure access
08	Sharing the benefits
09	Balancing talent needs
10	Access to water and energy (new to top 10)

Over 7 years

2008 (peak of supercycle)

01	Skills shortage (now balancing talent needs)
02	Industry consolidation
03	Infrastructure access
04	Social license to operate
05	Climate change concerns
06	Rising costs
07	Pipeline shrinkage
08	Resource nationalism
09	Access to secure energy
10	Increased regulation

Remained on the risk radar over seven years

- **Source: EY Report - *Business risks facing mining and metals 2014–2015*; Nov. 2014**
- **Optimizing the complete production chain from mine to mill to customer through integrated process control systems.**

Place for Robotics in the EU Horizon 2020 innovation programs.

HORIZON 2020 WORK PROGRAMME

5. Leadership in enabling and industrial technologies

i. Information and Communication Technologies **(ICT - SPARC)**

HORIZON 2020 WORK PROGRAMME

5. Leadership in enabling and industrial technologies

ii. Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing (**Factory of the Future - FoF**)

HORIZON 2020 WORK PROGRAMME

12. Climate action, environment, resource efficiency and raw materials

EIP on Raw Materials (SIP).

SPARC – EU largest civilian robotics programme.

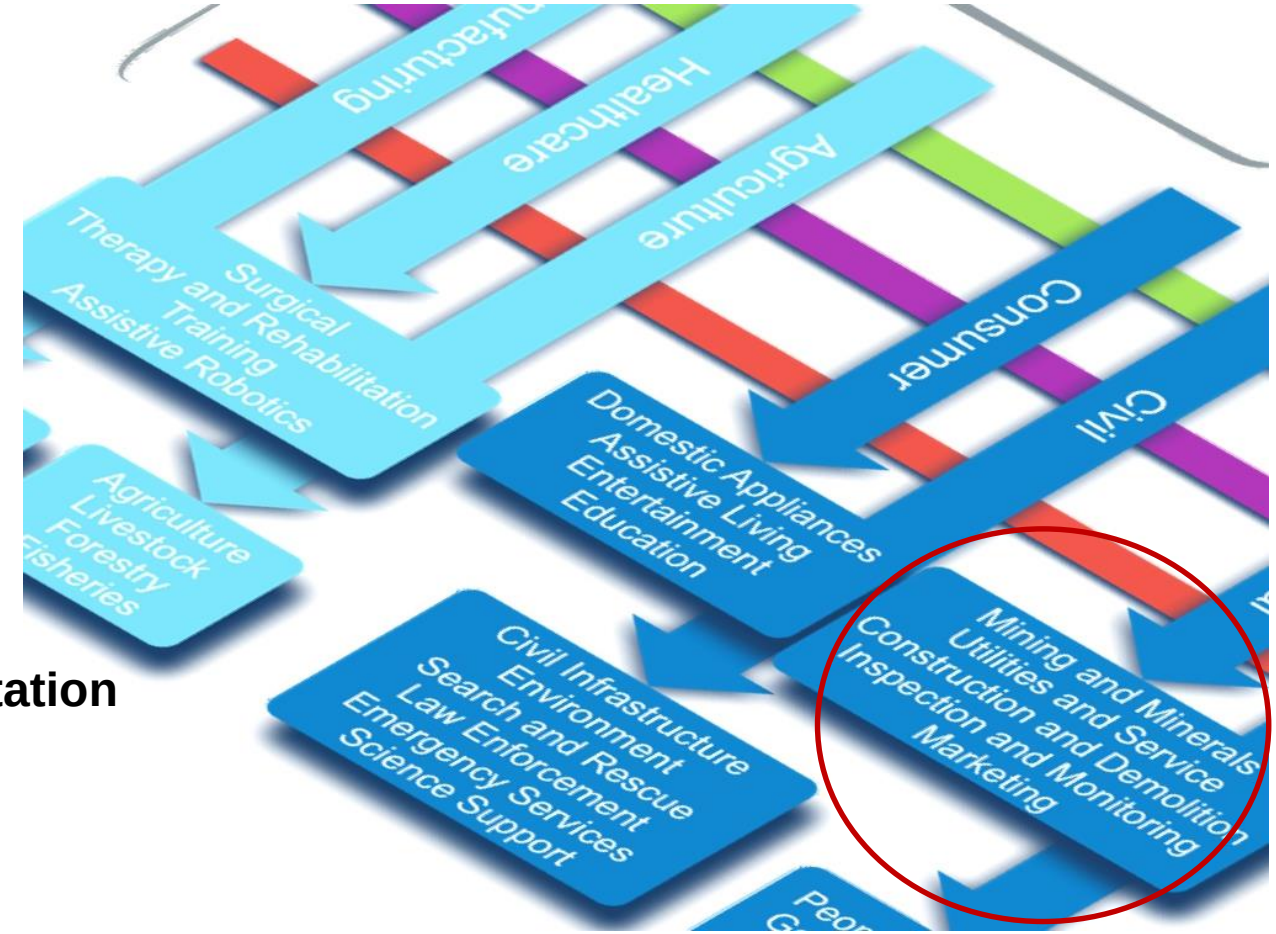
euRobotics was founded on 17 Sep 2012 by 35 organisations. By May 2014, euRobotics represented 182 companies, universities and research institutions, ranging from traditional industrial robotics manufacturers to producers of agricultural machinery and innovative hospitals.

