UNEXMIN DELIVERABLE D8.9

RESEARCH ROADMAPPING WORKSHOP

Summary:

This report documents the first workshop related to the UNEXMIN research roadmapping process. The workshop was held in Bled, Slovenia, on the 30th of January, 2018.

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1 Executive summary

This deliverable documents the first UNEXMIN research roadmapping workshop related to the kick-start of the roadmapping exercise that is one of the tasks of Work Package 8. Since a new technology line of use of robotics in mining will be developed and marketed within the UNEXMIN project, such research roadmapping activities are the key points to evaluate its "policy push/market pull" potential. The workshop provided useful information on possible future updates of the UNEXMIN technology components, related to software and hardware, on the short (5 years period), medium (15 years period) and long-term (30 years period) and collected inputs on the future of the technology considering different scenarios for raw materials in Europe. The outcomes of this workshop, where the first draft of possible technology updates were created, will feed the next roadmap activities and allow the development of the research roadmapping process. The entire process will be documented in Deliverable 8.16 – Research Roadmap.

2 Introduction

The mining sector is facing a series of challenges, from lower ore grades to extreme operating conditions such as increasing depth and more complex mineralizations. In consequence, there is a need for more innovative technologies to be developed in order to surpass the barriers the mining sector encounters - and the UNEXMIN project can respond to many of these challenges.

The UNEXMIN project will develop a new technology line focused on developing autonomous surveying units for geological exploration, with large potential for future improvements. Enhanced functionalities (more sophisticated sensor array including the integration of geophysical instruments for mineral exploration), further downsizing, the deployment of a heterogeneous swarm approaches of surveying robots with distributed task allocation, the implementation of various sampling functions, integration of low-impact drilling and methods, integration of different locomotion techniques etc., are just some of the possible future research pathways in the context of the UNEXMIN technology. All of these will need to take into account the potential future of the mining sector, which is very tightly linked with the demand of mineral raw materials from society. Not only quantity, quality, and variety of future demand, but also future social acceptance to extract minerals, future environmental constraints, future global politics etc., are all relevant questions to be addressed. The challenge is also linked to the funding sources of such research areas, either coming from governmental bodies or the private sector. All of such questions need to be addressed in order to plan mid- and long-term future activities of the spin-off company resulting from the UNEXMIN project.

To further advance technologies and map future activities, companies or projects recur to a technique known as “Technology Roadmaps". Roadmapping activities such as e.g. workshops allow paths to be planned and executed to reach a desired goal. In the end of the process, a roadmap connects strategies and future actions and creates a plan for needed capabilities and technologies to be in place at the right times.

Highly innovative solutions require a strategic, forward-looking assessment for leveraging its main functionalities and potential. The research roadmapping for the UNEXMIN project will determine possible research pathways for the multiple components that constitute the technology. The identified research areas, that can lead to an improvement of hardware and software and their traced pathways, can then be pursued by the spin-off company once the project lifetime is over, guaranteeing the adaptation and evolution of the technology to the future market conditions.

To kick-start the research roadmapping activities, a workshop was held in Bled, Slovenia, on the 30th of January 2018 in the context of the “Use of Robotics and automation for mineral prospecting and extraction” event. During the workshop, a mix of participants coming from different EU-projects with expertise in different areas, from the raw materials to robotics, contributed to the first discussions regarding the present and future research and technology possibilities for the UNEXMIN project.

3 Research Roadmapping Workshop, Bled, Slovenia

3.1 General information

The workshop was a part of the larger event "Use of robotics and automation for mineral prospecting and extraction", organized by the Geological Survey of Slovenia (GeoZS) from 29.1.2018 to 30.1.2018. This was a joint conference organized by the UNEXMIN, ¡VAMOS! and RTM projects, where the main aim was to inform about latest development in the field of using robotics and automation for mineral resources prospection and extraction. In total, 85 delegates participated on this event. Beside consortium members from the three aforementioned projects, approximately 30 experts from across Europe participated at the event, representing industry, SMEs, research organizations, universities and other educational institutions, and governmental bodies.

