Raw Materials Session MoM

Meeting Date	08.10.2024	Time	14:00-18:00
Meeting Called By	EUSPA	Location	Webex (remote event)
Minutes Taken By	N/A	Next Meeting Date	N/A
Attendees	**Alba German, EUSPA** **Eduard Escalona, EUSPA** **Moritz Kirsch, HZDR** **René Booysen & Alexander Bergstrom, Nordic strategy partners** **Erik Ronne, Boliden** **Luke Hopkins, Picterra with ERAMET** **Veronika Kopačková-Strnadová, Czech Geological Survey** **Lorenzo Solari, EEA** **Dr. Ignacio Marzan, CSIC-IGME** **Dr. Sean Salazar, NGI, MINEYE** **Marco Bianchi, Tre – Altamira** **Michele Crosetto, CCTC** **User Community Representatives (UCRs)** Complete list of attendees is in Annex 1.		
Distribution (in addition to attendees)	UCP Plenary, EUSPA, Public		

Agenda Items	Presenter
Raw Materials	
1. Welcome and introduction of the Raw Materials Panel	Eduard Escalona and Alba German (EUSPA). Dragos Bratasanu (EY).
Roundtable: Environmental Impact Monitoring for Mines	
2. *Results or MOSMIN project and market research.*	Moritz Kirsch (HZDR), René Booysen & Alexander Bergstrom (Nordic strategy partners) Erik Ronne (Boliden).
3. *Water management planning for mines*	Luke Hopkins (Picterra) **and Hani Zahiri** (ERAMET)

4. ***Efficient Earth Observation System for Acid Mine Drainage Monitoring with focus on Sentinel-2 data integration***	Veronika Kopačková-Strnadová, Czech Geological Survey
Roundtable Discussion	Coordinated by René Booysen (HZDR) and Alba German (EUSPA).
Roundtable: Mining Site Exploration, Planning, and Monitoring	
5. **European Ground Motion Service**	Lorenzo Solari (EEA)
6. ***Ground stability monitoring at the Rio Tinto mine using Sentinel-1.***	Ignacio Marzan (CSIC-IGME)
7. ***MINEYE Earth Observation Techniques for Mine Life Cycle Monitoring using ML Data Fusion Approach***	Sean Salazar (NGI)
8. ***InSAR products for Open Pit Mines***	Marco Bianchi (Tre – Altamira)
9. Conclusions and closing remarks	Coordinated by Sara Kasmaeeyazdi (UNIBO) and Alba German (EUSPA)

Summary

The Energy and Raw Materials panel of the User Consultation Platform (UCP) 2024 took place on 8th October 2024 as a fully remote event. The panel gathered around 70 participants coming from industry, research as well as from European Institutions, covering a wide spectrum of the market segment.

The panelists gave presentations of their applications, how they use satellite technologies (EO) and what their specific requirements are. This broad coverage generated interest from the participants and helped start good interactions with the attendees with questions and comments.

The most commented topics were the following:

10. Overall, Earth Observation technology holds significant potential in the Raw Materials sector. However, one key challenge is the high cost for users. Service providers often need to purchase high-resolution data which comes at a premium. This drives up the cost of the final product for end users. Another major hurdle is gaining trust in the reliability of EO-derived data, particularly within the mining and exploration sectors. Clients are often hesitant to fully rely on EO data, preferring ground sensor data instead. However, these ground-based data sources are often not compatible or easily integrated with EO data, complicating the adoption of EO technologies.

11. It was noted that while Sentinel-2 spatial resolution is adequate, the sensor was not specifically

designed for mineral mapping, meaning it lacks the optimal spectral bands for this application. However, the upcoming launch of the Copernicus Hyperspectral Imaging Mission (CHIME) is expected to make significant advancements in this area.

12. It was also highlighted that access to Copernicus data is transforming the life cycle of mining operations. From exploration and extraction to post-mining activities, including tailings management, environmental monitoring, and the monitoring of mining hazards and ground deformation, Copernicus is playing a key role in reshaping how these processes are managed.

The following challenges were identified in the Raw Materials sector:

Adoption barriers and technological limitations

13. **High capital expenditures**: The costs associated with adopting new technologies, particularly high-resolution datasets for monitoring, present a significant barrier. While Copernicus data is free, the need for supplementary data to enhance its value increases costs for both service providers and end users.

14. **Market reluctance and lack of stakeholder trust:** Remote sensing faces scepticism in the mining sector, largely due to previous failed attempts that have left a negative impression. Mining companies and stakeholders are hesitant to trust EO data because of past isolated failures and the lack of demonstrated reliability.

15. **Underutilization of EO technologies**: There is a general lack of awareness, expertise, and standardized methodologies for effectively integrating EO data into mining operations, leading to its underutilization in the industry.