With €700M in funding from the EC for 2014 – 2020, and triple that amount from European industry (€2100M) SPARC is the **largest civilian-funded robotics innovation programme** in the world.

The robotic market domains – place for mining.

1.Manufacturing,
2.Healthcare,
3.Agriculture.

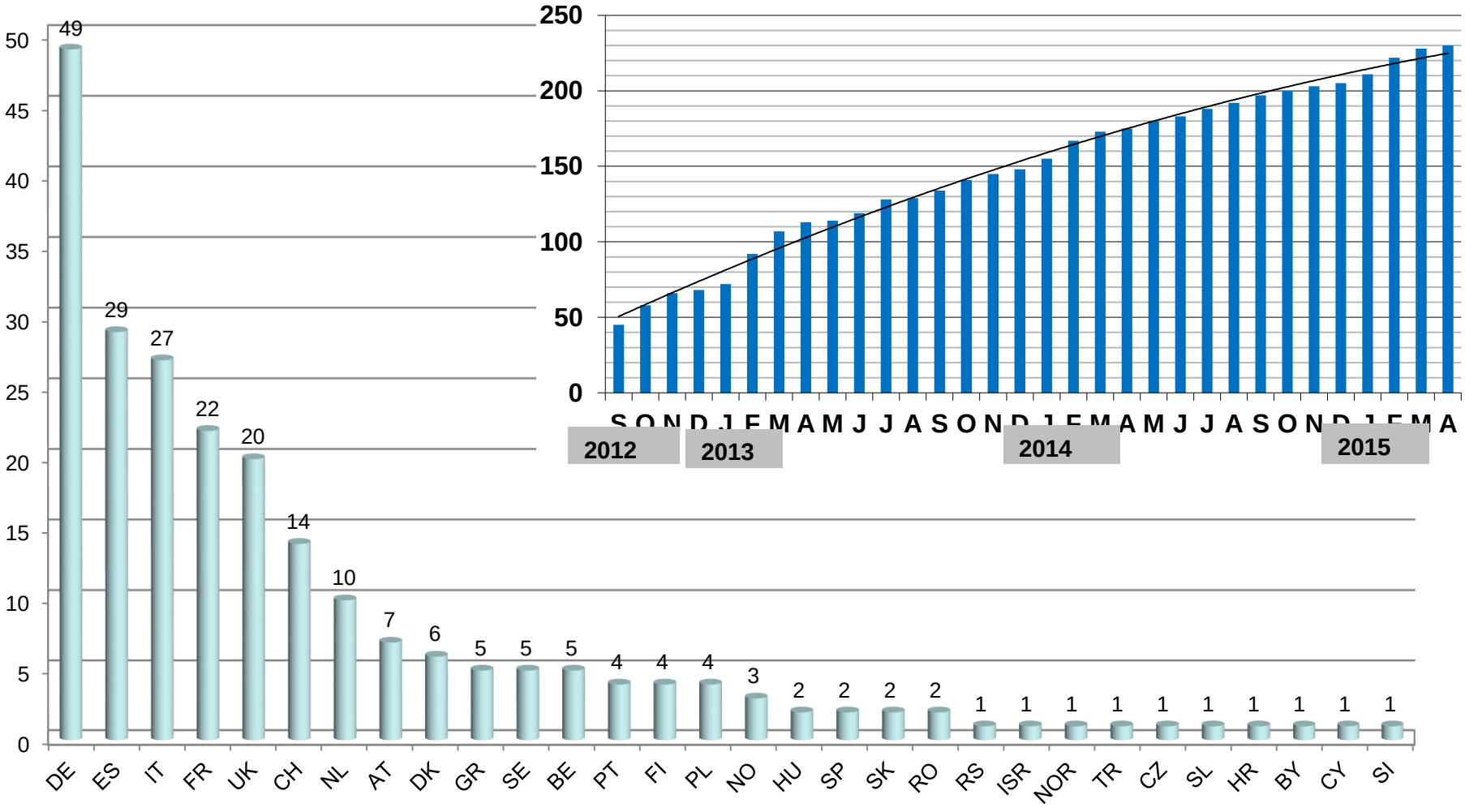
4.Consumer Robots,
5.Civil Robots,
6.Commercial Robots,
7.Logistics &Transportation
8.Military Robots.