The afternoon part of this conference on the day 30.1.2018 was composed of two parallel workshops. One workshop was dedicated to the technological exploitation (lead by GeoZS) and the second one to research roadmapping, led by La Palma Research Centre (LPRC). The conference participants were split into two groups by GeoZS and LPRC to assure a good mix of expertise among the participants coming from a variety of organizations on both workshops. All workshop participants were introduced to all three projects on a plenary session before the workshops.

The interactive roadmapping workshop was divided into two different sessions and lasted for approximately three hours. Twenty-two participants (see Annex), including UNEXMIN and ¡VAMOS! consortium partners and external experts from the fields of robotics, technology provision and mineral raw materials, were present and contributed to the development of the exercise.

3.2 Goals

The main proposed objective of the research roadmapping workshop was to initiate discussions about future research possibilities for the UNEXMIN project, especially related to the software and hardware components that make the core of the in-development technology. Another goal was to receive input from the project partners and experts, concerning short, medium and long-term strategic goals for the UNEXMIN project.

3.3 Methods

Two distinct methods were pursued during the workshop: The first one involved the use of future raw materials scenarios developed within the EU-funded project INTRAW (INTRAW World of Raw Materials Scenarios for 2050[1]). The second one focused on a technology-gap analysis, together with an evaluation of future research and technology opportunities to be pursued by the UNEXMIN consortium partners. This exercise focused in two different fields: Geological data collection and exploration, and Navigation and spatial awareness.

[1] http://intraw.eu/the-world-of-raw-materials-2050/

4 Outcomes of the workshop

4.1 Future raw materials scenarios exploration (INTRAW World of Raw Materials Scenarios for 2050) – part 1

The scenario exploration exercise was undertaken during the first part of the roadmapping workshop. The future scenarios developed by the INTRAW project were used as a backdrop to assess how the UNEXMIN technology would behave on the different conditions presented by specific scenarios.

During this exercise, participants were asked to make comments and/or suggestions on possible future opportunities and/or challenges that the UNEXMIN technology might face in light of the conditions envisaged by the different scenario situations. Each scenario presents a set of conditions that are related to society, technology, economy and policy aspects involving the mineral raw materials sector until the year 2050.

The three INTRAW scenarios are resumed below (data taken from the INTRAW project webpage). During the workshop, participants had access to the INTRAW project material which detailed the three different scenarios.

1) **Sustainability alliance[2]:** In 2050, the circular economy has become the norm in the big advanced economies. A new generation of political leaders has pushed forward a series of reforms that focus on increasing sustainability, not only in the raw materials industry. Almost every product is produced in an environmentally-friendly way with the aid of green technologies. The civil society puts sustainability above everything else to keep deposits for future generations.

Figure 1: Sustainability Alliance scenario

2) **Unlimited trade[3]:** In 2050, the world of raw materials has experienced steady growth, mainly due to ever-growing consumption. International cooperation and dialogue have created new opportunities to produce and trade raw materials. Access to

[2] http://intraw.eu/about-the-project/scenario-1-sustainability-alliance/
[3] http://intraw.eu/scenario-2-unlimited-trade/

capital has led to industry integration, technology development and productivity improvements alike. Increased global consumption leads to a growth in the raw materials sector.

Figure 2: Unlimited Trade scenario

3) **National Walls[4]:** In 2050, the world of raw materials got stuck as social and demographic pressures triggered a long period of economic standstill, which lead to a rise of protectionist measures. The absence of leadership and insufficient political will did not help to improve the situation. Each country fights for its own agenda. There is little progress in mining practices as reforms have stalled and private investments are low. Economic standstill gives rise to nationalist politicians and protectionist measures.

[4] http://intraw.eu/scenario-3-national-walls/

Figure 3: National Walls scenario

Considering the above statements and the possible changes envisaged for each future scenario, the workshop participants then made statements regarding the UNEXMIN technology on a scenario basis. A summary of the comments gathered for each of the scenarios, as well as general horizontal comments that apply to all scenarios, can be found in Table 1 and the Annex.

