ROBOMINERS

ROBOMINERS DELIVERABLE D 8.1

FIRST CLUSTER STATUS REPORT

Summary:

This report summarises the initial clustering activities within the ROBOMINERS project. As clustering is one of most important activities for boosting the project results to the implementation and market, projects with objectives similar or complementary to ROBOMINERS were selected to form clusters for information, experience and knowledge exchange and synergetic cooperation in order to add value and boost the projects' results. The document details the clustering strategy, the identification and selection of potential projects for clustering as well as the first steps made to identify projects' common challenges.

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TABLE OF CONTENTS

TABLES

FIGURES

LIST OF APPENDIXES

1 EXECUTIVE SUMMARY

Deliverable D8.1 - First cluster status report is the first out of three documents describing clustering activities within the ROBOMINERS project. Clustering of projects with a similar or complementary subject is regarded as one of the most important activities in bringing up synergetic use of knowledge and technology in order to add value and boost the projects results implementation closer to the market. Clustering strategy is not important only for the ROBOMINERS project, but, when properly developed, can contribute to the overall EU objectives on raw materials. Within Task T8.1 - Clustering, the ROBOMINERS project clustering strategy was developed to:

1. Identify projects potentially interesting (with similar or complementary objectives) for ROBOMINERS (ongoing, finished or in preparation within different EU programs and initiatives)
2. Range the selected projects by relevance to ROBOMINERS
3. Identify common challenges and themes of interest and synergies
4. Organise clustering events to strengthen and boost synergetic cooperation

In the first stage several projects from different EU programs and initiatives, like H2020 (field of raw materials and robotics), GeoERA, EIT Raw Materials, ERA MIN II and from national and industrial schemes were selected as potentially interesting for clustering with ROBOMINERS. Secondly, the topics of those projects were evaluated by importance for ROBOMINERS. Finally, 14 selected projects were directly contacted, to identify synergies and common challenges and best options for further cooperation and exchange of knowledge and experience.

Common challenges with clustering projects were identified in several focus fields, namely:

1. Ore deposits
2. Sustainable and environmentally sound mining industry
3. Mine equipment design and planning
4. Mineral processing
5. Artificial intelligence and digitalisation
6. Autonomy and autonomous devices
7. Communication system and sensors

The foreseen expected results of clustering activities are:

1. Facilitating coordination and exchange information between the different existing projects on related topics
2. Knowledge and approach exchange/transfer and increased awareness of actual challenges, including exchange results and open source software in the key areas of common interest and comparison of the used technologies
3. Networking with researchers and industry on common topics
4. Increased projects visibility
5. Forum for discussion, problem-solving and planning R&D activities and gaps in Europe
6. Acceleration of progress, by avoiding repetition of tasks
7. Technology development further into upscaling and industrialisation onsite
8. Future joint research projects.

2 INTRODUCTION

2.1. Project objectives

The main objective of the ROBOMINERS project is to develop a bio-inspired, modular, and reconfigurable robot-miner for small and difficult to access deposits. The aim is to create an amphibious robot that is capable of mining underground, underwater, in slurries or above water, and can be delivered in modules to the deposit via a large diameter borehole. Specific goals of the project are to construct a fully functional modular robot miner prototype following a bioinspired design, capable of operating, navigating and performing selective mining in a flooded underground environment, to design a mining ecosystem of expected future upstream/downstream raw materials processes via simulations, modelling and virtual prototyping, to validate all key functions of the robot-miner to a level of TRL-4, and further to use the prototypes to study and advance future research challenges concerning scalability, resilience, reconfigurability, self-repair, collective behaviour, operation in harsh environments, selective mining, production methods as well as for the necessary converging technologies on an overall mining ecosystem level.

The long-term strategic objective of the project is to enable EU access to mineral raw materials (including critical/strategic raw materials) from domestic resources. The horizontal objective of the project is to create an innovation ecosystem for mining with novel ideas from other sectors, in particular with the inclusion of disruptive concepts from robotics.

2.2. Clustering in ROBOMINERS

Within ROBOMINERS a particular task is dedicated to clustering activities. The objective of clustering is to liaise with similar projects in the field of raw materials, robotics, remote sensing and other relevant topics, to seek synergies and identify future opportunities. The aim of clustering within the ROBOMINERS project is also to exchange knowledge and know-how with similar and complementary projects, identify good practices and combine achievements in order to upgrade the efficiency of projects' results and products and also to shorten or speed up their way to the market.

Clustering of similar and complementary projects is of high importance for better and faster implementation of projects' results and acceleration of their products path towards the market. The project clustering concept builds on the idea that projects which share a common theme or address similar challenges form a cluster initiative and deliver shared strategic inputs. In order to support the EIP on Raw Materials actions on Innovative extraction of raw materials, ROBOMINERS envisages clustering activities with selected, highly relevant related projects in the field of raw materials as well as robotics, remote sensing and other relevant topics, to establish cross-projects co-operation, consultations and joint activities on cross-cutting issues and share of results as well as participating in joint meetings and communication events, prepared and modelled for identifying and implementing synergetic actions for boosting projects' results.

Since ROBOMINERS is a technically challenging project, its main benefit from clustering would be to explore potential technical and organisational solutions for challenges encountered within the project implementation, as well as to seek insight and novel breakthrough ideas in joint discussions with experts sharing similar interest and vision.

2.3. Scope and structure of clustering activities

Clustering activities in ROBOMINERS are performed within Task 8.1 (Clustering) in the framework of WP8 (Active roadmapping & clusters), aimed to mobilize internal and external expert knowledge via a series of dedicated activities that will concern both the Miner and the Mining Ecosystem and the corresponding 2030 and 2050 visions in a range of relevant technology domains (e.g. geophysical exploration methods, drilling technology, minerals processing, energy autonomy, etc.).

Clustering activities in ROBOMINERS are focused on projects with similar or complementary content, similar expected results or developing similar components as used in ROBOMINERS, mostly in the field of mining, raw materials, robotics, remote sensing but also on other similar thematics. Projects of ROBOMINERS' interest may be ongoing or already finished, implemented in the framework of different EU programmes or EU initiatives (Horizon 2020, Geo ERA, EIT Raw Materials, ERA MIN,…), as well as other projects on the national or industrial level.

The scope of clustering activities also includes the preparation of a clustering strategy, that could be implemented not only within the ROBOMINERS project but, when developed, could also serve for creating effective synergies and deliver strategic inputs contributing to the overall EU objectives on raw materials.

Beyond identification of the projects of interest, clustering activities encompass:

- active communication with potentially interesting projects (interviews, meetings online and in person)
- identification of projects' common challenges
- identification of projects' standard fields of work
- creation of clusters based on identified common challenges and fields of work
- identification and establishment of areas of possible cooperation in order to add value to the implementation of ROBOMINERS as well as similar or complementary projects results
- active exchange of knowledge at meetings (online and on-site), workshops and (web)conferences.

The aim of all planned activities is to raise awareness of the projects' subject and exchange of information on projects and projects' activities with the goal of finding synergies and standard solutions to boost the way to the projects' implementation and market.

Focus groups planned in Task 8.2 will upgrade the clustering activities by bringing together the relevant experts, also identified through clustering activities, and consortium members to reflect and advise regularly on specific topics of high interest to ROBOMINERS. Furthermore, the experts will also collaborate in activities of Task 8.3 – Horizon Scanning & Visions (e.g. Delphi Survey) and Task 9.5 – Roadmapping (e.g. roadmapping workshops).

3 CLUSTERING

The aim of the Clustering activity is to facilitate the exchange of information with projects that have developed or are developing relevant technologies for the ROBOMINERS ecosystem. In turn, this could considerably shorten the time to market for both technologies. The project clustering concept builds on the idea that projects which share a common theme or address similar challenges form a cluster initiative and deliver shared strategic outputs. This activity is, therefore, aimed at triggering involvement and endorsement of ROBOMINERS activities and results, seeking to enhance links and synergies with similar projects (both past, ongoing and future).

3.1. Methodology

The overall strategy for implementing the clustering activities is developed within the framework of Work Package 8 – Active roadmapping & clusters and runs throughout the whole project lifetime. The methodology was agreed among partners during our regular meetings and finalised during the Tallinn meeting in January 2020. In the first reporting period M1-M18 it consisted of two parts: relevant project identification, as described in chapter 3.2 (Figure 1a), establishing contacts with selected projects, as described in chapter 3.2 (Figure 1b) and the analysis of the outcomes, as described in chapter 3.3 (Figure 1c). In the next periods the consortium will continue with the three mentioned activities, but will also focus on follow-up activities, as described in chapter 3.4 (Figure 1c).

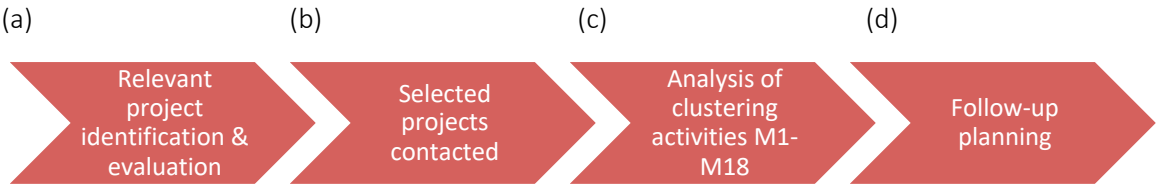

Figure 1. Schematic flow of clustering activities in ROBOMINERS in the period of M1-M18 and follow-up.

The first part consisted of the **search for potential projects** (finished or ongoing), **similar or complementary** to ROBOMINERS, which was performed through different platforms. A list of projects with potential to join the cluster was prepared for H2020 projects in the field of raw materials and robotics, for projects where funding instrument was dedicated to different aspects of raw materials (GeoERA, ERA MIN II and EIT RawMaterials projects) and other projects, funded mainly by industry, or individual companies from the field (Tables 1-6). We looked for appropriate projects via internet by screening different databases (mainly run by various funding bodies), and by screening relevant company and research institute profiles. This activity was mainly dome by desk research. Some of relevant projects and companies were also identified through our own professional networks, by asking colleagues and friends whether they are aware of some relevant ones.

The identified projects were listed and **evaluated** by partners **according to their importance** and potential synergetic effects to ROBOMINERS. The results of this activity are presented in Table 7, where potentially synergetic projects are evaluated regarding their importance for ROBOMINERS.

Table 1: H2020 – potentially synergetic projects in the field of raw materials

Name of the project	Short description of the project
CROCODILE - first of a kind commercial Compact system for the efficient Recovery Of CObalt Designed with novel Integrated LEading technologies	The CROCODILE project will showcase innovative metallurgical systems based on advanced pyro-, hydro-, bio-, iono- and electrometallurgy technologies for the recovery of cobalt and the production of cobalt metal and upstream products from a wide variety of secondary and primary European resources.
X-MINE - Real-Time Mineral X-Ray Analysis for Efficient and Sustainable Mining	The project will implement large-scale demonstrators of novel sensing technologies improving the efficiency and sustainability of mining operations based on X-Ray Fluorescence (XRF), X-Ray Transmission (XRT) technologies, 3D vision and their integration with mineral sorting equipment and mine planning software systems.
HiTech AlkCarb - New geomodels to explore deeper for High-Technology critical raw materials in Alkaline rocks and Carbonatites	This project will make a step-change in exploration models for alkaline and carbonatite provinces, using mineralogy, petrology, and geochemistry, and state-of-the-art interpretation of high-resolution geophysics and downhole measurement tools, to make robust predictions about mineral prospectivity at depth.
METGROW PLUS - Metal Recovery from Low Grade Ores and Wastes Plus	This project is developing new metallurgical technologies to unlock the use of potential raw materials in European regions. Since both primary and secondary materials are being evaluated as potential resources, this project can have a major impact in extracting important metals such as Ni, Cu, Zn, Co, In, Ga or Ge from low grade ores in a cost-effective way as well as from low grade polymetallic wastes and iron containing sludges that can't be currently targeted due to the lack of appropriate technology.
BioMOre - New Mining Concept for Extracting Metals from Deep Ore Deposits using Biotechnology	This project developed a new mining concept for in-situ stimulation and bioleaching for winning of ores. It aims at extracting metals from deep mineralised zones in Europe (> 1Km depth) by coupling solution mining and bioleaching, which will enable many regions throughout Europe to access the ores currently inaccessible in mines in an economical, sustainable and environmentally acceptable way.
FAME - Flexible and Mobile Economic Processing Technologies	FAME will contribute to the more efficient exploitation of European domestic mineral resources including previously undeveloped resources that have the potential to contribute to the securing of raw material supply by optimising the extraction and processing of ores that include raw materials critical to the economic development of the EU ("critical raw materials", CRM) and which occur in widespread deposits across the EU.
INFACT - Innovative, Non-invasive and Fully Acceptable Exploration Technologies	The project will develop innovative geophysical and remote sensing technologies (less-invasive than classical exploration methods) that promise to penetrate new depths, reach new sensitivities and resolve new parameters.

Name of the project	Short description of the project
SIMS - Sustainable Intelligent Mining Systems	SIMS aims to develop, test and demonstrate new innovative technologies within the designated consortium, consisting of well-developed mining operations, selected due to their maturity regarding innovative technologies, world-leading equipment and system suppliers, highly specialized SMEs and top-class universities. The consortium origins in the EIT Raw Materials partnership and has joined for this proposal due to the common challenges and needs.
Smart Exploration - Sustainable mineral resources by utilizing new Exploration technologies	The consortium will firstly focus on developing cost-effective, environmental-friendly tools and methods for geophysical exploration in highly challenging brownfield areas where exploration expenditure is greater and the return time (from exploration to production) shorter.
SLIM - Sustainable Low Impact Mining solution for exploitation of small mineral deposits based on advanced rock blasting and environmental technologies	SLIM aims to develop a cost-effective and sustainable selective low impact mining solution based on non-linear rock mass fragmentation.
ITERAMS - Integrated mineral technologies for more sustainable raw material supply	The aim of ITERAMS is to develop a proof of concept for more environmentally friendly and economical mine site operations, in Europe and globally.
PACIFIC - Passive seismic techniques for environmentally friendly and cost-efficient mineral exploration	The PACIFIC consortium will develop a new, low-cost and environmentally friendly tool for exploring for mineral deposits beneath the surface.
ROBUST - Robotic subsea exploration technologies	The ROBUST proposal aims to developing sea bed in situ material identification through the fusion of two technologies, namely laser-based in-situ element-analysing capability merged with underwater AUV (Autonomous Underwater Vehicle) technologies for sea bed 3D mapping.
UNEXMIN - Autonomous Underwater Explorer for Flooded Mines	UNEXMIN develops a multi-robotic platform for the exploration of flooded mines.
¡VAMOS! - ¡Viable and Alternative Mine Operating System!	¡VAMOS! will design and manufacture innovative automated excavation equipment and environmental impact monitoring tools.
BIORECOVER - Development of an innovative sustainable strategy for selective bio recovery of critical raw materials from Primary and Secondary sources	The objective of BIORECOVER is the R&D of a new sustainable & safe process, essentially based on biotechnology, for selective extraction of a range of Critical Raw Materials, from relevant unexploited secondary & primary sources.
SOLSA - Sonic Drilling coupled with Automated Mineralogy and chemistry On-Line-On-Mine-Real-Time	The objective is to “develop new or improved highly efficient and cost-effective, sustainable exploration technologies”.