It is highly likely that improved equipment and better mining techniques will enable extraction of minerals at greater depth and under the sea."

Source: 2014-2020 Robotics 2020; Strategic Research Agenda for Robotics in Europe

Members of the euRobotics AISBL.



Current SPARC Topic Groups

- Aerial Robots
- Agricultural Robots
- **AI and Cognition in Robotics**
- **Autonomous Navigation**
- Benchmarking and Competitions
- Bio-Inspired Robots
- Civil Robots
- Education and Training
- Entrepreneurship
- Ethical-Legal-Socio-Economic Issues (ELS)
- Field/Service Robots in unstructured Environments
- Healthcare
- **Industrial Robotics**
- **Logistics and Transport**
- **Maintenance and Inspection**
- **Marine Robotics**
- **Mechatronics**
- Miniaturised Robots
- **Robotics in Mining**
- Natural Interaction with Social Robots
- People Transport
- **Perception**
- Physical Human Robot Interaction
- Robot Companions for Assisted Living
- Socially Intelligent Robotics and Societal Applications
- Software Engineering, System Integration, Systems Engineering
- **Space Robotics**
- Standardisation
- **Telerobotics and Teleoperation**
- Construction Robots

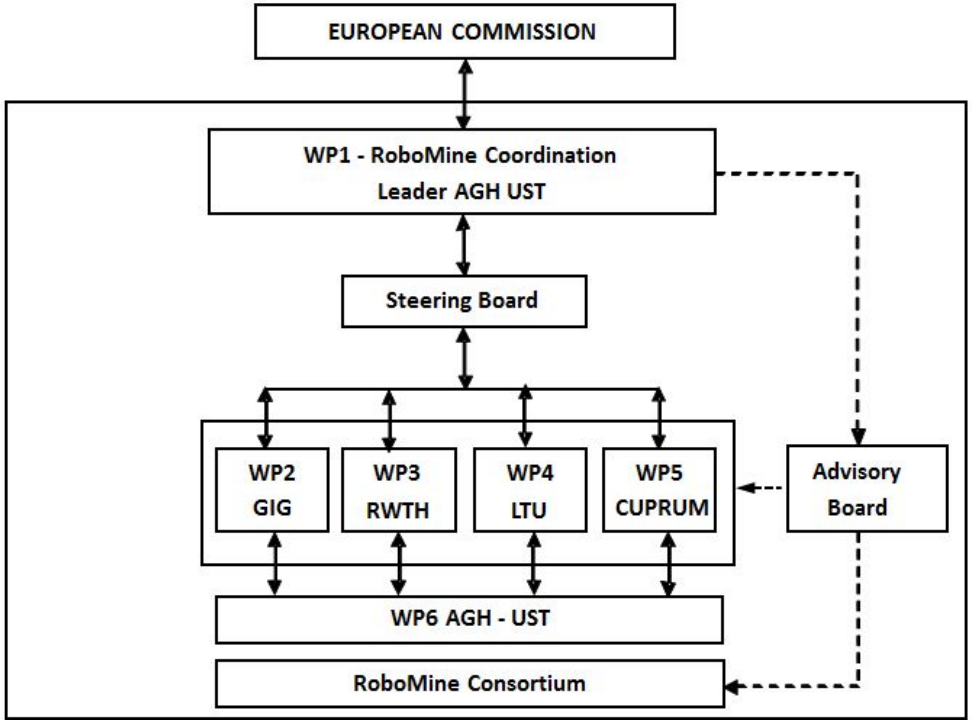
„Robotics in Mining” - „RoboMine” project.