Table 1: The prospect of the UNEXMIN technology in light of the future raw materials scenarios of the INTRAW project, as seen from the participants' perspective.

Scenario	**Specific scenario statements**	**General statements**
Sustainability Alliance	1. The UNEXMIN technology is used at large scale - in re-exploring abandoned mines to only get the materials needed. There are joint research funds made available from different countries to further develop the technology; 2. Abandoned mines have a second life and opportunities arise for the UNEXMIN technology such as environmental security assessments, geothermal exploration, high-tech laboratories, optimized exploration, multiple commodity mining; 3. Due to advancements in areas such as recycling and design of	1. Further development of the UNEXMIN technology will always be necessary: more/better sensors, more autonomy, etc. 2. There are opportunities to connect the mining industry with other sectors for further development and improvement of the UNEXMIN technology; 3. Innovation in mining is a cultural problem - resistance in innovation can limit UNEXMIN technology applications.

	new components, the UNEXMIN technology can become obsolete.	
Unlimited Trade	1. A bigger market means more applications for the UNEXMIN technology; 2. Demand in raw materials creates problems in adopting UNEXMIN technology, as the technology might not be ready to be applied at a large scale; 3. Short-term view from industry makes the technology fail;	
National Walls	1. The UNEXMIN technology provides economic opportunities for users; 2. Extreme interest in exploring abandoned mines facilitates the use of UNEXMIN technology; 3. Forcing towards innovation made by countries/country blocks benefits the implementation and upgrading of the UNEXMIN technology; 4. Slower advance in sensors' development limit the use of the technology.	

This exercise showed that the UNEXMIN technology is conceptualized as a viable technology by the experts in face of the future scenarios. It also shows, as seen by the different comments made by the experts, that the technology can have a positive impact in the raw materials sector, with numerous applications. However, there are conditions and challenges that might arise, limiting the spread and use of the technology in the market, or even making it economically or technologically unfeasible (e.g. slower advance in sensors' development limit the use of the technology). It is transversal to all participants that the technology needs to be further upgraded in order to fit under all the envisaged applications. The final UNEXMIN roadmap will outline the future research possibilities for the robotic technology.

5.2 Technological gap analysis & future research and technology possibilities – part 2

The second part of the workshop consisted of the technological gap analysis. Participants were divided into three groups. In these groups, the current and future state of research/technologies in some selected fields were assessed. These fields were:

- Geological data collection,
- Navigation and spatial awareness and
- Extraction of mineral raw materials.

Only the first two fields are relevant for the UNEXMIN project, whereas all of them are relevant to the ¡VAMOS! project, and therefore they are the ones mentioned hereupon. This exercise focused on evaluating the present state of the UNEXMIN technology components related to each field, the short-, medium-, and long-term (30 years) research opportunities as well as technology possibilities and finally, the strategies to reach them.

a) Geological data collection:

The exercise related to geological data collection focused on identifying fields of potential improvement of the UNEXMIN technology over short-, medium to long-term time-scales (spawning from 5, 15 and 30 years, respectively), considering current and future developments in those same fields. These fields are envisaged to improve the geological data collection by the UNEXMIN robotic platform. In this context, four main areas were defined: geological modelling (short-term future), integrated geophysical methods (mid-term future), sampling (mid-term future) and, finally, improvement spectroscopy in resolution and processing (long-term future).

Main inputs from the exercise are drawn on Table 2 and the Annex.

Table 2: Technological gap analysis, future research and technology possibilities for UNEXMIN – Geological data collection.