Name of the project	Short description of the project
INTMET - Integrated innovative metallurgical system to benefit efficiently polymetallic, complex and low grade ores and concentrates	This project is developing a technology to overcome the limitations related to difficult low grade and complex ores, common in many mining regions, to achieving high efficient recovery of valuable metals (Cu, Zn, Pb, Ag) and CRM (Co, In, Sb). Innovative hydrometallurgical processes and novel more effective metals extraction techniques can maximise metal recovery from complex deposits and minimise energy consumption and environmental footprint.
Real-time Mining - Real-time optimization of extraction and the logistic process in highly complex geological and selective mining settings	The overall aim of Real-Time-Mining is to develop a real-time framework to decrease environmental impact and increase resource efficiency in the European raw material extraction industry.
NEXT - New Exploration Technologies	NEXT will develop new geomodels, novel sensitive exploration technologies and data analysis methods which together are fast, cost-effective, environmentally safe and socially accepted.
OptimOre - Increasing yield on Tungsten and Tantalum ore production by means of advanced and flexible control on crushing, milling and separation process	OptimOre focus on two important critical raw materials for many regions in Europe: tungsten and tantalum. The project develops modelling and control technologies, using advanced sensing and advanced industrial control by using artificial intelligence techniques, for the more efficient and flexible Tantalum and Tungsten ores processing from crushing to separation process.
ThermoDrill - Fast track innovative drilling system for deep geothermal challenges in Europe	The goal of the ThermoDrill project is to develop an innovative drilling system which will enable faster and cost-efficient drilling. The new system will be suitable for drilling hard and abrasive rock types, withstand the extreme temperature and pressure conditions involved in geothermal drilling and meet the most stringent standards in terms of health, safety and environmental protection.
CHPM2030 - Combined Heat, Power and Metal extraction from ultra-deep ore bodies	CHPM2030 is developing concepts for combined heat, power and metals extraction from ultra-deep orebodies using boreholes and nanotechnology.
GeoWell - Innovative materials and designs for long-life high-temperature geothermal wells	The objective of GeoWell is to develop reliable, cost effective and environmentally safe well completion and monitoring technologies.
TARANTULA - Recovery of Tungsten, Niobium and Tantalum occurring as by-products in mining and processing waste streams	TARANTULA will develop a suite of cost-effective, scalable and eco-friendly – bio-, hydro-, iono-, solvo-, pyro- and electro-metallurgical – processes with high selectivity and recovery rates.
FINEFUTURE - Innovative technologies and concepts for fine particle flotation: unlocking future fine-grained deposits and Critical Raw Materials resources for the EU	FineFuture project will advance the fundamental understanding of fine particle flotation phenomena, which will lead to the development of ground-breaking technological solutions. This will not only help unlock new CRM deposits but also contribute to increasing the resource and energy efficiency of current operations where the fines are lost to tailings.

Name of the project	Short description of the project
MINERAL EYE - Real-time on-line mineralogical analysis for the process optimization and more sustainable mining	The project is on a more detailed feasibility study, development activities, demonstration, piloting, commercialisation and product launch for the robust, real time mineralogical analysis device based on Timegated® Raman technology.
AlSiCal - Towards sustainable mineral and metal industry: ZERO Bauxite Residue and ZERO CO2 from co-production of Alumina, Silica and precipitated Calcium carbonate by the Aranda-Mastin technology	AlSiCal will de-risk and develop from TRL 3 to TRL 5 the Aranda-Mastin technology under sustainability and efficiency principles. It will assess and quantify the techno-economic feasibility, the potential value creation for Europe, as well as the impact and risks of this technology upon three key sustainability pillars: economy, society and environment. AlSiCal will also set a roadmap for the exploitation of project results, to foster the later commercialisation of the technology. Targeted dissemination and communication actions will contribute to increasing social and industrial engagement for developing innovative sustainable technologies for mineral processing. AlSiCal will be performed by a balanced team of R&D and industrial partners representing the whole value chain.
ION4RAW - A new cost-efficient mineral processing technology to recover by-products from primary sources	The main objective of Ion4Raw project is to develop a novel and sustainable ionometallurgical process to resource- and cost-effectively recovery of mainly by-products from primary sources (and the main metal in the ore), i.e. ores and concentrates following a complete value chain. Others include: Encourage and support by-product recovery by conducting a comprehensive by-product potential identification and assessment; Maximise upstream recovery of by-products from primary sources for ionometallurgical processing and minimise the downstream environmental impact; Cost-efficiently recover by-products from primary sources through ionometallurgical route; Design and optimise the overall process from a holistic point of view following a Multidisciplinary Design Optimisation (MDO) approach; Provide proof of process sustainability from economic, technical and environmental point of view, as well as to promote the exploitation of the project's results.
Dig_IT - A human-centred Internet of Things platform for the sustainable digital mine of the future	Dig_IT project aims to develop a human-centred IIoT platform [O1] connecting the mining ecosystem of assets, environment, and humans [O2-4] to increase mining efficiency: saving costs using optimised scheduling [O8], increasing uptime using predictive operation and maintenance [O7], identifying new revenue opportunities using advanced geological interpretation on exploration mining phase [O6a]. To address industry needs of minimising accidents [O4,9,10], optimising production processes and reducing costs, [O6-8,10] intelligent systems will provide real-time insights [O6d, 7-10] for the enterprise at all operational levels.

Table 2: H2020 – potentially synergetic projects in the field of robotics

Name of the project	Short description of the project
AutoFlyMap - AUTOnomous FLYing Robots in GNSS denied environments for 3D Underground infrastructure MAPping and inspection.	Autonomous flying robots for underground inspection of operations. Comprehensive inspections of channels, conduits and other closed environments (e.g. in mining, hydropower, construction sectors) are carried out by special skilled persons (normally climbers) trained to work in vertical surfaces (angles vary from 30º to 90º, which means totally vertical). This method entails risks for humans and a wide variety of operational issues. Due to safety factors, besides the inspection team, extra people are needed to be ready during inspections to rescue people working in the event of problems. Hovering Solution's flying platform can fly autonomously in GNSS-denied environments and allows to scan indoor scenarios in a fraction of time and to produce richly detailed 3D models, including survey grade geo-referenced point clouds and high definition texture layers. This way, Autoflymap can replace the comprehensive visual inspection by using the autonomous drone for carrying out the mapping of the internal part of the tunnels.
MAGNIFY - From nano to macro: a ground-breaking actuation technology for robotic systems	Development of artificial muscles for robotic systems. MAGNIFY aims to develop a new generation of artificial muscles for robotic systems. The artificial muscle will be realized by using artificial molecular machines, organized in polymer nanofibers and individually controlled by external stimuli. By learning from Nature, MAGNIFY relies on a bottom-up methodology, in which the nano-scale movement of molecular machines will be incrementally amplified to the macro-scale in the artificial muscle. The MAGNIFY artificial muscles will be characterized by: high force-to-weight ratio, high flexibility, fast reactivity and intrinsic variable stiffness.
ERGO - European Robotic goal-oriented autonomous COntroller (ERGO)	The specific objective of ERGO is to deliver the most advanced but flexible space autonomous framework/system suitable for single and/or collaborative space robotic means/missions (orbital and surface rovers) demanding robust operations with adaptable levels of autonomy. Due to the intrinsic similarities of addressed scenarios, especially for what concerns surface applications, ERGO has to be/and has been thought so to be applicable to terrestrial and underground robotic applications requiring a high level of autonomy.
RAWFIE - Road-, Air- and Water-based Future Internet Experimentation	The purpose of the RAWFIE initiative is to create a federation of different network testbeds that will work together to make their resources available under a common framework. Specifically, it aims at delivering a unique, mixed experimentation environment across the space and technology dimensions.
ReconCycle - Self-reconfiguration of a robotic workcell for the recycling of electronic waste	Currently, industrial robots perform rigidly programmed tasks in highly constrained settings. Any change in product or process requires costly restructuring of hardware and software. ReconCycle will address these issues by introducing the concept of robotic self-reconfiguration in the largely unconstrained domain of electronic waste recycling, which is still dominated by manual labour.

Name of the project	Short description of the project
ORIENT- Goal-directed eye-head coordination in dynamic multisensory environments	Rapid object identification is crucial for the survival of all organisms, but poses daunting challenges if many stimuli compete for attention, and multiple sensory and motor systems are involved in the processing, programming and generating of an eye-head gaze-orienting response to a selected goal. How do normal and sensory-impaired brains decide which signals to integrate ("goal"), or suppress ("distracter")?
ROBUST - Robotic subsea exploration technologies	There is a need to develop an autonomous, reliable, cost-effective technology to map vast terrains, in terms of mineral and raw material contents which will aid in reducing the cost of mineral exploration, currently performed by ROVs and dedicated SSVs and crew. Furthermore, there is a need to identify, in an efficient and non-intrusive manner (minimum impact to the environment), the richest mineral sites.
BIOMODULAR - A Biomimetic Learning Control Scheme for control of Modular Robots	Motor control is an essential feature in the human brain for the performance of a motor skill. The biological basis of this feature can be better understood by emulating the cerebellar mechanisms of learning. The cerebellum plays a key role in implementing fine motor control since it extracts the information from sensory-motor signals and uses it to respond to the environment. The purpose of this project is to benefit from the interplay between a body agent and an embodied artificial brain to understand the role of the first in the behaviour of the latter and vice versa.
LeMo - Learning Mobility for Real Legged Robots	Research and applications in legged robotics have made significant progress over the last decade, driven by more advanced actuation systems, better onboard computation, and significantly improved sensors for perceiving the environment. State-of-the-art model-based planning and control algorithms can plan for contact points and body motions to move legged systems over complex environments. However, these methods have shown clear performance limits when it comes to behaviours and situations that are more complex, and it is unclear if and how these limits can be overcome with classical control methods. On the other hand, recent advances in reinforcement learning have put forward unprecedented capabilities to learn control policies for complex behaviours.
RODEO - Robotized Orbital Drilling Equipment and Optimized residual stresses	The main objective of the RODEO project is to propose a lightweight robotized orbital drilling equipment, and associated operating conditions and tools, to enable the drilling of tightly spaced small diameter holes in aluminium with the control of induced residual stresses.

Name of the project	Short description of the project
Co4Robots - Achieving Complex Collaborative Missions via Decentralized Control and Coordination of Interacting Robots	Imagine a scenario where multiple robots have been deployed to provide services such as object handling/transportation, or pickup and delivery operations. In such a context, different robots with varying capabilities must be coordinated in order to achieve various multi-tasking procedures. Thus, the effective supervision and coordination of the overall heterogeneous system mandates a decentralized framework that integrates high-level task-planning, low-level motion control and robust, real-time sensing of the robots' dynamic environment.
STEP2DYNA - Spatial-temporal information processing for collision detection in dynamic environments	STEP2DYNA consortium proposes an innovative bio-inspired solution for collision detection in dynamic environments. It takes the advantages of low-cost spatial-temporal and parallel computing capacity of visual neural systems and realises it in chip specifically for collision detection in dynamic environments. Realising visual neural systems in chips demands multidisciplinary expertise in biological system modelling, computer vision, chip design and robotics.
SWARMs - Smart and Networking UnderWAter Robots in Cooperation Meshes	The major part of offshore repair/installation operations is done by divers in dangerous missions. The extended use of unmanned underwater vehicles (AUVs/ROVs) could solve this problem but since they are usually tailor-made for a specific task and difficult to operate their deployment is very expensive. The overall goal of the SWARMs project is to expand the use of AUVs/ROVs and facilitate the creation, planning and execution of maritime and offshore operations. Enabling AUVs/ROVs to work in a cooperative mesh thus opening up new applications and ensuring re-usability as no specialized vehicles are needed but heterogeneous standard vehicles can combine their capabilities, increasing the autonomy of AUVs and improving the usability of ROVs.
DEEPFIELD - Deep Learning in Field Robotics: from conceptualization towards implementation	Robots are active agents that need to interact with the physical world. To do so, robots are equipped with different sensors, whose data is used to build models that ultimately will allow robots to plan actions and make decisions. Currently, there is a strong focus in developing deep learning strategies "data-driven" to help solve this perception problem, even though these approaches work well in dataset and benchmark scenarios. There are still strong limitations in the use of these techniques in real-world robot activities, especially due to the strong dynamics in robots operational environment, that is pushing the development of new tools and methods to make these approaches feasible in the real world.
NatDyReL - Utilizing Natural Dynamics for Reliable Legged Locomotion	NatDyReL project aims at a fundamental shift in the design and control of humanoid robots, towards a new generation of intrinsically compliant robots that can adjust their open-loop actuator impedance in real-time to the task. This project follows two scientific tracks for achieving (a) energetically efficient and high performant legged locomotion and (b) robust and dynamic contact transitions and in-contact motions for whole-body locomotion in uncertain and confined spaces.