application for funding in **H2020/ICT 24e CSA 2015.**

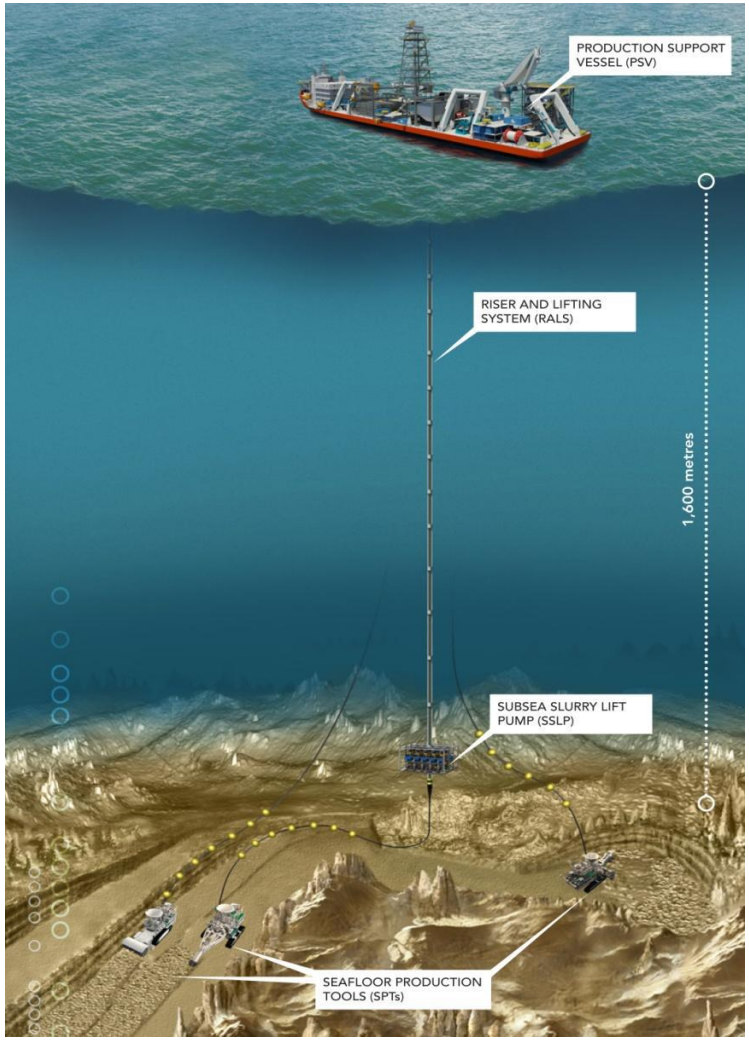
Scope of Work: list of WPs:

WP 1: Project management; **AGH Cracow; Poland**
WP 2: Robot Minable resources in the EU countries; **GIG Institute; Poland**
WP 3: Analysis and outreach to robotic technology, key performers; experts and state of the art of robotics in mining; **RWTH Aachen; Germany**
WP 4: Identification of Technological Gap and Overall Impact. Assessment of the feasibility and benefits when introducing robotics in mining; **LTU, Sweden**
WP 5: Actions and strategies for robotics in mining; **KGHM Cuprum, Poland**
WP 6: Dissemination and communication activities. **AGH Cracow; Poland**

Members of international consortium which is applying for EU fund in the H2020 ICT 24e CSA 2015 call: „Challenges for Robotics in Mining”: Poland (8 - including KGHM); Sweden (5 – including ABB, LKAB and Bolidən); Austria (1); Germany (1); Finland (1); Italy (1). Members of consortiumare: mining companies, mining machine producers; institutes of robotics, universities, SME.