	Short-term ⟷ **Long-term**			
Field of development	Geological modelling (micro, mid and megascale)	Integrated geophysical methods (megascale)	Sampling (medium scale)	Spectroscopy upscaling (micro scale) - resolution & processing
Benefits of implementation	• Augmented reality analysis • Better structural geology • 3D/4D restauration	• Well logging • 3D seismic potential • 3D component gravity	• Extended spatial sampling (e.g. lake sampling) • Water sampling in-situ measurements • On-site sampling and analysis • Smaller sample sizes	• Reduction in size and price • Better position system • Better detection limit • Amount of data • Reduced data noise

Pathway	• Better concepts for geological mapping • Better capacity/computing • Better and faster software	• Better capacity/computing • Progress in inversion • Demonstrative examples	• Drones • Automation • New sample protocols	• Better capacity/computing • Better and faster software • Improvement in sensors technology • Application of technologies from other fields

The areas of research and technology identified during this exercise can be translated in better, faster and more precise geological data acquisition than what is currently seen in available technological solutions. This is mainly due to technological limitations faced at present times. As geological data collection and its further interpretation is an essential functionality of the UNEXMIN technology, these areas can greatly improve it. Together with the research and technology fields identified, also their envisaged benefits and pathways were pre-mapped (as seen in Table 2).

The participants considered that there is no real priority in which improving and implementing certain technologies into UNEXMIN should be done because all areas are of considerable importance in order to obtain the most valuable geoscientific data possible from flooded mine environments.

b) Navigation and spatial awareness:

The Navigation and spatial awareness group participant focused on two different, although complementary dimensions: Hardware and software. The evaluated hardware components included Laser, 3D/LIDAR, cameras, GNSS (Global Navigation Satellite Systems), acoustic, communication, locomotion, and IMUs (Inertial Measurement Units). The software components considered were the SLAM (Simultaneous Localization and Mapping)/sensor fusion, real-time mine models, information management and decision-making systems, and artificial intelligence (AI).

Main inputs from the exercise can be seen on Table 3 and Annex 1.

Table 3: Technological gap analysis, future research and technology possibilities for UNEXMIN – Navigation and spatial awareness.

	Current state	**Short-term**	**Long-term**	**End-state (2030+)**
Hardware				
1 - Laser 3D/Lidar	• Available for U/W		-2x resolution -2x range	-5x resolution
2 - Cameras	• 8k in film industry	• 8k cameras		
3 - GNSS	• GNSS-denied environments (tunnels, etc.)	• Short baseline systems improved accuracy • Improved coverage	• Reduce costs • Flexibility • U/W adaptation	
4 - Acoustic	• M/R Sonar • Good resolution / Range	• Size reduction (depending on application)		
5 - Communication	• Acoustic • LI-FI • Wi-Fi • Cables	• Size reduction • Bandwidth	• Through-the-rock communications	• U/W inter-robot communic. (Wi-Fi, camera-like) • U/W C2 (command and control)
6 - Locomotion	• Propellers/Jets • Caterpillars	• Dual means (legs/wheels)		• Multiple means • Biomimetic • Metamorphic
7 - IMUS	• Drift is a big problem			• No drift
Software				
A – SLAM/Sensor fusion	• CPU intensive	• Google says it is a problem solved, but not true for U/W - uncertainty	• Integrated in HW • Semantic SLAM • Topological mapping	• Sub-mm accuracy
B - Real Time Mine Models				• Model delivered to C2 station
C - Information Mgmt. System / Decision-making systems				
D - Artificial Intelligence	• Fault tolerance	• Self-awareness		• Opportunistic Science

The potential future components identified from both the software and hardware sides may become essential parts of the UNEXMIN technology. Their possible future state, including future research and technology opportunities, will mean great improvements in the navigation and spatial awareness systems currently on the UNEXMIN technology. Advances in the components that constitute the bulk of these fields can transversely improve the UNEXMIN technology, towards better and faster exploration and mapping of flooded mine environments.

5 Next steps in the research roadmap development

The research roadmapping exercise for the UNEXMIN project aims to deliver a strategic research plan, focusing on future research and technology priorities for hardware and software components. Ultimately, this will be translated into an upgrade of the overall technology. The final roadmap shall deliver a list of actions and pathways drawn in a timely ordered and prioritized manner that lead to the desired improvement.