Name of the project	Short description of the project
DeeViSe - Deep Learning for Dynamic 3D Visual Scene Understanding	Deep neural networks (DNNs) can realize their full potential when applied in an end-to-end manner, i.e., when every stage of the processing pipeline is differentiable with respect to the network's parameters, such that all of those parameters can be optimized together. Such end-to-end learning solutions are still rare for computer vision problems, in particular for dynamic visual scene understanding tasks. Feedback processes, temporal information processing, and memory mechanisms form an important part of our human scene understanding capabilities. Those mechanisms are currently underexplored in computer vision. The goal of this proposal is to remove this bottleneck and to design end-to-end deep learning approaches that can realize the full potential of DNNs for dynamic visual scene understanding.
MicroSpot - The first portable, low-cost, robotized scanner microscope that converts any smartphone into a high quality and intelligent tele-microscopy image diagnosis system	MicroSpot is the first portable, low-cost, robotised scanner microscope that converts any smartphone into a high quality and intelligent microscopic image diagnostic system. MicroSpot is connected to a cloud ecosystem, capable of real-time streaming and remote control and an artificial intelligence assistant for image analysis. MicroSpot aims to replace the actual obsolete equipment and processes used in microscopic medical image diagnosis while revolutionising current manufacturing methods. MicroSpot democratises the access to clinical image diagnosis by creating a new generation of medical devices that reduces time, costs and distances, bringing microscopic image diagnostics closer to the point of care.
INSPEX - Integrated Smart Spatial Exploration System	The objective of INSPEX is to make obstacle detection capabilities that are currently only feasible on autonomous vehicles available as a personal portable/wearable multi-sensor, miniaturised, low power spatial exploration system. The INSPEX System will be used for real-time 3D detection, location and warning of obstacles under all environmental conditions in indoor and outdoor environments with static and mobile obstacles. Applications include navigation for the visually/mobility impaired, safer human navigation in reduced visibility conditions and small robot/drone obstacle avoidance.
BADGER - RoBot for Autonomous unDerGround trenchless opERations, mapping and navigation	The goal of the proposed project is the design and development of the BADGER autonomous underground robotic system that can drill, manoeuvre, localise, map and navigate in the underground space, and which will be equipped with tools for constructing horizontal and vertical networks of stable bores and pipelines. The proposed robotic system will enable the execution of tasks that cut across different application domains of high societal and economic impact including trenchless constructions, cabling and pipe installations, geotechnical investigations, large-scale irrigation installations, search and rescue operations, remote science and exploration, and defence applications.

Name of the project	Short description of the project
ADIR - Next generation urban mining - Automated disassembly, separation and recovery of valuable materials from electronic equipment	The goal of ADIR is to demonstrate the feasibility of a key technology for next-generation urban mining. An automated disassembly of electronic equipment will be worked out to separate and recover valuable materials. The concept is based on image processing, robotic handling, pulsed power technology, 3D laser measurement, real-time laser material identification (to detect materials), laser processing (to access components, to unsolder these selectively ; to cut off parts of a printed circuit board), and automatic separation into different sorting fractions. A demonstrator will be developed and evaluated in field tests at a recycling company. The obtained sorting fractions will be studied with respect to their further processing and recovery potential for raw materials. Refining companies will define requirements and test the processing of sorting fractions with specific material enrichments.
SmokeBot - Mobile Robots with Novel Environmental Sensors for Inspection of Disaster Sites with Low Visibility	SmokeBot is driven by the application needs for robots that operate in domains with restricted visibility. The focus is on civil robots supporting fire brigades in search and rescue missions, e.g. in post-disaster management operations in response to tunnel fires.

Table 3: GeoERA potentially synergetic projects

Name of the project	Short description of the project
EuroLithos - European Ornamental Stone Resources	EuroLithos is founded on the idea that increased knowledge of the geology, quality and history of use of natural stone in Europe will stimulate both more sustainable use of stone resources in Europe for the benefit of SME's and our cultural heritage. EuroLithos will result in an ornamental stone knowledge base under the umbrella of EGDI, covering harmonised spatial data on European stone resources, an atlas of resources and use, a directory of ornamental stone properties and guidelines for valorising ornamental stone heritage.
FRAME - Forecasting and Assessing Europe's Strategic Raw Materials needs	FRAME is designed to research the critical and strategic raw materials in Europe. It will still be necessary to extract them from primary mineral deposits, focusing on applying new technologies for deep exploration and mining, turning low-grade ores to exploitable resources.
MINDeSEA - Seabed Mineral Deposits in European Seas: Metallogeny and Geological Potential for Strategic and Critical Raw Materials	This project addresses an integrative metallogenetic study of principal types of seabed mineral resources (hydrothermal sulfides, ferromanganese crusts, phosphorites, marine placers and polymetallic nodules) in the European Seas. The MINDeSEA working group has both knowledge of and expertise in such types of mineralisation, providing exploration results, sample repositories and databases to produce innovative contributions. The importance of submarine mineralisation systems is related to the abundance and exploitation-potential of many strategic metals and Critical Raw Materials (CRM), necessary for modern society development.
Mintell4EU - Mineral Intelligence for Europe	The overall aim of this proposal is to improve the European Knowledge Base on raw materials by updating the electronic Minerals Yearbook produced in the Minerals4EU project and to extend the spatial coverage and quality of data currently in the Minerals Inventory. The project will, furthermore, aim to increase the degree of harmonisation, communication, and interaction between existing data platforms.

Table 4: ERA MIN II potentially synergetic projects

Name of the project	Short description of the project
IMPaCT - Integrated Modular Plant and Containerised Tools for Selective, Low-impact Mining of Small High-grade Deposits	IMPaCT is developing a new mining paradigm to improve the viability of many critical metals and other small complex deposits, improving conditions for technological innovations in mining equipment design and mine planning. Mining and processing technologies can be adapted to multiple deposits and commodities and thus, have a large impact on mining, exploration and exploitation scheme at European and regional level
HITEM - Highly sensitive receiver for measuring transient electromagnetic responses in Exploration for deep buried mineral occurrences	The development of a new tool for the electromagnetic (EM) exploration of primary resources. Amongst the variety of EM methods in geophysics, the time-domain method TEM is used to generate a 3D illustration of the sub-surface electrical conductance especially for geological structures which provide a continuous conducting layer. The task in this project is to develop a new extremely high sensitive receiver based on high transition temperature superconducting quantum interference devices (HTS SQUID)
COGITO-MIN - COst-effective Geophysical Imaging Techniques for supporting Ongoing MINeral exploration in Europe	This research initiative joins the forces of research institutions and industry and aims at comprehensive methodological advances in the use of seismic imaging for mineral exploration in Europe and beyond. We also acknowledge the need for well-integrated geophysical and geological approaches and aim at developing joint analyses of different data. The overall goal is to develop integrated geophysical-geological approaches for building realistic 3D geological models, delineation of known deposits and identifying new reliable drilling targets, with further impact on reducing the cost of drilling, and as such fitting the objectives of the ERA-MIN network.
REMinE - Improve Resource Efficiency and Minimize Environmental Footprint	The project vision is to “clean up” historical mine sites by extracting critical metals and separating minerals, thereby minimizing the amount of harmful mine waste.
BIOCriticalMetals - Recognition of microbial functional communities and assessment of the mineralizing potential (bioleaching) for high-tech critical metals	Innovative methods and processes for extracting even faint traces of these elements are the focus of the project. New characterized microorganisms with potential to be applied in biosolubilization, biomineralization and bioaccumulation will be obtained. The consortium will assess the microbial biodiversity in tailings where potentially critical high-tech metals may exist (In, Ga, Te and W) but also relevant pollutants (As, Sb), located in different geological and climatic settings. Isolates will be tested in macrocosm conditions in the last part of the project.
BATRE-ARES - Battery Recycling – Achieving Rare Earth Separation	The latter will start with the treatment of real battery residues (brought by the industrial stakeholder) and will end up by the recovery of pure REE. The main originality of this project lies in the fact that hydrometallurgical processes will be based on alternative solvents, namely ionic liquids, yielding a potential process in line with the principles of sustainable chemistry that will go beyond the state of the art of REE recycling.

Name of the project	Short description of the project
CHARPHITE - Coal char as a substituting material of natural graphite in green energy technologies	Selection and characterisation of fresh and landfilled coal ash identified as suitable secondary raw material to be used for graphite supply and natural graphite substitution. Optimisation of the recovery methods and technologies to maximise the CHAR recovery, and to increase the CHAR quality in relation to its utilisation. Optimisation of the iron-rich morphotype recovery methods and technologies to maximise their recovery at high purity levels, to increase "a priori" the quality of these iron concentrates in relation to its utilisation as metallic oxides to be incorporated in graphite in electro-assisted reactions.
AMTEG - Advanced Magnetic full TEnsor Gradiometer instrument	To meet future needs of exploration technologies, we aim to develop a new airborne magnetic exploration tool using a hybrid SQUID (Superconducting Quantum Interference Devices) based full tensor magnetic gradiometer and vector magnetometer as well as an ancillary optically pumped magnetometer (OPM) for absolute measurements which goes beyond current technology limits in sensitivity and dynamic range e.g. 24bit of signal digitisers.
Gold_Insight - Tracing Gold-Copper-Zinc with advanced microanalysis	The innovative new techniques will arise from a novel combination of state-of-the-art micro-chemical analysis: trace element mapping and in situ Pb and S isotope analysis as well as trace-element informed geochronology. The technology readiness level of these techniques will be elevated by increasing the speed and throughput of analysis. The tools will be tuned on known orogenic gold (Au) deposits for which full 3D geological and structural models will be developed and integrated with absolute geochronology.
LIGHTS - Lightweight Integrated Ground and Airborne Hyperspectral Topological Solution	As a result of technological advances, the use of hyperspectral cameras with drones is now possible to map the mineralogy of rocks. This recent tool introduces new possibilities to easily map future exploitable mineral resources and possibly enhance associated resources and reserves. For this end, we are introducing the Lightweight Integrated Ground and Airborne Hyperspectral Topological Solution (LIGHTS) that comprises cutting edge drone, camera and software technology.
REWO-SORT - Reduction of Energy and Water consumption of mining Operations by fusion of sorting technologies LIBS and ME-XRT	This project classifies mineral particles on a conveyor belt by combining LIBS and ME-XRT by using deep learning technology. The combination of laser-induced breakdown spectroscopy (LIBS) and multi energy X-ray transmission (ME-XRT) is very promising, as it combines complementary features of the scanned material: LIBS can provide elemental analysis but is limited the surface and ME-XRT offers volumetric data but is limited in terms of elemental accuracy as it provides integral elemental information. By combining both technologies, surface measurement data can be extrapolated to the entire sample and therefore create representative data per specimen.
MONAMIX - New concepts for efficient extraction of mixed rare earths oxides from monazite concentrates and their potential use as dopant in high temperature	The objective of MONAMIX project is to demonstrate the potential use of mixed REOs with naturally occurring composition, obtained from monazite concentrates, as dopant in the design of high-temperature zirconia coatings and sintered materials. The naturally mixed REOs doped zirconia thermal barrier coatings (TBC) will be designed to increase the lifetime of Ni/Cr alloys or reduce the critical raw materials (CRMs) content in substrate alloys. A hydro-chemical

Name of the project	Short description of the project
coatings and sintered materials	method for monazite concentrates purification by selective leaching and their usage for hydrothermal synthesis of mixed nanostructured zirconia doped with different REO/ZrO2 molar ratios by a cost-efficient process will be developed.
DEASPHOR - Design of a product for SUBSTITUTION of phosphate rocks	The project DEASPHOR aims P-recycling from poultry litter ash since the direct utilisation of poultry litter has eight times more P than plants need. However, further P-concentration is needed to make poultry litter capable of substituting phosphate rocks.
Li+Water - Membrane electrolysis for resource-efficient lithium and water recovery from brines	With the Li+WATER project we propose a radically new, electrochemical process. We will in three stages, driven by renewable electricity and without the input of chemicals, harvest not just the lithium but also other products present in the brines such as magnesium hydroxide, as well as recover the water. The latter is very important, particularly in South America where most brines are found in water-depleted regions.
FLOW - Lightweight alkali activated composite foams based on secondary raw materials	The main objective of this project is to develop new lightweight alkali-activated foams based on secondary raw materials (e.g. fly ash, slags). To obtain highly porous structures, properly selected foaming agents and foam stabilising agents need to be included in the basic compositions.
MINTECO - Integrated eco-technology for a selective recovery of base and precious metals in Cu and Pb mining by-products	MINTECO project aims to develop an integrated innovative, efficient and ecological technology for the recovery of base (Cu, Pb, Zn) and precious (Au, Ag) metals from copper and lead-bearing mining waste. The project will allow establishing a global management methodology to treat historical mining sites and reduce disposed volumes of metal-bearing waste. Lab scale experiments (TRL< 4), on well-known representative samples, will first allow establishing optimised protocols to concentrate the metals in smaller fractions and recover them by innovative mineral processing and hydrometallurgy techniques.
MaXycle - Circular economy, magnet recycling, NdFeB magnets, end-of-life magnets, Eco-labelling	The objective of MaXycle is to create a much more environmentally friendly 'short cycle' re-processing route achieved by: a) the development of an eco-labelling system for newly produced RE permanent, b) using the highly effective HPMS process by re-processing the extracted materials directly from the NdFeB alloy, c) better treatments to eliminate pre-processing residue, d) upgrading the magnetic properties of EOL NdFeB magnets by tailoring the microstructure and phase composition and e) elaborating the industrial up-scalability, including a thorough life cycle assessment.
BASH-TREAT - Optimization of bottom ash treatment for an improved recovery of valuable fractions	BASH-TREAT objectives are: 1) a complete assessment of EU state-of-the-art bottom ash treatment options considering technical/economic/environmental viewpoint; 2) an optimisation of the exploitation of the refining treatment of the fine fraction deriving from full-scale trial tests; 3) the development of EU guidelines for the enhanced and innovative full valorisation of valuable components of bottom ash (metals and mineral fraction).