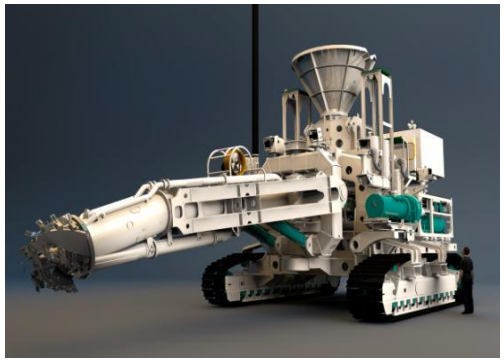
Seabed mining – an example of solution.



Ore transport on the surface

High technology, high quality products, less waste, low pollution of environment.

Production support vessel



Seafloor production machine.

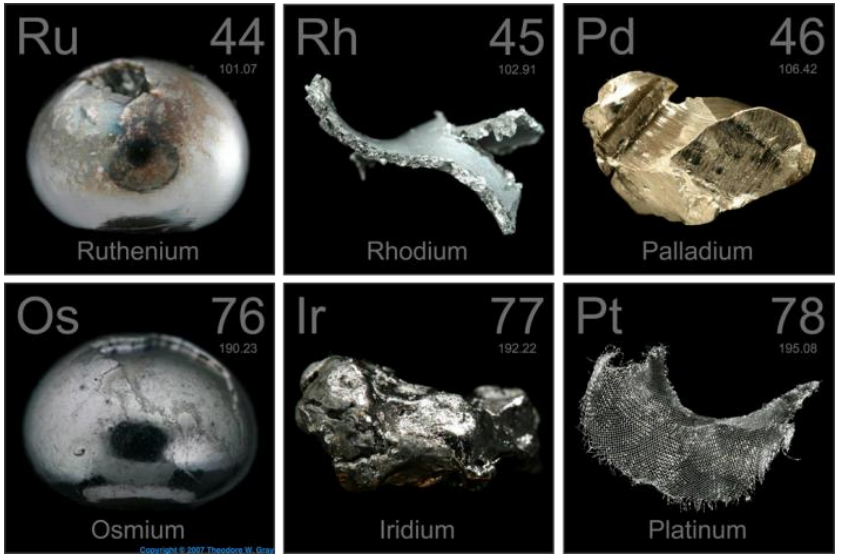
source: New Frontiers - Ocean Minerals Exploration and Development; Jonathan Lowe V.P. Strategic Development and Exploration; Brussels; 14 June, 2014

Metals are abundant in space

Prospecting and Exploration

Platinum group metals are some of the most rare and useful elements on Earth. They exist in such high concentrations on asteroids that a single 500-meter platinum-rich asteroid can contain more platinum group metals than have ever been mined in human history.

Asteroids contain more common metallic elements such as iron, nickel, and cobalt, sometimes in incredible quantities and often in their pure, non-oxidized metal form.



Source: http://www.planetaryresources.com/asteriods/#market-for-h20

Planetary subsurface exploration, space mining

Institutions

1.NASA (National Aeronatics and Astronautics Agency) – USA

2.ESA (European Space Agency).

3.In-situ Resource Utilization (ISRU).

4. National space agencies in many EU member states.

Three major directions of technology development

1.Surface construction
- Site characterization
- Earthwork and ground improvement
- Foundations and lateral support
- Building with regolith

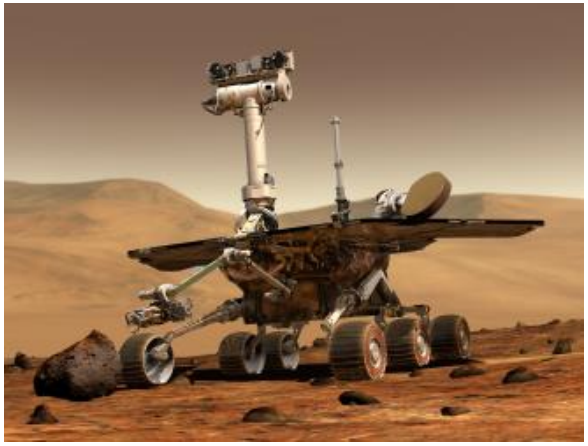
2.Surface and subsurface robots development
- Rovers, hoppers, locomotion problems
- Drills, penetrometers, „bigger” devices