16. **Spatial resolution and scalability issues:** Sentinel-2 10-meter resolution may not provide sufficient detail for monitoring small or vegetated mines. Additionally, scaling monitoring efforts from local to regional or global levels requires more advanced data fusion and machine learning techniques. InSAR technology faces limitations in areas with dense vegetation or rapid ground movements, reducing its effectiveness in certain environments.

Data integration and monitoring systems

17. **Lack of comprehensive monitoring**: Existing geotechnical and environmental monitoring systems suffer from gaps in spatial and temporal data coverage, as well as a lack of integration protocols. There is also a limited development of non-invasive geophysical techniques for monitoring both subsurface and surface environments. Additionally, discrepancies between different space data sources create challenges in data interpretation and analysis.

Real-time and automated monitoring

18. **Need for automation**: Real-time monitoring systems for ground stability, water management, and environmental hazards are still underdeveloped.

19. **Update delays**: Services like EGMS have a 1-2 year delay, limiting their effectiveness for real-

time decision-making.

Collaboration and data sharing

20. **Siloed operations:** Limited collaboration between different mining sites and departments hinders knowledge sharing.
21. **Data sharing constraints**: Legal and regulatory barriers restrict data sharing within and between companies.

Regulatory and Compliance Challenges

22. **Regulatory compliance**: Monitoring often needs to comply with strict regulations and reporting standards.
23. **Legal considerations**: Challenges around contracts, data acquisition, and storage need to be managed for successful technology adoption.

1 Minutes of Meeting

Agenda Item 1 - Welcome and introduction of the Raw Materials Segment by Eduard Escalona Zorita and Alba German from EUSPA and Dragos Bratasanu (EY).

The segment leader at EUSPA welcomed all participants to the User Consultation Platform (UCP) session. They provided a brief overview of the day's objectives, and how the entire UCP is a tool allowing EUSPA to achieve closer contact with the user community.

Agenda Item 2 – Results or MOSMIN project and market research. Moritz Kirsch (HZDR), René Booysen (HZDR), Alexander Bergstrom (Nordic Strategy Partners), Erik Ronne (Boliden). Results or MOSMIN project and market research

Mr. Kirsch presented the Multiscale Observation Services for Mining-related Deposits (MOSMIN) project. The context of the project is based on society's increasing reliance on raw materials primarily sourced through mining. Mining activities, while necessary, produce residues that pose environmental and safety risks. Despite positive developments in the mining industry, current systems for geotechnical and environmental monitoring are lacking, with limitations in spatial and temporal data coverage and a lack of data integration protocols. The underutilization of EO technologies in the mining sector could be attributed to a lack of awareness, technological constraints of EO data, or a shortage of technical expertise and standardized processing methods.

The MOSMIN project, funded under the Horizon Europe Innovation Action scheme with a budget of 3 million euros over three years, aims to enhance the integration and uptake of Copernicus data into the economy and address societal challenges. The expected outcome is the development of new or improved applications, products, and services by exploiting Copernicus data assets and data from other vertical domains.

The project's objectives include:

- Environmental Monitoring: To create services and tools for comprehensive environmental impact assessments of mining residues.
- Geotechnical Monitoring: To develop an integrated service for monitoring critical parameters that control the physical stability of tailings and waste rocks.
- Raw Material Valorisation: To develop integrated 3D models for characterizing secondary raw resources in mine waste.

The methodology involves using Copernicus EO data for time-resolved, spatially extensive remote monitoring of ground deformation and surface composition, combined with other EO data to enhance resolution. High-resolution data from UAVs will bridge the gap between in-situ sensors and satellite data. Additionally, novel, non-invasive geophysical techniques like distributed fiber-optic sensing will provide subsurface information.

Pilot sites for the project include:

- Aitik & Laisvall in Sweden and Kevitsa in Finland, both operated by Boliden.
- Roșia Poieni in Romania, managed by CupruMin.
- Talabre & Ovejería in Chile, overseen by Codelco.
- Trident & Kansanshi in Zambia, run by FQM.

These sites offer a broad range of conditions, including size, stage of development, climate zone, and monitoring technology. The project focuses on copper due to its crucial role in society and targets sulphide ores with a high potential for acid mine drainage.

Following Mr Kirsch, Mr Bergström from Nordic Strategic Partners shared insights from over 40 interviews conducted with the mining sector. He outlined the key learnings, which focused on understanding the current state of the industry and identifying the most critical needs in relation to monitoring. These areas include geotechnical monitoring, environmental monitoring, and raw material valorisation.

He then discussed the business development activities within the MOSMIN project.