Name of the project	Short description of the project
MetRecycle - Recycling of metals using functionalized magnetic nanoparticles	The MetRecycle project contributes to the Strategic Implementation Plan of the European Innovation partnership on the recycling of raw materials, dealing with the novel strategic approach using advanced nanotechnology to achieve selective, efficient recycling process of REE's, with the focus on the Heavy (HREE) REE's. REEs are key components of green energy and high-tech growth industries and they are imported into the European Union (EU) from a very limited number of producers.
BIOMIMIC - Innovative biotechnological methods for effective mining of secondary mineral	The project will explore naturally occurring bioprocesses, namely biosulfide precipitation and biosorption. It will employ beyond state-of-the-art innovations in microorganism mixtures and reactor design which is expected to increase the rate of these typically slow biotechnological methods.
INSTAnT - Innovative sensor technology for optimized material recovery from bottom ash treatment	The objective of the INSTAnT project is to close the material cycle of resources/materials present in bottom ashes by using smart recycling technologies to 1) optimise process conditions in bottom ash treatment plants to maximise metal recovery; 2) separate out a valuable pure glass fraction, and 3) detect and remove impurities that hamper the high-grade recycling of the mineral fraction. INSTAnT will develop innovative sensor-based characterisation technology allowing for fast, non-destructive, reliable material description to create data-driven decision tools for bottom ash treatment plant optimisation and enhanced resource recovery (metals and minerals).
RecEOL - Recycling of End-of-Life Products (PCB, ASR, LCD)	The objective and expected outcome of the RecEOL project is to demonstrate (1) the capability of the process to recycle metals including critical (indium) and special (tantalum), (2) that the metal recycling yields are significantly improved over current processes, (3) that the process is economical and environmentally sustainable. RecEOL is applied research. The aim is to show on the pilot plant scale that the scaled-up commercial plant is feasible.
SUPERMET - Recovery of Precious Metals from Spent Catalysts by Supercritical CO2 Extraction Assisted by Polymers	SUPERMET project proposes to explore a disruptive eco-friendly technology for the recycling of precious metals, especially palladium (Pd) and platinum (Pt), from spent catalysts, e.g. from petrochemistry catalysts, by extraction in supercritical CO2 (scCO2) thanks to complexing polymers bringing the insoluble precious metals into the scCO2 medium.
MIWACUT - Investigating the microwave assisted cutting of carbonate rocks	In order to make the excavation of hard rocks possible by mechanical excavators except for tunnel boring machines (TBM) or to increase cutting rate and decrease wear rate while cutting very hard rocks, recently, the research on some innovative methods such as microwave-assisted (MWA) rock cutting have been drawing attention. However, there is no currently MWA cutting machine used in the laboratory or the field. In this study, the cuttability of carbonate rocks by an integrated MWA linear cutting machine will be investigated. Carbonate rocks are excavated by drilling and blasting that is a challenging method compared to the mechanical excavation. However, the mechanical excavation of carbonate rocks is generally impossible or inefficient. The objective of this proposal is to reveal the cuttability of carbonate rocks by MWA-continuous miners (CMs).

Name of the project	Short description of the project
AUREOLE - tArgeting eU cRitical mEtals (Sb, W) and predictability of Sb-As-Hg envirOnmentaL issuEs	Antimony (Sb), a critical metal for Europe strategic for the European (EU) aircraft industry & battery manufacturing plants, is widely used in industrial operations. Its most promising use may be for rechargeable Li- & Na-ion batteries. The project is based on disruptive concepts: i) new 3D large-scale metallogenic model integrating deep-seated processes to determine the spatial distribution of ore deposits; ii) the use of mineral prospectivity data weighted by surface data to determine the probability of environmental risk over large areas. Despite a high EU potential, the knowledge on Sb remains poorly constrained. EU remains under the threat of the Chinese supply. In parallel, metalloids (Sb, As, Hg) of geogenic origin are recognised as a global threat for human health. Then, large-scale identification of these areas should be a priority. In this 3 year project, it will produce i) a new 3D metallogenic model that will contribute to the understanding of the mineralising processes; ii) a new understanding of surface processes that control the mobilisation & transport of metalloids; iii) a new large-scale mineral prospectivity and iv) a new large-scale environmental risk assessment by weighting mineral prospectivity with earth surface properties.
MINECO - New Eco-innovative Materials for Mining Infra	The aim of the MINECO project is to develop new eco-innovative product solutions for mining infrastructures based on waste materials resulting from the mining operation, thus contributing to sustainable development. Vast amounts of mining-related materials, such as tailings and waste rock, are left behind when the mine is finally closed, thus requiring sustainable treatments which, ideally, should include very high recycling rates. Sulfidic mining waste, being generated from the production of base metals (Cu, Pb, and Zn), represents the largest volume of extractive waste in Europe (ca. 600 Mtn/yr), causing a potential severe Acid Mine Drainage (AMD) hazard.
Sb-RECMEMTEC - Electro-electrodialysis technology on the copper minerals processing industry to the recovery of antimony from mining tailings and recycling the solution media	No details available yet The main objective of Sb-RECMEMTEC project is the recovery of antimony (Sb), a Critical Raw Material, from wastes and effluents generated during the pyro- and hydrometallurgical processing of copper (Cu) using membrane separation processes (MSP): electrodialysis (ED) and electro-electrodialysis (EED). While Sb is of fundamental importance to newly developed technologies, it is generally obtained as a by-product of other metallic ores. Therefore, the current and future supply of Sb depends not only on Sb production, but also on the efficient recovery of other primary ores. Sb-RECMEMTEC will address the challenging subject of applying MSP in the processing of Cu-low-grade mining tailings and of Cu-sulphide minerals, not only to concentrate/purify the electrolytes, but also to recover Sb and acid solutions. ED/EED processes will be studied, using the circular economy approach, to the primary Cu-production, avoiding Sb losses and minimising the generation of effluents.
MiCCuR - Microbial Consortia for enhanced Copper Recovery	Biomining is the biotechnological process for metal extraction from sulphidic ores. This process exploits the ability of acidophilic microorganisms to catalyse chemical oxidation of insoluble metal sulphides to acid soluble sulphates. Bioleaching of copper minerals is usually performed in engineered heaps and this technology accounts for approximately 15-20% of the worldwide copper production.

Name of the project	Short description of the project
	Presently there is an increase in the European demand for metals. The consortium will cover the process in terms of innovation and research and will comprehensively study engineering, chemical, microbiological, molecular biological and 'omics' methods. This project contributes to the RMI and EIP strategies on raw materials through the enhanced resource efficiency achieved for both copper resources in Europe and those globally with potential to supply Europe. In achieving this, the project addresses the circular economy as well as the implementation of low carbon process options for copper recovery. By incorporating a German company and having two associated companies, the knowledge of these stakeholders will contribute to the progress in the project. In turn, this also results in new insights having a substantially greater probability of being applied in the mining sector.
RedOxRec - Reduction/ Oxidation Recycling	Our vision is to enable a more distributed recycling chain, where Small-Medium Enterprises (SME), individual production plants and municipalities become the main stakeholders of the recycling process chain. This shift in the recycling paradigm hinges on the dissemination of green recycling solutions throughout the territory. The core innovation is the development of a medium-scale, environmentally friendly and low-cost hydrometallurgical process for the extraction of noble metals from End-of-Life products (e.g. electronics waste). Based on this technological breakthrough, we expect to trigger multiple ramifications from the technical, economic, social and environmental point of view. The cornerstone of this new hydrometallurgical recycling process is an entirely new concept for noble metals chemical extraction by exploiting the so-called transient dissolution.
NEXT-LIB - Novel Circular Economic Approaches for Efficient Extraction of Valuables from Spend Li-Ion Batteries	The NEXT-LIB project has the intention to develop a number of new technologies to meet the challenges addressed above, which will enable safe shredding operation, possible electrolyte recovery, graphite recovery and Li-enrichment by pyrometallurgical approaches etc. The project aims for developing technologies for an over 20% increased overall recovery efficiency comparing to the current processes. The project will be realized via a cross-discipline approach with experts in material characterization, mineral processing, pyro and hydrometallurgy, sustainability analysis, from leading universities, research institutes, SME, major battery recycler and metal producer located in Sweden, Finland, France, Italy and Portugal. The project has an economic potential of at least 1 billion €, thereby a possibility to create >2000 jobs for the EU and an energy-saving potential of >1000 GWh on a global perspective.
Siderec - Siderophores assisted Biorecovery of Technology Critical Elements: Gallium (Ga), germanium (Ge) and indium (In) from end-of-life products	High techs such as communications, renewable energies, displays are heavily dependent on metals such as germanium (Ge), indium (In) and gallium (Ga). These metals are used in photovoltaics, fibre optics, liquid crystal displays – among others. The supply of these metals is essential for the continuous supply of high-tech devices. However, due to the export control and hoarding, the supply of these metals to the high-tech industry of Europe is not assured, and hence, the European Commission has listed these metals supply as critical. Recycling of these metals from their end-of-life (EOL) products is a way

Name of the project	Short description of the project
	to overcome the shortage of these metals. However, there are no technologies available for recycling these metals due to their low concentrations and the presence of a large number of contaminants. A highly selective and sensitive solvent, ligand or reaction is needed to recover these metals. Siderophores have been shown to bind selectively bind to Ga, In and Ge even when these metals are present in very low concentrations. Thus, exploiting of siderophores for these metals' recovery can be very interesting. However, no work has been carried out to recover these metals from their EOL products using siderophores. There are two main challenges in the recovery of metals from their EOL products using siderophores. The challenges are 1) Right selection and production of siderophores, 2) Access of siderophores to the target metals in EOL products. Upon successful leaching of target metals and siderophore complexes, the decomplexation, and recovery of metals and siderophores will be carried out as by implementing the GaLIophore technology. This project aims to develop ambitious and highly innovative technology for the recovery of these critical elements. This project will fill the technology gap where no technology exists. This project will help in improving EU competitiveness in resource recovery and recycling.
LIMEX - Innovative Membrane Extraction of Lithium for Spent Lithium-Ion Battery Recycling	The LIMEX project proposes an innovative and clean technology for recovering metals from secondary resources such as batteries. The overall objective is to evaluate its technical feasibility and economic and environmental impacts when using solvent extraction and membrane separation for the recovery of target metals from the leach liquors formed during the recycling of spent LIBs. This objective constitutes a real scientific and technical challenge due to complex matrices with different levels of metal concentrations. Thus, LIMEX responds the axis N° 4 of the ERA-MIN 2 call "Recycling and Re-use of the End-of-life products" and proposes a multidisciplinary approach combining organic synthesis (Partner 2), solution chemistry (Partner 1, 2), membrane process design (Partner 1, 3, 4) and environmental impact assessment (Partner 1, 4).
RECEMENT - Re-generating (raw) materials and end-of-life products for re-use in Cement/Concrete	The key innovation in RECEMENT is developing the regeneration of high SCM-content EOL materials, while the main objective is to replace at least 30% of the Portland clinker in cement with re-generated SCMs. We aim to produce recipes for re-generated cement blends in mortar with equivalent performance and durability. The team responsible for this interdisciplinary project has precisely the broad range of expertise for realizing the engineering of cement—geochemical and mineralogical understanding of reject materials and advanced (in-situ) structure-chemistry characterization of pozzolanic reaction pathways and their final products. The output of RECEMENT is foreseen to have a high impact as a paradigm for transforming locally sourced end-of-life materials into remanufactured cement, i.e. from a linear into a circular concrete economy.
LICOBAT - Lithium and Cobalt recovery from batteries coming from the	The scientific basis of the project is the patented hydrometallurgical process (European patent EP2450991) by Eco Recycling srl. The proposed process integrates mechanical pretreatment with a chemical (hydrometallurgical) treatment route to recover plastics,

Name of the project	Short description of the project
reverse logistics chain of WEEE	ferrous and non-ferrous metals. The process will be demonstrated by the construction and operation of a pilot plant with a capacity to process 100 kg of batteries per day. For this, the consortium of this project has specialists in mechanical processes, hydrometallurgical processes, reverse logistics and entrepreneurs with significant experience in the solid waste management market. This project also aims at a positive social impact, important in emerging countries such as Brazil, where part of WEEE reverse logistics is carried out by Recyclable Material Collectors, people who work manually collecting waste materials without healthcare and security and social dignity.
SupplyPBM - Securing the Supply chain for rare earth Polymer-Bonded Magnets by recycling	The main objective of the project SupplyPBM is the demonstration of a circular economy route for rare earth polymer-bonded magnets. Scrap sintered permanent magnets from End-of-Life (EoL) products will be recycled by rapid solidification and processed to polymer-bonded magnets. Moreover, technologies suitable for recycling of polymer-bonded magnets in a continuous supercritical hydrothermal reactor will be investigated. The aim is to produce polymer-bonded magnets out of recycled magnet powder with the same performance than magnets made from primary material, so that entering the market by these magnets does not require any adaption of the products or systems themselves. Additionally, to the recycling aspect of polymer-bonded magnets, the biodesign of these magnets is addressed, by the first time use of bio-polymers in permanent magnet applications. Finally, the environmental impact of the production and recycling of polymer-bonded magnets will be investigated by a Life Cycle Assessment analysis.

Table 5: EIT – RawMaterials potentially synergetic projects

Name of the project	Short description of the project
3DMPWIRE - Material-efficient Cu wire-based 3D printing technology	To manufacture, with 3D printing, corrosion-resistant and affordable components.
ALIM - Advanced LI Metal electrodes	Alternative solutions that would contribute to more effective production of affordable Li batteries.
ALPE - Advanced Low-Platinum hierarchical Electrocatalysts for low-T fuel cells	Developing a new range of cheaper, more powerful batteries.
BlueHarvesting - Hydraulic Collector for Polymetallic Nodules from the Deepsea	To improve the mechanical capture of underwater polymetallic nodules, at depths of 3-6km.
CaproKIC - Upscaling of one step process for automotive continuous fiber Polyamide 6 composite parts based on the in-situ polymerization of e-caprolactam	Lowering production costs, with the incorporation of carbon fibre in plastic parts in the automotive industry (this kind of plastic is 60 % lighter than steel and as strong).
ECO COM'BAT - Ecological Composites for High-Efficient Li-Ion Batteries	Explores the new generation of Li batteries (high voltage batteries).
FIREM-II - Fire and Rescue in Mines II	Remotely controlled underground firefighting units in mines.
HARSHWORK - Optimizing raw material handling and processing under harsh working condition	Computer modelling, that gives us information on wear of parts that operate in difficult conditions.
HIPERCO - HIgh PERformance COmposite based on aluminium	Improving the production of aluminium parts, using nanoparticles and 3D print.
HoloMine - Mixed Reality in Mining	Digitalisation of mines with the help of MR (mixed reality).
I-EDDA-TC - Innovative Exploration Drilling and Data Acquisition Test Center	Exploring new technologies to facilitate the transition into commercial products.
IEDDA - Innovative Exploration Drilling and Data Acquisition	Optimisation of drilling and recording borehole data.
iMine - European Demonstration and Test Facilities	Testing new mining equipment, on the field and in the laboratory.
inSPECtor - Integrated spectroscopy sensor system for laser-induced fluorescence and hyperspectral imaging	Improvement of technologies that gather data (laser induced native fluorescence).
MaDurOS - Material Durability for Off-Shore	Testing of materials in difficult environments.
MaMMa - Maintained Mine & Machine	Optimisation of mining machinery maintenance, and the mining network.
MetLight - Network of Infrastructure for Metal-based Lightweight Materials	Connecting with companies engaged in ultra-light metals and technologies to strengthen ultra-light metals.
PAiRED-X - Portable Analyzer combining fluoREscence and Diffraction of X-rays	To create a small portable XRD inXRD detector all in one device.