3.Mining
- **Mineral Resource Classification**
- **Generic resource extraction**
- **Resource assessment**
- **Resource acquisition**
- **Resource beneficiation**
- **Mine site management**

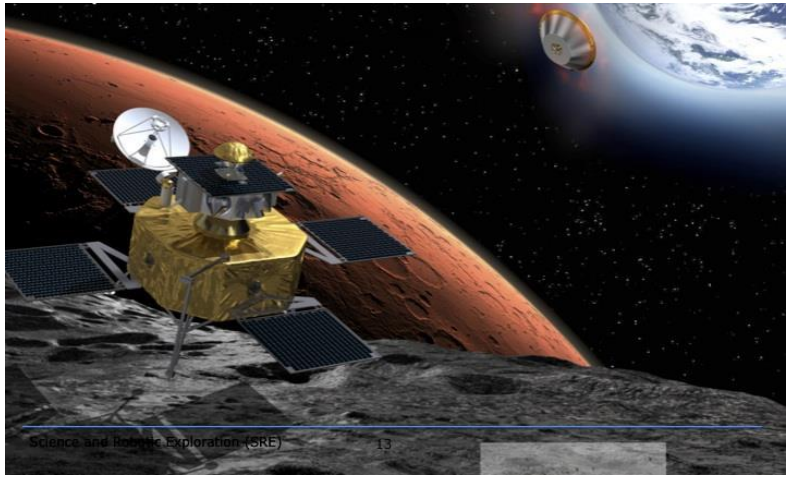
source: **Karol Seweryn, Centrum Badań Kosmicznych PAN 2015**

From Mars to Underground Robotics.

Mars Science Laboratory Mission's Curiosity Rover



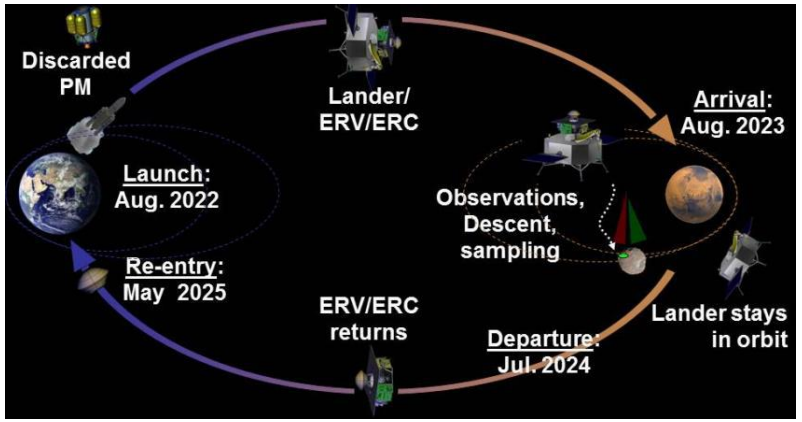
http://www.planetaryresources.com/news/



Future ESA mission - Mars

Three missions are considered in the frame of Mars Robotic Exploration Program (ESA):

1. Inspire – a network mission on Mars
2. Phootprint – mission to Phobos
3. Mars Precision Lander



source: **Karol Seweryn, Centrum Badań Kosmicznych PAN 2015**

Conclusions.

1.Automation and robotics may become a reality at a number of key underground mines and may bring many opportunities to improve safety and efficiency of mining operations both on the earth and space.

2.One of the biggest challenges the mining industry faces today is the ability to manage the complete the entire value chain as one operation.

3. **Solving the problems of deep underground metal mining can give Europe technological leadership in the resource-efficient production of raw materials.**

4. Robotics and automation in mining operations does not eliminate jobs, it shifts the nature of jobs.

Europe's first competition of Mars rovers was be held in Poland in September 2014.

Thank you.

Source: http://www.polska.pl/en/business-science/investments-projects/mars-challenge-poland/

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