The scenario workshop – to which this report refers – intended to provide a background to kick-start discussions for the near, medium and long-term future development of the components that make the UNEXMIN technology. Other roadmapping tools will be applied from now on to ensure that discussions are continued. In the end, it is envisaged that the activities pursued during the roadmapping exercise lead to possible disruptive research/technology areas that can influence the further development of the technology. Some possible research and technology areas have already been pre-identified by the consortium. They include:

- Enhanced functionalities;
- Further downsizing;
- Deployment of a heterogeneous swarm of surveying robots with distributed task allocation;
- Implementation of sampling functions;
- Implementation of low-impact drilling.

These and other areas of technology and research will be mapped, and pathways outlined to achieve them. The research challenges will also be identified. They are related, as previously pinpointed by the consortium, to needs of dedicated funding instruments and/or industry financing. The UNEXMIN research roadmap will address these points together with further identified research topics that require R&D support in the near future.

The final outcomes of the UNEXMIN research roadmap will be detailed in Deliverable 8.16 – Research roadmap, due in Month 40 (date).

Annex

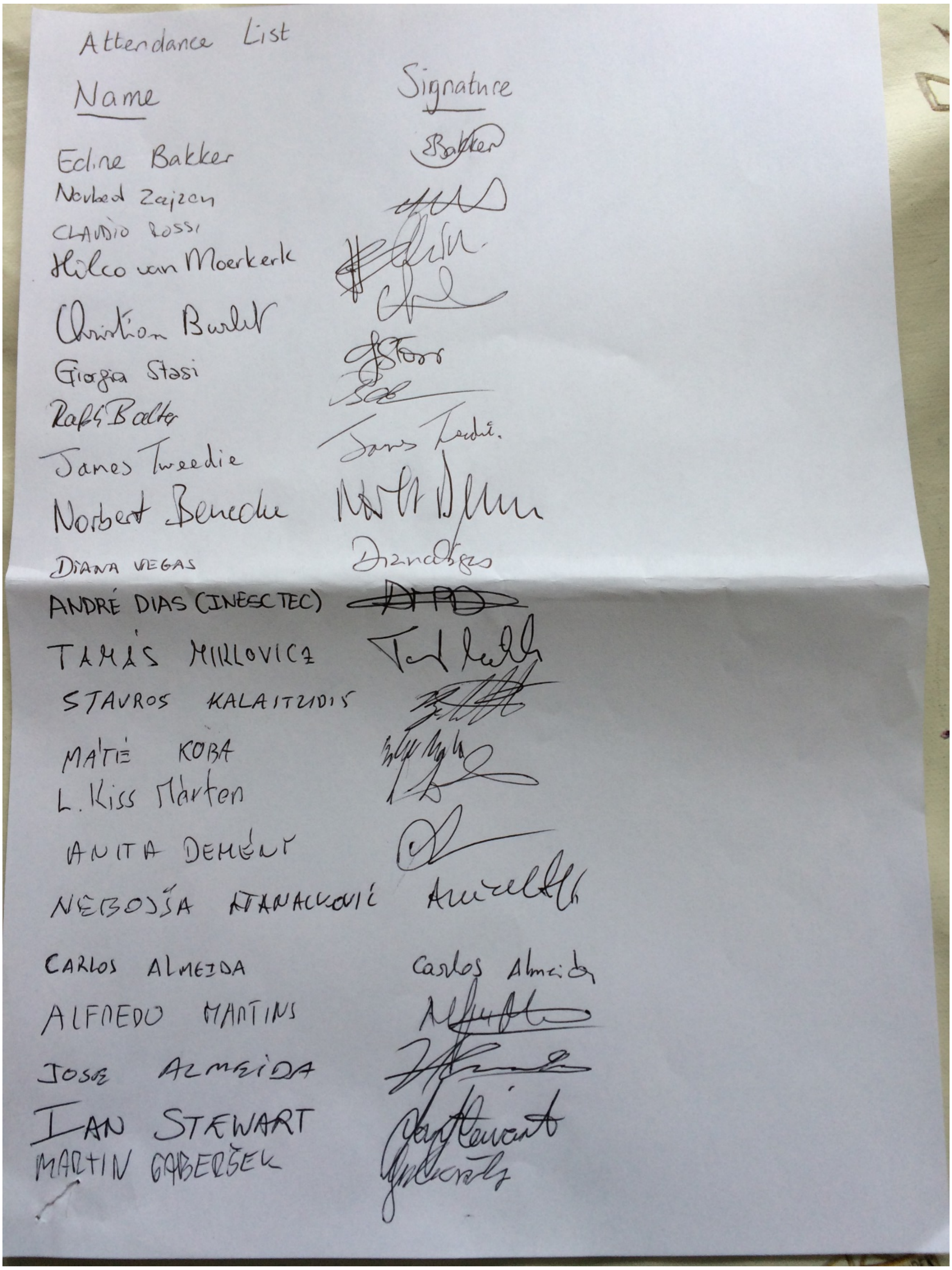

Figure A1: List of participants from the Research Roadmap Workshop

Figure A2: Research roadmapping workshop, part 1: UNEXMIN at the light of future scenarios (INTRAW World of Raw Materials Scenarios for 2050) discussion