Name of the project	Short description of the project
RE-ACTIVATE - Developing superior technical infrastructure throughout EIT RawMaterials community to foster technologies and methodologies for re-activation of former mine sites	The project is establishing a group of skilled experts in order to re-activate closed mines.
Rock Vader - Smart Hard Rock Mining System	The project is trying to optimise mining with a computer programme.
UNDROMEDA - Underground Robotic System for Monitoring, Evaluation and Detection Applications	Attempting to create a robot for underground exploration of mines, for 3D mapping and monitoring.
SafeDeepMining - Rock Engineering for Deep Mines Programme	SafeDeepMining addresses the shortage of rock engineering personnel in the European mining industry. The emphasis of the education program is on the application of rock engineering principles in the mining industry to make deep mining operations safer and more efficient. It provides the participants with the necessary knowledge and skills required to address and solve practical rock engineering problems.

Table 6: Other potentially synergetic projects or companies

Name of the project	Short description of the project
Mine of the Future™	The project deals with autonomous mining (it is trying to minimise the human factor with autonomous vehicles).
Longwall automation mining in china	The automated underground coal mine, where all the mining is remotely controlled with the help of cameras, personnel only controls the subterranean conditions and performs repairs.
BHP Billiton	The company manufactures autonomous vehicles and drilling equipment for mining, based on machine learning.
ARIDuA project underground mining robot	The company has produced an underground research robot to help explore and install IoT networks.
ASI mining	The company is looking for technological solutions for autonomous mining and overall mining improvement.
Mining-ROX	The project is trying to create a research robot that would go into the areas of mine that are too dangerous for people.
DARPA subterranean challenge	The goal of this competition is to make an underground robot for the exploration and mapping of mines in the event of an accident.
Amphibian subterranean robot for mine exploration	The project aim is to develop amphibious robot designed to explore partly flooded mines.
I2Mine	The project is engaged in underground mining as the whole process of the ore expedition and the disposal of mineral waste under the surface.

Name of the project	Short description of the project
Exyn's Autonomous Aerial Robots (A3R™s)	The company is producing autonomous drones that fly into the mine and produce the 3D model of mine as well as obtain data.
The Groundhog	A robot that was made for mine mapping (2003), a very simple and robust design.
MSRBOTS	Robot system that was designed to help find people in case of a disaster in coal mines.
EXPLORA	Australian company is manufacturing robots to explore hard-to-access spaces.
Equipois INC	The company produces mechanical hands that hold heavy tools.
Sandvik	The company is producing automated mining equipment.
SuperDroid Robots	The company is producing various robots, to assist in the exploration of mines, and the protection of miners.
National Robotics Engineering Center	The company deals with solutions in the mining industry regarding automated mining. The company also produces robots engaged in underground mapping.
BROKK	The company is producing remote-controlled drilling robots (there are several accessories that allow different functions of robots).
CSIRO	The company is producing robots for various uses (including research robots) as well as programming autonomous vehicles.
UGV	List of military robots, that could potentially be used for research purposes.
FLUX POWER	The company produces high-performance Li batteries for heavy machinery (in 2014 they have developed a special battery for the electric underground digger).
QUT robotics researches	Researchers have developed a vehicle that can navigate in mines with help of sensors, even in very poor situations, where there is almost zero visibility.
A System for Volumetric Robotic Mapping of Underground Mines	This is actually an article describing successful cooperation between USA and Germany - 2 robotic systems for high-resolution mapping of underground mines. Although it is an article we find this as a highly relevant for ROBOMINERS.
NORDGOLD	Nordgold is LSEG diversified gold producer with operation assets in Russia, Kazakhstan, Burkina Faso, Guinea and Canada. Nordgold is one of the most advanced mining companies in terms of digital transformation and innovation.
PIPEBOTS	PIPEBOTS is a UK EPSRC-funded multi-university project to develop autonomous robots for inspection of water and sewage pipes.

Table 7: Rating of importance for ROBOMINERS of potentially synergetic projects (1: maximal relevance, 2: medium relevance; 3: minimal relevance, *: projects considered after the first batch of projects was already rated; assessment will be made in the next period).

Name of the project	Importance for ROBOMINERS
X-MINE - Real-Time Mineral X-Ray Analysis for Efficient and Sustainable Mining	1
BioMOre - New Mining Concept for Extracting Metals from Deep Ore Deposits using Biotechnology	1
SLIM - Sustainable Low Impact Mining solution for exploitation of small mineral deposits based on advanced rock blasting and environmental technologies	1
UNEXMIN - Autonomous Underwater Explorer for Flooded Mines	1
¡VAMOS! - ¡Viable and Alternative Mine Operating System!	1
BIORECOVER - Development of an innovative sustainable strategy for selective biorecover of critical raw materials from Primary and Secondary sources	1
INTMET - Integrated innovative metallurgical system to benefit efficiently polymetallic, complex and low grade ores and concentrates	1
AlSiCal - Towards sustainable mineral and metal industry: ZERO Bauxite Residue and ZERO CO2 from co-production of Alumina, Silica and precipitated Calcium carbonate by the Aranda-Mastin technology	1
ION4RAW - A new cost-efficient mineral processing technology to recover by-products from primary sources	1
Dig_IT - A human-centred Internet of Things platform for the sustainable digital mine of the future	1
BADGER - RoBot for Autonomous unDerGround trenchless opERations, mapping and navigation	1
IMP@CT - Integrated Modular Plant and Containerised Tools for Selective, Low-impact Mining of Small High-grade Deposits	1
MONAMIX - New concepts for efficient extraction of mixed rare earths oxides from monazite concentrates and their potential use as dopant in high temperature coatings and sintered materials	1
MIWACUT - Investigating the microwave assisted cutting of carbonate rocks	1
BlueHarvesting - Hydraulic Collector for Polymetallic Nodules from the Deepsea	1
UNDROMEDA - Underground Robotic System for Monitoring, Evaluation and Detection Applications	1

Name of the project	Importance for ROBOMINERS
SafeDeepMining - Rock Engineering for Deep Mines Programme	1
NORDGOLD	1
PIPEBOTS	1
HiTech AlkCarb - New geomodels to explore deeper for High-Technology critical raw materials in Alkaline rocks and Carbonatites	2
INFACT - Innovative, Non-invasive and Fully Acceptable Exploration Technologies	2
Smart Exploration - Sustainable mineral resources by utilizing new Exploration technologies	2
ITERAMS - Integrated mineral technologies for more sustainable raw material supply	2
PACIFIC - Passive seismic techniques for environmentally friendly and cost efficient mineral exploration	2
ROBUST - Robotic subsea exploration technologies	2
SOLSA - Sonic Drilling coupled with Automated Mineralogy and chemistry On-Line-On-Mine-Real-Time	2
Real-time Mining - Real-time optimization of extraction and the logistic process in highly complex geological and selective mining settings	2
NEXT - New Exploration Technologies	2
ThermoDrill - Fast track innovative drilling system for deep geothermal challenges in Europe	2
CHPM2030 - Combined Heat, Power and Metal extraction from ultra-deep ore bodies	2
GeoWell - Innovative materials and designs for long-life high-temperature geothermal wells	2
ERGO - European Robotic goal-oriented autonomous COntroller (ERGO)	2
ReconCycle - Self-reconfiguration of a robotic workcell for the recycling of electronic waste	2
RODEO - Robotized Orbital Drilling Equipment and Optimized residual stresses	2
STEP2DYNA - Spatial-temporal information processing for collision detection in dynamic environments	2
DEEPFIELD - Deep Learning in Field Robotics: from conceptualization towards implementation	2

Name of the project	Importance for ROBOMINERS
INSPEX - Integrated Smart Spatial Exploration System	2
ADIR - Next generation urban mining - Automated disassembly, separation and recovery of valuable materials from electronic equipment	2
FRAME - Forecasting and Assessing Europe's Strategic Raw Materials needs	2
Mintell4EU - Mineral Intelligence for Europe	2
HITEM - Highly sensitive receiver for measuring transient electromagnetic responses in Exploration for deep buried mineral occurrences	2
COGITO-MIN - COst-effective Geophysical Imaging Techniques for supporting Ongoing MINeral exploration in Europe	2
REWO-SORT - Reduction of Energy and Water consumption of mining Operations by fusion of sorting technologies LIBS and ME-XRT	2
Li+Water - Membrane electrolysis for resource-efficient lithium and water recovery from brines	2
Gold_Insight - Tracing Gold-Copper-Zinc with advanced microanalysis	2
MINECO - New Eco-innovative Materials for Mining Infra	2
FIREM-II - Fire and Rescue in Mines II	2
HoloMine - Mixed Reality in Mining	2
iMine - European Demonstration and Test Facilities	2
PAiRED-X - Portable Analyzer combining fluoREscence and Diffraction of X-rays	2
Rock Vader - Smart Hard Rock Mining System	2
OptimOre - Increasing yield on Tungsten and Tantalum ore production by means of advanced and flexible control on crushing, milling and separation process	3
TARANTULA - Recovery of Tungsten, Niobium and Tantalum occurring as by-products in mining and processing waste streams	3
FINEFUTURE - Innovative technologies and concepts for fine particle flotation: unlocking future fine-grained deposits and Critical Raw Materials resources for the EU	3
MINERAL EYE - Real-time on-line mineralogical analysis for the process optimization and more sustainable mining	3
AutoFlyMap - AUTOnomous FLYing Robots in GNSS denied environments for 3D Underground infrastructure MAPping and inspection.	3
MAGNIFY - From nano to macro: a groundbreakIng actuation technology for robotic systems	3
RAWFIE - Road-, Air- and Water-based Future Internet Experimentation	3
ORIENT- Goal-directed eye-head coordination in dynamic multisensory environments	3
ROBUST - Robotic subsea exploration technologies	3

Name of the project	Importance for ROBOMINERS
BIOMODULAR - A Biomimetic Learning Control Scheme for control of Modular Robots	3
LeMo - Learning Mobility for Real Legged Robots	3
Co4Robots - Achieving Complex Collaborative Missions via Decentralized Control and Coordination of Interacting Robots	3
SWARMs - Smart and Networking UnderWAter Robots in Cooperation Meshes	3
NatDyReL - Utilizing Natural Dynamics for Reliable Legged Locomotion	3
DeeViSe - Deep Learning for Dynamic 3D Visual Scene Understanding	3
MicroSpot - The first portable, low-cost, robotized scanner microscope that converts any smartphone into a high quality and intelligent tele-microscopy image diagnosis system	3
SmokeBot - Mobile Robots with Novel Environmental Sensors for Inspection of Disaster Sites with Low Visibility	3
EuroLithos - European Ornamental Stone Resources	3
MINDeSEA - Seabed Mineral Deposits in European Seas: Metallogeny and Geological Potential for Strategic and Critical Raw Materials	3
REMinE - Improve Resource Efficiency and Minimize Environmental Footprint	3
BIOCriticalMetals - Recognition of microbial functional communities and assessment of the mineralizing potential (bioleaching) for high-tech critical metals	3
CHARPHITE - Coal char as a substituting material of natural graphite in green energy technologies	3
AMTEG - Advanced Magnetic full TEnsor Gradiometer instrument	3
LIGHTS - Lightweight Integrated Ground and Airborne Hyperspectral Topological Solution	3
BIOMIMIC - Innovative biotechnological methods for effective mining of secondary mineral	3
AUREOLE - tArgeting eU cRitical mEtals (Sb, W) and predictability of Sb-As-Hg envirOnmentaL issuEs	3
Sb-RECMEMTEC - Electro-electrodialysis technology on the copper minerals processing industry to the recovery of antimony from mining tailings and recycling the solution media	3
3DMPWIRE - Material-efficient Cu wire-based 3D printing technology	3
ALIM - Advanced LI Metal electrodes	3
ALPE - Advanced Low-Platinum hierarchical Electrocatalysts for low-T fuel cells	3

Name of the project	Importance for ROBOMINERS
ECO COM'BAT - Ecological Composites for High-Efficient Li-Ion Batteries	3
HARSHWORK - Optimizing raw material handling and processing under harsh working condition	3
IEDDA - Innovative Exploration Drilling and Data Acquisition	3
inSPECtor - Integrated spectroscopy sensor system for laser-induced fluorescence and hyperspectral imaging	3
MaDurOS - Material Durability for Off-Shore	3
MaMMa - Maintained Mine & Machine	3
RE-ACTIVATE - Developing superior technical infrastructure throughout EIT RawMaterials community to foster technologies and methodologies for re-activation of former mine sites	3
BATRE-ARES - Battery Recycling – Achieving Rare Earth Separation	*
DEASPHOR - Design of a product for SUBSTITUTION of phosphate rocks	*
MINTECO - Integrated eco-technology for a selective recovery of base and precious metals in Cu and Pb mining by-products	*
MaXycle - Circular economy, magnet recycling, NdFeB magnets, end-of-life magnets, Eco-labelling	*
BASH-TREAT - Optimization of bottom ash treatment for an improved recovery of valuable fractions	*
MetRecycle - Recycling of metals using functionalized magnetic nanoparticles	*
INSTAnT - Innovative sensor technology for optimized material recovery from bottom ash treatment	*
RecEOL - Recycling of End-of-Life Products (PCB, ASR, LCD)	*
SUPERMET - Recovery of Precious Metals from Spent Catalysts by Supercritical CO2 Extraction Assisted by Polymers	*
MiCCuR - Microbial Consortia for enhanced Copper Recovery	*
RedOxRec - Reduction/ Oxidation Recycling	*
NEXT-LIB - Novel Circular Economic Approaches for Efficient Extraction of Valuables from Spend Li-Ion Batteries	*
Siderec - Siderophores assisted Biorecovery of Technology Critical Elements: Gallium (Ga), germanium (Ge) and indium (In) from end-of-life products	*

Name of the project	Importance for ROBOMINERS
LIMEX - Innovative Membrane Extraction of Lithium for Spent Lithium-Ion Battery Recycling	*
RECEMENT - Re-generating (raw) materials and end-of-life products for re-use in Cement/Concrete	*
LICOBAT - Lithium and Cobalt recovery from batteries coming from the reverse logistics chain of WEEE	*
SupplyPBM - Securing the Supply chain for rare earth Polymer-Bonded Magnets by recycling	*
CaproKIC - Upscaling of one step process for automotive continuous fiber Polyamide 6 composite parts based on the in situ polymerization of e-caprolactam	*
HIPERCO - HIgh PERformance COmposite based on aluminium	*
I-EDDA-TC - Innovative Exploration Drilling and Data Acquisition Test Center	*
MetLight - Network of Infrastructure for Metal-based Lightweight Materials	*
Mine of the Future™	*
Longwall automation mining in china	*
BHP Billiton	*
ARIDuA project underground mining robot	*
ASI mining	*
Mining-ROX	*
DARPA subterranean challenge	*
Amphibian subterranean robot for mine exploration	*
I2Mine	*
Exyn's Autonomous Aerial Robots (**A3R™s**)	*
The Groundhog	*
MSRBOTS	*
EXPLORA	*
Equipois INC	*
Sandvik	*
SuperDroid Robots	*
National Robotics Engineering Center	*

Name of the project	Importance for ROBOMINERS
BROKK	*
CSIRO	*
UGV	*
FLUX POWER	*
QUT robotics researches	*
A System for Volumetric Robotic Mapping of Underground Mines	*

3.2. Contacting of relevant project representatives

The second part of clustering activities was focused on **contacting selected most relevant projects**. The aim of this part was to make contacted project coordinators or other key staff aware of ROBOMINERS project, as well as to discuss and identify common challenges, potential synergies and exchange future visions from the field. We used several clustering tools in this part:

- personal meetings one-to-one;

- personal meeting in conferences, workshops, networking and other events;

- teleconferences;

- on-line meetings;

- email exchanges.

The situation with COVID-19 unfortunately forced us to adapt initial clustering plans to the new circumstances, which prevented travelling and personal meetings and meetings in large groups, so we needed to shift the clustering activities mainly by using available online meeting tools (i.e. Skype, GoToMeeting, Zoom, MS Teams), alongside phone and email exchanges.

A ROBOMINERS **Cluster Facilitator** was selected among the ROBOMINERS consortium. During the project meetings it became clear that a Cluster Facilitator should be delegated to someone with the office in Brussels, because many events connected to raw materials happen there, and thus make the clustering for ROBOMINERS easier. **Luís Lopes from LPRC** was delegated to this position, and this decision was made with consensus within the consortium during the Tallinn meeting in January 2020.

The role of Cluster Facilitator was to establish contact with the representatives of the most relevant projects on both online and presential basis. Following the preparation phase, strategic elements and themes were identified, from where synergies can be established. The clustering activities are based on five pillars:

1) Fostering connections with communities working on relevant similar topics and challenges

2) Create long-term research collaborations and scientific investigations

3) Increase projects visibility

4) Shorten time to market for ROBOMINERS and clustered projects

5) Share knowledge and experience on technical challenges encountered

These initial steps in the ROBOMINERS clustering activities provided input on the potential synergies between the projects that share similar interests. With this exercise, ROBOMINERS aims at preparation of a series of clustering events (workshops, focus groups, online meetings, others) with relevant projects in the next stages, that can push the European innovation scene in robotics, raw materials and related fields forward in the next period.

From all potentially synergic projects, the 14 most relevant projects for ROBOMINERS were selected to be directly contacted, as a first approach. Eight (8) projects were selected from H2020 group, 3 from EIT RawMaterials group, one from group ERA MIN II and 2 from group other (1 industrial and 1 national). During 2020 more projects were contacted. Contacted projects by type and information on the date of the survey and the ROBOMINERS project partner that performed the survey are listed in Table 8. To evaluate the value of such contact, a special survey was prepared to be filled by the ROBOMINERS partner, who performed the connection. The key inputs of the survey addressed the following points:

a) Potential interest areas/key topics for cooperation/synergy

b) Common challenges

c) Shared technological objectives

d) Expected results of the clustering activity

Table 8: Contacted projects and information on the date and the project partner that performed survey

Contacted clustered project acronym	Type of clustering project	Date of survey	Contact performed by
AlSiCal_- Towards sustainable mineral and metal industry: ZERO Bauxite Residue and ZERO CO2 from co-production of Alumina, Silica and precipitated Calcium carbonate by the Aranda-Mastin technology	H2020	30. 9. 2020	LPRC Luís Lopes
BADGER - RoBot for Autonomous unDerGround trenchless opERations, mapping and navigation	H2020	15. 9. 2020	UPM Claudio Rossi
CHPM2030 - Combined Heat, Power and Metal Extraction	H2020	20. 7. 2020	UNIM Eva Hartai
IMP@CT - Integrated Modular Plant and Containerised Tools for Selective, Low-impact Mining of Small High-grade Deposits	H2020	22. 4. 2020	EFG Vitor Correia
ION4RAW - Ionometallurgy of primary sources for an enhanced raw materials recovery	H2020	29. 9. 2020	LPRC Luís Lopes
ReconCycle - Self-reconfiguration of a robotic workcell for the recycling of electronic waste	H2020	25. 5. 2020	GeoZS Gorazd Žibret
X-MINE - Real-Time Mineral X-Ray Analysis for Efficient and Sustainable Mining	H2020	16. 4. 2020	LPRC Luis Lopes
Dig_IT - A Human-centred Internet of Things Platform for the Sustainable Digital Mine of the Future	H2020	5. 10. 2020	LPRC Luís Lopes
SafeDeepMining - Advanced Rock Engineering Education for Deep Mines	EIT RM	8. 4. 2020	MUL Michael Berner
UNDROMEDA - Underground Robotic System for Monitoring, Evaluation and Detection Applications	EIT RM	23. 4. 2020	LPRC Luís Lopes

Contacted clustered project acronym	Type of clustering project	Date of survey	Contact performed by
UNEXUP – UNEXMIN Upscaling	EIT RM	16. 4. 2020	UNIM Norbert Zajzon
COGITO-MIN - COst-effective Geophysical Imaging Techniques for supporting Ongoing MINeral exploration in Europe	ERA MIN	9. 4. 2020	EFG Vitor Correia
NORDGOLD - one of the most advanced mining companies in terms of digital transformation and innovation.	Industrial	28. 8. 2020	EFG Vitor Correia
PIPEBOTS - aims to revolutionise buried pipe infrastructure management with the development of micro-robots designed to work in underground pipe networks and dangerous sites	National	2. 6. 2020 18. 6. 2020	RCI, UNIM & UPM Stephen Henley, Mike McLoughlin, Norbert Zajzon, Zorana Milošević

3.3. Projects common challenges & analysis of outcomes

Representatives of each of the selected projects were contacted and interviewed. Clustering main points, description of common challenges and main expected results of clustering activity were discussed in order to identify and determine common challenges and synergetic activities, to plan appropriate clustering activities for boosting clustered projects towards product implementation. Clustering activity reports are collected in Appendix 1. Table 9 summarizes the identified added value of establishing such contacts by ROBOMINER partners, and presents clustering points and common challenges, and main expected results.

Table 9: Clustering activities reports on clustering main points and common challenges, description of common challenges and expected results.

Contacted clustered project acronym	Clustering main points, common challenges	Description of common challenges	Main expected results of clustering activity
AlSiCal - Towards sustainable mineral and metal industry	Mining industry more environmentally sound; industrial engagement for developing innovative sustainable technologies for	Targeted, automatized mining might contribute to increase overall efficiency and lower environmental impact for the whole value chain of raw materials production For certain locations, targeted/automatised mining might be the only	Knowledge transfer and increased awareness of sustainability challenges in the mining operations. -Connecting AlSiCal´s partners on exploration and mining with cutting-edge technologies for robot-based mining -The synergy is identified to

Contacted clustered project acronym	Clustering main points, common challenges	Description of common challenges	Main expected results of clustering activity
	mineral processing	option for economic and environmental feasibility	be on the longer term, when AlSiCal´s technology develops further into upscaling and industrialisation onsite.
BADGER - RoBot for Autonomous unDerGround trenchless opERations, mapping and navigation	Autonomy; underground navigation; drilling; geotechnics; geolocalisation.	Common challenges are advanced manoeuvrability and motion capability using on-board georadars, interpretation of the surrounding underground environment thought the PID sensing and improving the perception and cognition abilities.	Exchange results in the key areas of common interest; comparison of the used technologies; exchange open-source software and try to find new applications.
CHPM2030 - Combined Heat, Power and Metal Extraction	ore deposits, old mines, metal enrichments Identification of ore deposits in Europe. CHPM2030 is looking for the deep continuation of the metal enrichments for geothermal energy and metal extraction, while ROBOMINERS can utilize abandoned or working mines, or non-economic parts of the deposits.	A common challenge for both projects is the data scarcity from the depths below 1 km. Lack of data from the old, abandoned mines is also a common problem.	Sharing the collected data, potential joint workshop on the mineral deposits of metal enrichments in Europe which can be targets for both projects.
IMP@CT - Integrated Modular Plant and Containerised Tools for Selective, Low-impact Mining of Small High-grade Deposits	Small complex deposits; mine equipment design and planning;	Feasibility analysis of exploitation of small deposits; use of the switch on-switch off mining paradigm to improve the economics of mining; incorporation and valuation of risks associated with geological uncertainty, metallurgical variability and social acceptance	A greater understanding of the timescales of the roll-out of mining solutions; Collaboration to understanding the challenges facing the adoption of small-scale mining techniques; Acceleration of progress, by avoiding the repetition of tasks;

Contacted clustered project acronym	Clustering main points, common challenges	Description of common challenges	Main expected results of clustering activity
			Prediction of future technical challenges, based on prior experience.
ION4RAW - Ionometallurgy of primary sources for an enhanced raw materials recovery	Mineral processing;		Facilitate coordination and exchange information between the different existing projects from Horizon 2020 related to the call topic: "New solutions for sustainable production of raw materials". Expected result of clustering activities is to provide a forum for discussion, problem-solving and planning R&D activities and gaps in Europe.
ReconCycle	self-configuration, artificial vision, AI, robotic arms	We are doing a bit different thing - ReconCycle project is using available components to finish up with the application on higher TLR level, while ROBOMINER is much more technically challenging and will finish on lower TLR. Some components, like self-repair, use of robotic arms, AI, object detection etc. could be similar.	joint seminar/conference organisation, networking, future joint proposals.
X-MINE - Real-Time Mineral X-Ray Analysis for Efficient and Sustainable Mining	Mine planning; mineral sorting; mineral analysis; 3D modelling; drill core analysis	The X-Mine project is developing mineral analysis methods, mineral sorting and 3D modelling of mineral deposits. The mineral analysis methods could be integrated into the Robominers robot in the future to do mineral analysis on-the-job. Mineral sorting could also be a part of the robotic solution in the future. Advanced X-Mine drill core analysis combined with 3D modelling yields much better characterisation of	The X-Mine project (TRL level up to 8) and the Robominers project (TRL level up to 4) are quite far from each other in terms of TRL levels. Probably the most important result from the clustering activity could be to generate ideas related to the future of mining. As the mineral deposits become poorer, smaller, more complex or otherwise challenging, the need for technological advances increases. For example, drill core scanning

Contacted clustered project acronym	Clustering main points, common challenges	Description of common challenges	Main expected results of clustering activity
		mineral deposits. This information could be used in planning the use of the robots developed in the Robominers project.	and advanced 3D modelling methods could also be used to figure out the best mining and processing techniques for a new prospect. A mineral deposit deemed to be uneconomic to exploit might turn out profitable if a combination of on-site mineral analysis, robots and mineral sorting would be used.
Dig_IT - A Human-centred Internet of Things Platform for the Sustainable Digital Mine of the Future	Digitalisation of mining operations. Challenges in sensing and communication systems in mining environment.	Dig_IT project is highly focussed on improving health and safety in the mining industry. ROBOMINERS proposes a solution to enable the exploitation of difficult to access deposits, while avoiding workers health risks.	The ROBOMINERS control software could be embedded in the Dig_IT IIoT platform. Dig_IT end-users are potential end-users for the ROBOMINERS solution (robots).
SafeDeepMining	Rock mechanics, rock pressure, support systems, safe mining, underground mining, deep mining	Mining for critical raw materials is going deeper in underground mining, stable roof conditions is important for both mining with human operators and robots. The know-how necessary for both projects can be shared.	Networking with researchers and industry active in mining. Exchange ideas on safe deep mining operation. Robots will enable in the future to remove humans from dangerous and unhealthy working places.
UNDROMEDA - Underground Robotic System for Monitoring, Evaluation and Detection Applications	Underground mining; autonomous 3D mapping; monitoring; drones	Autonomous underground navigation of a robot implementing 3D SLAM with data fusion	Knowledge and approach exchange in this field, networking, project visibility
UNEXUP – UNEXMIN Upscalling	communication, navigation, rough environment, energy source,	Navigation: difficult, many times unknown 3D map, with many times unstructured walls and	With joint efforts well distributed and communicated the common challenges can

Contacted clustered project acronym	Clustering main points, common challenges	Description of common challenges	Main expected results of clustering activity
	miniaturisation, sensing	cavities which can be small or large in a GPS-less environment. Visibility easily can be bad. No effective communication can be managed without cable in this environment in the size the projects' work. High chance to get stuck and/or lost, or run out of battery. In-situ sensing thru water in a pressurised environment is difficult.	have better solutions. Realising synergies and submitting proposals for the common interest.
COGITO-MIN - COst-effective Geophysical Imaging Techniques for supporting Ongoing MINeral exploration in Europe	Seismic imaging; integrated geophysical/geological approaches; perception technologies.	Integration of geophysical and geological data.	
NORDGOLD	Operation in harsh environments, selective small-scale mining.	Research challenges concerning scalability, resilience, reconfigurability, self-repair, collective behaviour, operation in harsh environments, selective mining, production methods as well as for the necessary converging technologies on an overall mining ecosystem level.	Nordgold shows interest in supporting Robominers testing in real mining environments.
PIPEBOTS	communications, sensors, autonomy/SLAM, navigation, software, photogrammetry	• Communication – ultrasound, light, radio frequencies (Pipebots will not be tethered) • Sensor development – Pipebots requirements in particular for miniaturised sensor devices including acoustic/sonar units	Research collaboration on identified areas of common interest.