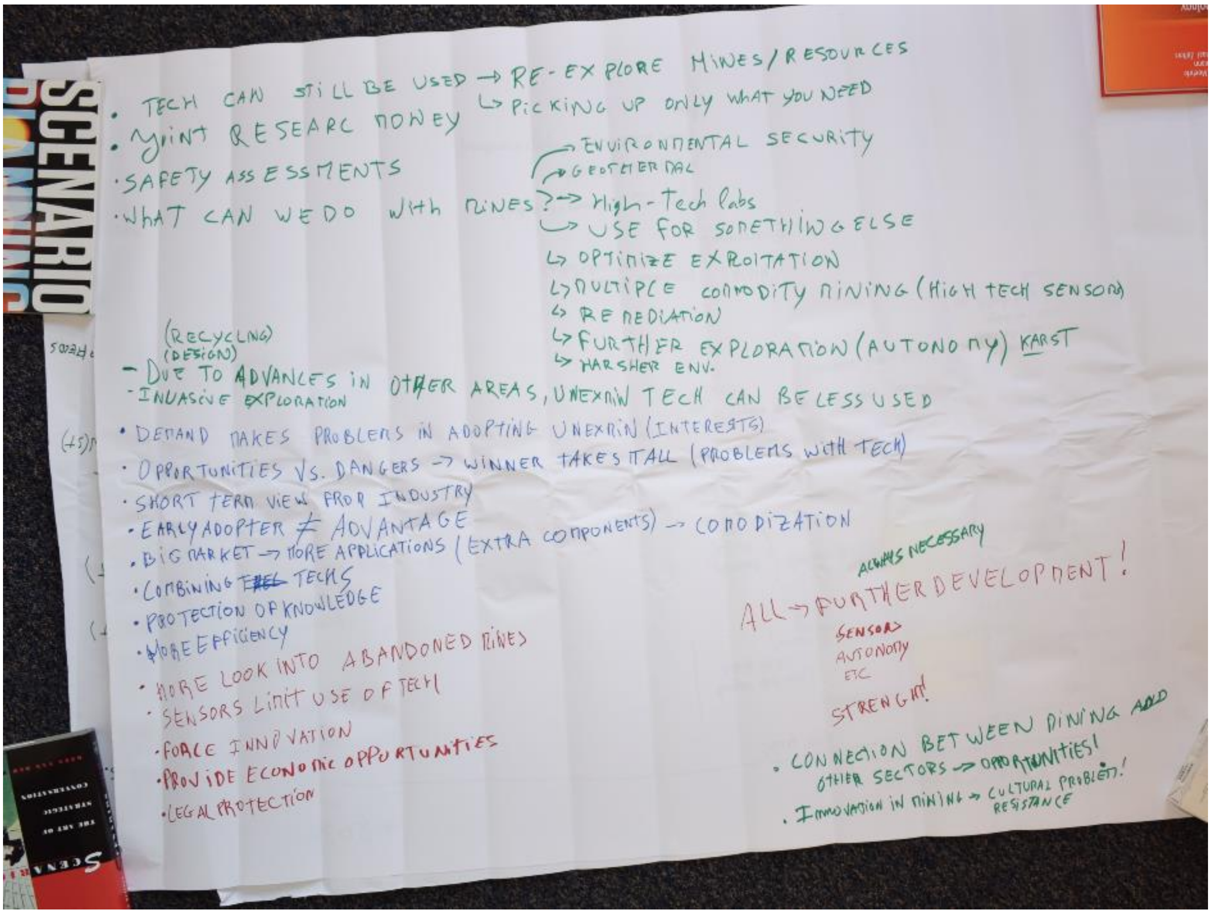

Figure A3: Research roadmapping workshop, part 1: UNEXMIN at the light of future scenarios (INTRAW World of Raw Materials Scenarios for 2050). Color code: green – Sustainability Alliance scenario; blue – Unlimited trade scenario; Red – National walls scenario.