Contacted clustered project acronym	Clustering main points, common challenges	Description of common challenges	Main expected results of clustering activity
		• Autonomy and SLAM applications (in particular we identified similar problems of unreliable prior base maps – old water-pipe and sewage networks, surveys of abandoned mines) • Navigation • Software – Pipebots almost certainly using ROS1, no plans to move to ROS2. They are also considering simpler solutions on Raspberry Pi or stand-alone microprocessors • Photogrammetry for point-cloud extraction and processing	

The analysis of projects common challenges shows a wide range of variety of fields, where project objectives overlap or complement. They were grouped to the fields, connected to raw materials, and robotics. The synthesis is as follows.

Common challenges in the field of raw materials:

1. Ore deposits, with focus on identification of ore deposits in Europe, metal enrichments, old mines, and small complex deposits, which could be potential targets for ROBOMINERS. The data scarcity from the depths below 1 km and lack of data from the old, abandoned mines are common challenges.
2. Sustainable and environmentally sound mining industry in the sense of industrial engagement for developing innovative sustainable technologies for mineral processing and developing more environmentally sound mining industry. Feasibility analysis of the exploitation of small deposits and use of the switch on-switch off mining paradigm to improve the economics of mining, incorporation and evaluation of risks associated with geological uncertainty, metallurgical variability, and social acceptance.
3. Mine equipment design and planning, including safe mining in harsh environments (deep, underground, small scale). Challenges concern scalability, resilience, reconfigurability, self-repair, collective behaviour, operation in harsh environments, selective mining, production methods as well as for the necessary converging technologies on an overall mining ecosystem level. Mining for critical raw materials is going deeper in underground mining, stable roof conditions are important for both mining with human operators and robots. Targeted, automatised mining might contribute to increase overall efficiency and lower environmental impact for the whole value chain of raw materials production. For certain locations, targeted/automatised mining might be the only option for economic and environmental feasible mine operations.
4. Mineral processing, including mineral sorting and mineral analysis. Focus on development of mineral analysis methods, smart mineral sorting, and 3D modelling of mineral deposits, that could be integrated in the future to mineral analysis on-the-job. Mineral sorting could also be a part of the robotic solution in the future.

Common challenges in the field of robotics:

1. Artificial intelligence and digitalisation, including 3D modelling, artificial vision, digitalisation of mining, robotic arms, operations and software as well as support systems. The general aim is highly focussed on improving health and safety in the mining industry, proposing solutions to enable the exploitation of difficult to access deposits, while avoiding workers health risks. In these terms development of some components, like self-repair, use of robotic arms, AI, object detection etc. are similar common challenges. Also, of high interest is advanced manoeuvrability and motion capability using on-board georadar, interpretation of the surrounding underground environment thought the PID sensing and improving the perception and cognition abilities.
2. Autonomy and autonomous devices, including autonomous 3D mapping, drones, and self-configuration. Especially autonomous underground navigation of a robot implementing 3D SLAM with data fusion.
3. Communication system, underground positioning and sensors, including challenges in sensing and communication systems in a mining environment, perception technologies, monitoring, photogrammetry, and seismic imaging. Possible communication of untethered device (ultrasound, light, radio frequencies) and sensor development, in particular for miniaturised

sensor devices including acoustic/sonar units. Use of photogrammetry for point-cloud extraction and processing is also in focus. Challenges are also related to precise positioning underground.

The expected results of clustering from contacted projects (fully listed in Table 9 and Appendix 1), can be summarised as follows:

1. Facilitating coordination and exchange information between the different existing projects on related topics
2. Knowledge and approach exchange/transfer and increased awareness of actual challenges, including exchange results and open source software in the key areas of common interest and comparison of the used technologies
3. Networking with researchers and industry on common topics
4. Increased projects visibility
5. Forum for discussion, problem-solving and planning R&D activities and gaps in Europe
6. Acceleration of progress, by avoiding repetition of tasks
7. Technology development further into upscaling and industrialisation onsite
8. Future joint research projects.

3.4. Follow up

In next steps follow up meetings with selected project coordinators will be performed to connect projects partners and foster the discussion of different topics in dedicated events, organised by ROBOMINERS, that will be addressing common challenges.

Two follow up meetings were already organised between ROBOMINERS and (three) of the selected projects, COGITO MIN and IMP@CT in April and PIPEBOTS in June 2020. The details will be presented in the D8.2 - Second cluster report in M36.

The consortium will also focus on contacting more related projects. The initial plan was to organise a joint workshop, connected to any ROBOMINERS project meetings, or as a side event of other larger events (i.e. Raw materials week, or EIT RawMaterials annual events, scientific conferences - i.e. EGU annual meeting or similar), and to invite external experts. However, due to COVID-19 situation, this plan needs to be modified, and the consortium will aim to organise such discussions via on-line meetings. Since the consortium will not need to travel during the COVID-19 pandemic, it will be able to invest more efforts to successfully organise online workshops with a high number of external participants.

4 CONCLUSIONS

Clustering of projects with similar and complementary thematic is of high importance for using the synergetic effect and boost the results of the project. The project clustering concept builds on the idea that projects which share a common theme or address similar challenges form a cluster initiative and deliver shared strategic inputs and outputs. To support the EIP on Raw Materials actions on innovative extraction of raw materials, clustering activities started with selected, highly relevant related projects in the field of raw materials as well as robotics, to establish cross-projects co-operation. Search for potential projects, similar or complementary to ROBOMINERS was performed through different platforms (H2020 projects in the field of raw materials and in the field of robotics, GeoERA, ERA MIN II, EIT RM and others) and list of projects with potential to join the cluster was prepared. Coordinators of selected similar projects with high potential for clustering were contacted and interviewed to determine common challenges and expected results of clustering.

Common challenges with clustering projects were identified in several focus fields, namely:

1. Ore deposits
2. Sustainable and environmentally sound mining industry
3. Mine equipment design and planning
4. Mineral processing
5. Artificial intelligence and digitalisation
6. Autonomy and autonomous devices
7. Communication system and sensors

The key foreseen results of clustering activities at current stage are:

1. Facilitating coordination and exchange information between the different existing projects on related topics
2. Knowledge and approach exchange/transfer and increased awareness of actual challenges, including exchange results and open source software in the key areas of common interest and comparison of the used technologies
3. Networking with researchers and industry on common topics
4. Increased projects visibility
5. Forum for discussion, problem-solving and planning R&D activities and gaps in Europe
6. Acceleration of progress, by avoiding repetition of tasks
7. Technology development further into upscaling and industrialisation onsite
8. Future joint research projects.

In follow up actions, partners of the projects will be approached and invited to join common discussions and events, focused on established common challenges themes.

Appendix 1: Individual clustering activity reports

No.	Item	Description
1	Who (performed clustering)	Luis Lopes (LPRC)
2	Date of clustering	30. 9. 2020
3	Clustered project acronym	AlSiCal - Towards sustainable mineral and metal industry: ZERO Bauxite Residue and ZERO CO2 from co-production of Alumina, Silica and precipitated Calcium carbonate by the Aranda-Mastin technology
3.1	Clustered project short abstract (up to 100 words)	AlSiCal is an ambitious Research and Innovation effort to make the mineral and metal industry more sustainable and environmentally sound. The project will further research, develop and de-risk a ground-breaking concept; the patented Aranda-Mastin (AM) technology. This technology enables the co-production of three essential raw materials (alumina, silica and precipitated calcium carbonate), using new resources - e.g. anorthosite, abundantly available worldwide - whilst generating ZERO Bauxite Residue and ZERO CO2.
4	Clustered project web site	https://www.alsical.eu/
5	Contact person	Anastasios (Tassos) Kladis, anastasios.kladis@admiris.eu
6	Type of clustering project	☒H2020 ☐National ☐EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☒Web ☐Workshop ☐Conference ☐Business network ☐Seminar ☐Other (please specify):
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	Mining industry more environmentally sound; industrial engagement for developing innovative sustainable technologies for mineral processing
9	Description of common challenge(s) addressed (up to 100 words)	Targeted, automatized mining might contribute to increase overall efficiency and lower environmental impact for the whole value chain of raw materials production For certain locations, targeted/automatized mining might be the only option for economic and environmental feasibility
10	Main expected results of clustering activity (up to 100 words)	-Knowledge transfer and increased awareness of sustainability challenges in the mining operations. -Connecting AlSiCal´s partners on exploration and mining with cutting-edge technologies for robot-based mining -The synergy is identified to be on the longer term, when AlSiCal´s technology develops further into upscaling and industrialization onsite.

No.	Item	Description
1	Who (performed clustering)	Claudio Rossi (claudio.rossi@upm.es) (UPM)
2	Date of clustering	15.9.2020
3	Clustered project acronym	BADGER - RoBot for Autonomous unDerGround trenchless opERations, mapping and navigation
3.1	Clustered project short abstract (up to 100 words)	The goal of the proposed project is the design and development of the BADGER autonomous underground robotic system that can drill, manoeuvre, localise, map and navigate in the underground space, and which will be equipped with tools for constructing horizontal and vertical networks of stable bores and pipelines. The proposed robotic system will enable the execution of tasks that cut across different application domains of high societal and economic impact including trenchless constructions, cabling and pipe installations, geotechnical investigations, large-scale irrigation installations, search and rescue operations, remote science and exploration, and defence applications.
4	Clustered project web site	http://www.badger-robotics.eu/badger/
5	Contact person	Carlos Balaguer
6	Type of clustering project	☒H2020 ☐National ☐EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☒Web ☐Workshop ☐Conference ☐Business network ☐Seminar ☐Other (please specify)
8	Clustering main points, common challenges (keywords, e.g miniaturisation, navigation)	Autonomy; underground navigation; drilling; geotechnics; geolocalization.
9	Description of common challenge(s) addressed (up to 100 words)	Common challenges are advanced manoeuvrability and motion capability using on-board georadars, interpretation of the surrounding underground environment thought the PID sensing, and improving the perception and cognition abilities.
10	Main expected results of clustering activity (up to 100 words)	Exchange results in the key areas of common interest; comparison of the used technologies; exchange open source software and try to find new applications.

No.	Item	Description
1	Who (performed clustering)	Éva Hartai (UNIM)
2	Date of clustering	20 July 2020
3	Clustered project acronym	CHPM2020
3.1	Clustered project short abstract (up to 100 words)	CHPM2030 was an EU funded H2020 project with a strategic objective to develop a novel technological solution that can help satisfy the needs for energy and strategic metals in a single interlinked process. In the CHPM technology vision, an enhanced geothermal system (EGS) will be established in a deep seated (4 km or more) metal-bearing geological formation. By leaching metals from the mineralised rock body and recovering them at surface, the co-production of energy and metals will be possible and may even be optimised according to market demands. The project ended in June 2019 but CHPM2030 prepared two roadmaps: for 2030 and 2050 and is looking for further funding opportunities.
4	Clustered project web site	https://www.chpm2030.eu/
5	Contact person	Tamás Madarász, University of Miskolc
6	Type of clustering project	☒H2020 ☐National ☐EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☐Web ☐Workshop ☐Conference ☒Business network ☐Seminar ☐Other (please specify):
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	Keywords: ore deposits, old mines, metal enrichments Identification of ore deposits in Europe. CHPM2030 is looking for the deep continuation of the metal enrichments for geothermal energy and metal extraction, while ROBOMINERS can utilize abandoned or working mines, or non-economic parts of the deposits.
9	Description of common challenge(s) addressed (up to 100 words)	Common challenge for both projects is the data scarcity from the depths below 1 km. Lack of data from the old, abandoned mines is also a common problem.
10	Main expected results of clustering activity (up to 100 words)	Sharing the collected data, potential joint workshop on the mineral deposits of metal enrichments in Europe which can be targets for both projects.

No.	Item	Description
1	Who (performed clustering)	Vitor Correia (EFG)
2	Date of clustering	22/04/2020
3	Clustered project acronym	IMP@CT - Integrated Modular Plant and Containerised Tools for Selective, Low-impact Mining of Small High-grade Deposits
3.1	Clustered project short abstract (up to 100 words)	IMP@CT is developing a new mining paradigm to improve the viability of many critical metals and other small complex deposits, improving conditions for technological innovations in mining equipment design and mine planning. Mining and processing technologies can be adapted to multiple deposits and commodities and thus, have a large impact on mining, exploration and exploitation scheme at European and regional level.
4	Clustered project web site	http://www.impactmine.eu/
5	Contact person	Kathryn Moore; Dana Finch
6	Type of clustering project	☒H2020 ☐National ☐EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☒Web ☐Workshop ☐Conference ☐Business network ☐Seminar ☐Other (please specify)
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	Small complex deposits; mine equipment design and planning;
9	Description of common challenge(s) addressed (up to 100 words)	Feasibility analysis of exploitation of small deposits; use of the switch on-switch off mining paradigm to improve the economics of mining; incorporation and valuation of risks associated with geological uncertainty, metallurgical variability and social acceptance.
10	Main expected results of clustering activity (up to 100 words)	1. Greater understanding of the timescales of roll-out of mining solutions. 2. Collaboration to understanding the challenges facing adoption of small-scale mining techniques. 3. Acceleration of progress, by avoiding repetition of tasks. 4. Prediction of future technical challenges, based on prior experience

ROBOMINERS / IMP@CT follow-up meetings

No.	Date	Participants	Topics discussed / follow-up measures
1	22/04/2020	Luís Lopes (ROBOMINERS project) Vitor Correia (ROBOMINERS project) Kathryn Moore (IMP@CT project) Dana Finch (IMP@CT project)	- Goals, state of the projects and future developments - Common areas between the two projects: small scale mining, production tools, innovative mining solutions, social license to operate, clustering focus - Follow-up: ROBOMINERS and IMP@CT partners to engage in discussion in different topics

No.	Item	Description
1	Who (performed clustering)	Luís Lopes (LPRC)
2	Date of clustering	29. 9. 2020
3	Clustered project acronym	ION4RAW - Ionometallurgy of primary sources for an enhanced raw materials recovery
3.1	Clustered project short abstract (up to 100 words)	The Ion4Raw project proposes an energy-, material- and cost-efficient new mineral processing technology to recover by-products from primary sources by means of innovative Deep Eutectic Solvent (DES) ionic liquids and advanced electrorecovery as an only step. A joint recovery of by-products from primary sources which belong to the Cu-Ag-Au group is proposed.
4	Clustered project web site	http://ion4raw.eu/
5	Contact person	Laura Borge del Rey (laura.borgedelrey@pnoconsultants.com)
6	Type of clustering project	☒H2020 ☐National ☐EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☒Web ☐Workshop ☐Conference ☐Business network ☐Seminar ☐Other (please specify):
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	Mineral processing;
9	Description of common challenge(s) addressed (up to 100 words)	
10	Main expected results of clustering activity (up to 100 words)	Facilitate coordination and exchange information between the different existing projects from Horizon 2020 related to the call topic: "New solutions for sustainable production of raw materials". Expected result of clustering activities is to provide a forum for discussion, problem solving and planning R&D activities and gaps in Europe.

No.	Item	Description
1	Who (performed clustering)	Gorazd Žibret (GeoZS)
2	Date of clustering	25 MAY 2020
3	Clustered project acronym	ReconCycle
3.1	Clustered project short abstract (up to 100 words)	Self-reconfiguration of a robotic workcell for the recycling of electronic waste It is about developing an industrial robotic cell which is able to automatically detect and extract battery from electronic waste, and successfully remove it, so that this waste is recycled more easily. Currently this job is done manually, but it would be nice if it is automated. Project use robotic arms, machine vision and artificial intelligence.
4	Clustered project web site	http://reconcycle.eu/
5	Contact person	Aleš Ude, IJS Ljubljana
6	Type of clustering project	☒H2020 ☐National ☐EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☒Web ☐Workshop ☐Conference ☐Business network ☐Seminar ☐Other (please specify):
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	self-configuration, artificial vision, AI, robotic arms
9	Description of common challenge(s) addressed (up to 100 words)	We are doing a bit different thing - ReconCycle project is using available components to finish up with the application on higher TLR level, while ROBOMINER is much more technically challenging and will finish on lower TLR. Some components, like self-repair, use of robotic arms, AI, object detection etc. could be similar.
10	Main expected results of clustering activity (up to 100 words)	maybe joint seminar/conference organisation (similar as we have in Bled in 2018), networking, future joint proposals

No.	Item	Description
1	Who (performed clustering)	Luís Lopes (LPRC)
2	Date of clustering	16.4.2020
3	Clustered project acronym	X-MINE - Real-Time Mineral X-Ray Analysis for Efficient and Sustainable Mining
3.1	Clustered project short abstract (up to 100 words)	The project will implement large-scale demonstrators of novel sensing technologies improving the efficiency and sustainability of mining operations based on X-Ray Fluorescence (XRF), X-Ray Transmission (XRT) technologies, 3D vision and their integration with mineral sorting equipment, drill core analysis prototypes and mine planning software systems.
4	Clustered project web site	http://www.xmine.eu/
5	Contact person	Janne Paaso
6	Type of clustering project	☒H2020 ☐National ☐EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☒Web ☐Workshop ☐Conference ☐Business network ☐Seminar ☐Other (please specify)
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	Mine planning; mineral sorting; mineral analysis; 3D modelling; drill core analysis
9	Description of common challenge(s) addressed (up to 100 words)	The X-Mine project is developing mineral analysis methods, mineral sorting and 3D modelling of mineral deposits. The mineral analysis methods could be integrated in the Robominers robot in the future to do mineral analysis on-the-job. Mineral sorting could also be a part of the robotic solution in the future. Advanced X-Mine drill core analysis combined with 3D modelling yields much better characterization of mineral deposits. This information could be used in planning the use of the robots developed in the Robominers project.
10	Main expected results of clustering activity (up to 100 words)	The X-Mine project (TRL level up to 8) and the Robominers project (TRL level up to 4) are quite far from each other in terms of TRL levels. Probably the most important result from the clustering activity could be to generate ideas related to the future of mining. As the mineral deposits become poorer, smaller, more complex or otherwise challenging, the need for technological advances increases. For example, drill core scanning and advanced 3D modelling methods could also be used to figure out the best mining and processing methods for a new prospect. A mineral deposit deemed to be uneconomic to exploit might turn out profitable if a combination of on-site mineral analysis, robots and mineral sorting would be used.

No.	Item	Description
1	Who (performed clustering)	Luís Lopes (LPRC)
2	Date of clustering	05/10/2020
3	Clustered project acronym	Dig_IT - A Human-centred Internet of Things Platform for the Sustainable Digital Mine of the Future
3.1	Clustered project short abstract (up to 100 words)	The objective of the project is the development of an Industrial Internet of Things platform (IIoTp) that collects data from the mining industry (data sources: humans, machines, environment and market) and transform them into knowledge and actions aimed at improving the worker health and safety, improving the operations efficiency and minimizing the environmental impact of mining.
4	Clustered project web site	http://digit-h2020.eu/
5	Contact person	María García-Camprubí (Project Coordinator)
6	Type of clustering project	☒H2020 ☐National ☐EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☒Web ☐Workshop ☐Conference ☒Business network ☐Seminar ☐Other (please specify):
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	Digitalization of mining operations. Challenges in sensing and communication systems in mining environment.
9	Description of common challenge(s) addressed (up to 100 words)	Dig_IT project is highly focussed on improving health and safety in the mining industry. ROBOMINERS proposes a solution to enable the exploitation of difficult to access deposits, while avoiding workers health risks.
10	Main expected results of clustering activity (up to 100 words)	The ROBOMINERS control software could be embedded in the Dig_IT IIoT platform. Dig_IT end-users are potential end-users for the ROBOMINERS solution (robots).

No.	Item	Description
1	Who (performed clustering)	Michael Berner (MUL)
2	Date of clustering	08.04.2020
3	Clustered project acronym	SafeDeepMining
3.1	Clustered project short abstract (up to 100 words)	SafeDeepMining addresses the shortage of rock engineering personnel in the European mining industry. The emphasis of the education program is on the application of rock engineering principles in the mining industry to make deep mining operations safer and more efficient. It provides the participants with the basic knowledge and skills required to address and solve practical rock engineering problems.
4	Clustered project web site	http://www.safedeepmining.eu/
5	Contact person	Nikolaus A. Sifferlinger Nikolaus-august.sifferlinger@unileoben.ac.at
6	Type of clustering project	☐H2020 ☐National ☒EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☐Web ☐Workshop ☐Conference ☒Business network ☐Seminar ☐Other (please specify)
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	Rock mechanics, rock pressure, support systems, safe mining, underground mining, deep mining,
9	Description of common challenge(s) addressed (up to 100 words)	Mining for critical raw materials is going deeper in underground mining, stable roof conditions is important for both mining with human operators and robots. Know-how necessary in both projects can be shared.
10	Main expected results of clustering activity (up to 100 words)	Networking with researchers and industry active in mining. Exchange ideas on safe deep mining operation. Robots will enable in the future to remove humans from dangerous and unhealthy working places.

No.	Item	Description
1	Who (performed clustering)	Luís Lopes (LPRC)
2	Date of clustering	23/04/2020
3	Clustered project acronym	UNDROMEDA: Underground Robotic System for Monitoring, Evaluation and Detection Applications
3.1	Clustered project short abstract (up to 100 words)	The project aims to develop a robotic underground measurement system for autonomous 3D mapping and monitoring. The system is based on a wheel-driven platform which additionally carries a flying drone to approach difficult to access, or hazardous areas in underground environments reducing the risk for personnel by replacing manual measurements. It will strongly enhance the quality of information while significantly reduce time expenditure and costs.
4	Clustered project web site	https://eitrawmaterials.eu/project/undromeda/
5	Contact person	Karsten Zimmerman
6	Type of clustering project	☐H2020 ☐National ☒EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☒Web ☐Workshop ☐Conference ☐Business network ☐Seminar ☐Other (please specify)
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	Underground mining; autonomous 3D mapping; monitoring; drones
9	Description of common challenge(s) addressed (up to 100 words)	Autonomous underground navigation of a robot implementing 3D SLAM with data fusion
10	Main expected results of clustering activity (up to 100 words)	Knowledge and approach exchange in this field, networking, project visibility

No.	Item	Description
1	Who (performed clustering)	Norbert Zajzon (UNIM)
2	Date of clustering	16th of April 2020
3	Clustered project acronym	UNEXUP – UNEXMIN Upscaling
3.1	Clustered project short abstract (up to 100 words)	Making the exploration of flooded mines a reality The UNEXUP project, funded under EIT RawMaterials, is a direct continuation of the Horizon 2020 UNEXMIN project. While in UNEXMIN efforts were made towards the design, preparation and testing of an innovative exploration technology for underground flooded mines, in UNEXUP the objective is to launch the UNEXMIN technology into the market, while further improving the system's hardware, software and capabilities.
4	Clustered project web site	https://www.unexmin.eu/unexup/
5	Contact person	Norbert Zajzon
6	Type of clustering project	☐H2020 ☐National ☒EIT RawMaterials ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☐Web ☐Workshop ☒Conference ☐Business network ☐Seminar ☒Other (please specify) Project writer
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	communication, navigation, rough environment, energy source, miniaturisation, sensing
9	Description of common challenge(s) addressed (up to 100 words)	Navigation: difficult, many times unknown 3D map, with many times unstructured walls and cavities which can be small or large in a GPS-less environment. Visibility easily can be bad. No effective communication can be managed without cable in this environment in the size the projects work. High chance to get stuck and/or lost, or run out of battery. In-situ sensing thru water in pressurized environment is difficult.
10	Main expected results of clustering activity (up to 100 words)	With joint efforts well distributed and communicated the common challenges can have better solutions. Realising synergies and submitting proposals for common interest.

No.	Item	Description
1	Who (performed clustering)	Vitor Correia (EFG)
2	Date of clustering	09/04/2020
3	Clustered project acronym	COGITO-MIN - COst-effective Geophysical Imaging Techniques for supporting Ongoing MINeral exploration in Europe
3.1	Clustered project short abstract (up to 100 words)	Aims at comprehensive methodological advances in the use of seismic imaging for mineral exploration in Europe and beyond. We acknowledge also the need for well-integrated geophysical and geological approaches and aim at developing joint analyses of different data. The overall goal is to develop integrated geophysical-geological approaches for building realistic 3D geological models, delineation of known deposits and new reliable drilling targets.
4	Clustered project web site	https://www.era-learn.eu/network-information/networks/era-min/the-third-era-min-joint-call-2015/cost-effective-geophysical-imaging-techniques-for-supporting-ongoing-mineral-exploration-in-europe
5	Contact person	Emilia Koivisto, University of Helsinki
6	Type of clustering project	☐H2020 ☐National ☐EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☒ERA-MIN
7	Where did you find out about this project	☐Web ☐Workshop ☐Conference ☐Business network ☐Seminar ☐Other (please specify)
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	Seismic imaging; integrated geophysical/geological approaches; perception technologies.
9	Description of common challenge(s) addressed (up to 100 words)	Integration of geophysical and geological data.
10	Main expected results of clustering activity (up to 100 words)	

No.	Item	Description
1	Who (performed clustering)	Vitor Correia (EFG)
2	Date of clustering	28.08.2020
3	Clustered project acronym	Not applicable
3.1	Clustered project short abstract (up to 100 words)	Nordgold is LSEG diversified gold producer with operation assets in Russia, Kazakhstan, Burkina Faso, Guinea and Canada. Nordgold is one of the most advanced mining companies in terms of digital transformation and innovation.
4	Clustered project web site	http://nordgold.com/
5	Contact person	Evgeny Tulubensky
6	Type of clustering project	☐H2020 ☐National ☐EIT RM ☒Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☐Web ☐Workshop ☐Conference ☒Business network ☐Seminar ☐Other (please specify)
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	Operation in harsh environments, selective small-scale mining.
9	Description of common challenge(s) addressed (up to 100 words)	Research challenges concerning scalability, resilience, re-configurability, self-repair, collective behaviour, operation in harsh environments, selective mining, production methods as well as for the necessary converging technologies on an overall mining ecosystem level.
10	Main expected results of clustering activity (up to 100 words)	Nordgold shows interest in supporting Robominers testing in real mining environments.

No.	Item	Description
1	Who (performed clustering)	Stephen Henley, Mike McLoughlin, Norbert Zajzon, Zorana Milosevic (RCI, UNIM, UPM)
2	Date of clustering	2/6/2020 and 18/6/2020 (two webinars)
3	Clustered project acronym	PIPEBOTS
3.1	Clustered project short abstract (up to 100 words)	PIPEBOTS is a UK EPSRC-funded multi-university project to develop autonomous robots for inspection of water and sewage pipes
4	Clustered project web site	http://pipebots.ac.uk/
5	Contact person	Dr Kirill Horoshenkov, Dr Jonathan Aitken, Prof. Lyudmila Mihaylova, and others
6	Type of clustering project	☐H2020 ☒National ☐EIT RM ☐Industrial ☐GeoERA ☐other (please specify) ☐ERA-MIN
7	Where did you find out about this project	☐Web ☐Workshop ☐Conference ☐Business network ☐Seminar ☒Other (please specify) initial introduction by Dr Kirill Horoshenkov, member of advisory board of UNEXMIN project
8	Clustering main points, common challenges (keywords, eg miniaturisation, navigation)	communications, sensors, autonomy/SLAM, navigation, software, photogrammetry
9	Description of common challenge(s) addressed (up to 100 words)	• Communication – ultrasound, light, radio frequencies (Pipebots will not be tethered) • Sensor development – Pipebots requirements in particular for miniaturised sensor devices including acoustic/sonar units • Autonomy and SLAM applications (in particular we identified similar problems of unreliable prior base maps – old water-pipe and sewage networks, surveys of abandoned mines) • Navigation • Software – Pipebots almost certainly using ROS1, no plans to move to ROS2. They are also considering simpler solutions on Raspberry Pi or stand-alone microprocessors • Photogrammetry for point-cloud extraction and processing
10	Main expected results of clustering activity (up to 100 words)	Research collaboration on identified areas of common interest as listed in (9) above