Figure A4: Research roadmapping workshop, part 2: Geological data collection discussion

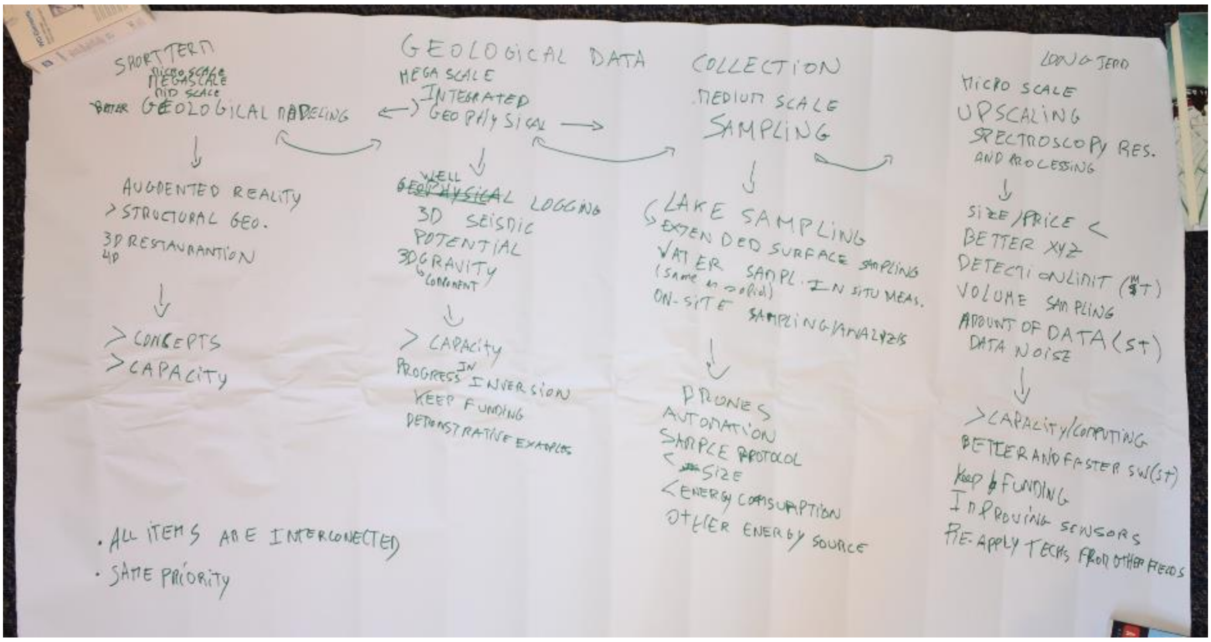

Figure A5: Research roadmapping workshop, part 2: Geological data collection – present and future status

Figure A6: Research roadmapping workshop, part 2: Navigation and spatial awareness discussion

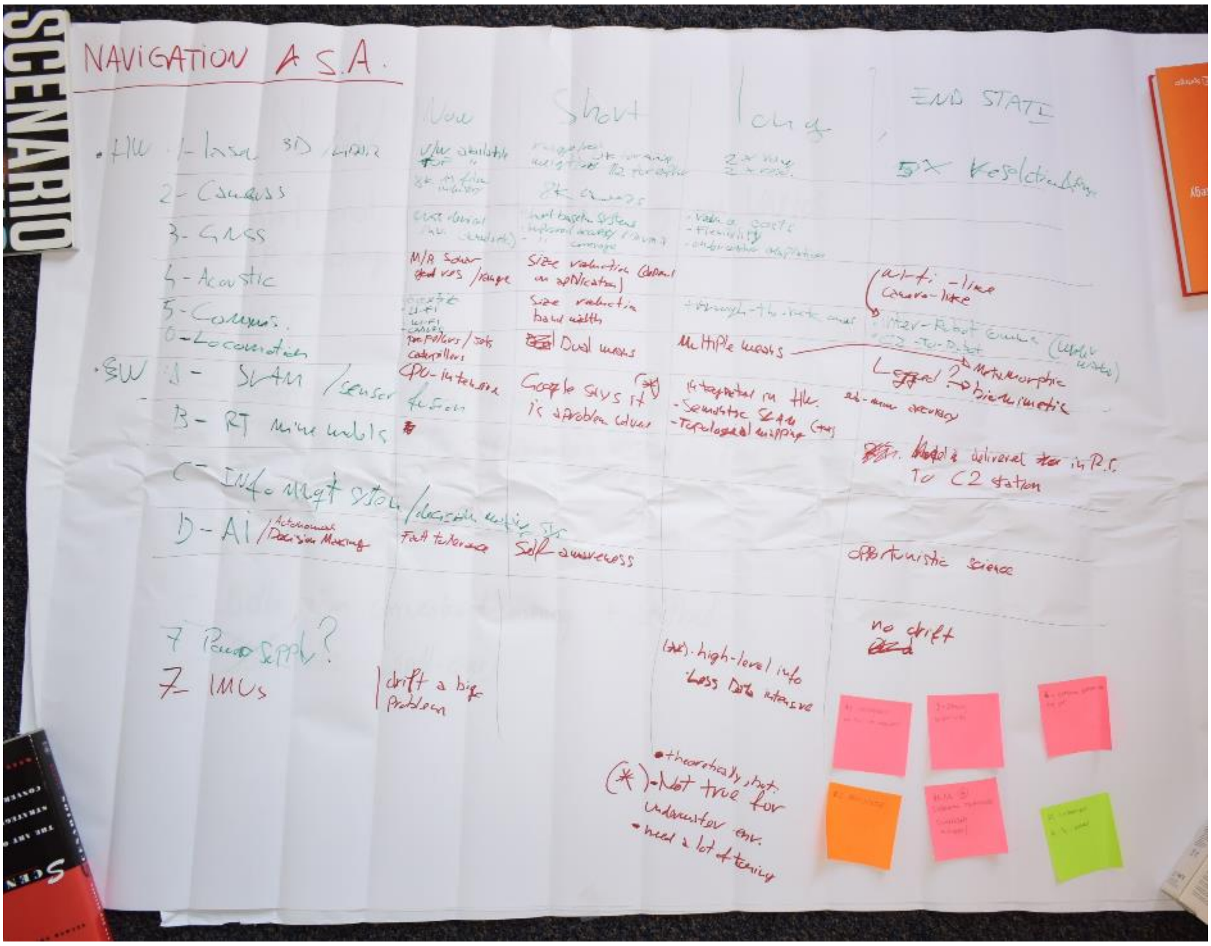

Figure A7: Research roadmapping workshop, part 2: Navigation and spatial awareness – present and future status