- Market validation. This involved understanding the needs, pains, and current state of the industry through a technology-agnostic approach.
- Hypothetical services, which bridge the market perspective with technological possibilities to foster idea generation and service validation.
- Service validation, gathering knowledge and feedback from actual customers about these hypothetical services to assess their viability and relevance to the industry's needs.

The general findings presented by Mr. Bergström revealed a high demand for integrated monitoring services within the mining sector. These services are considered crucial for enhancing decision-making processes. Many companies recognize the real value of such integration, with key benefits including increased efficiency through lower costs and improved decision-making capabilities due to enhanced analysis.

The adaptability of monitoring services to various stakeholders was also emphasized as highly important, with the understanding that each case is unique, and services must be tailored to different market segments, including active mines, closed mines, NGOs, and governmental organizations.

Mr. Bergström noted a negative bias towards remote sensing in the mining industry. The observation was made that most companies have experimented with remote sensing solutions in isolation and that very few have explored the potential of combining different datasets and integrating analyses to produce a more synergistic output.

Additionally, he pointed out that while significant progress has been made in terms of data quality, acquisition, and frequency, there has been insufficient development in visualization and presentation features. These are critical for the solutions to be adaptable to the actual workflows and day-to-day challenges faced by the mining sector.

To conclude, Mr. Bergström shared specific learnings related to the use of remote sensing in the mining industry. Key findings indicated:

- Industry tends to operate in silos, with a lack of collaboration both between different mining sites and within various locations on the same site.
- Data sharing is often limited, not only between different companies but also between departments within the same organization.
- The need for monitoring is closely tied to regulatory compliance, reporting requirements, and adherence to industry standards.
- Furthermore, there are symptoms of lock-in due to challenges in data sharing and integration, as well as capital expenditures (CAPEX) associated with adopting new technologies.

Additionally, Mr. Bergström emphasized the implications for developing effective solutions in the mining industry. He outlined that any solution must be modular, allowing for various applications and combinations tailored to each specific mine and the different areas within it.

He stressed the importance of data security from multiple perspectives. Solutions should consider implementing role-based access restrictions to ensure that users have appropriate permissions based on their roles, positions, and the sites they are associated with.

Furthermore, Mr. Bergström highlighted that a key value of any solution is its ability to facilitate reporting requirements. Solutions must be designed to comply with relevant regulations and standards, such as the Global Industry Standard on Tailings Management (GISTM).

Lastly, he pointed out that solutions must be flexible in terms of integration with third-party suppliers. Legal considerations, such as contract infringements, data acquisition, and storage, must be carefully managed to ensure the solution's viability and legal compliance.

Agenda Item 3 – Water management planning for mines. Luke Hopkins (Picterra) and Hani Zahiri (ERAMET)

Mr. Hopkins introduced a project aimed at enhancing water management planning for mines. The project utilizes Picterra, a platform that integrates satellite, aerial, and drone data from both open and commercial sources. This Machine Learning-based platform enables the accurate and near real-time analysis of imagery without the need for coding skills. The platform's cloud-based dashboards can be fully set up in a matter of days, rather than months, saving 95% of the time typically required. Users can interactively navigate through different assets in time and space for actionable insights.

The system has been applied to a use case with ERAMET, focusing on various aspects:

- Prospection: Identifying geological objects/areas, vegetation indicative of subsoil characteristics, drillhole areas, and exploration roads.
- Environment: Conducting pre-operation biodiversity studies, assessing rehabilitation areas for biodiversity, and monitoring protected forest areas.
- Communities: Mapping households, villages, roads, wells, and cemeteries.
- Risk Management: Observing hill water and water bodies, detecting faults and cracks, identifying past landslide patterns, and pinpointing erosion areas.
- Operations: Detecting slopes and road cracks.

The benefits of using this system include:

- Faster detection model training: A no-code solution for geospatial machine learning using less training data.

24. Faster results: Reduced time for training a detector, from 2 hours to 2 days, for application to large-scale images.

- Cost-effectiveness and elimination of the need for coding expertise.
- Interoperability with geospatial image services and APIs for running detectors and importing/exporting data.
- Ease of maintenance

To illustrate the benefits of the system, Mr. Hopkins presented a few case studies:

- Hill water reservoirs: the challenge in this case was the detection of water reservoirs at the edge of the tracks. Using LiDAR data from 2022 as the input, the system was able to transition to production in just 2 days.

25. Modelling of surface overflow under canopy.

- Hill water reservoirs: A comparison was made between manual identification of hill water resources in a specific area and detection through the combined use of Picterra and GIS, with the latter proving to be considerably more effective.

26. Water bodies: The task was to dynamically detect the contours of water bodies and active areas of the mine site to aid in the management of mine water. The system used LiDAR data as the input and was able to transition to production in 5 days, facilitating the management of water at the mine site.

Agenda Item 4 – Efficient Earth Observation System for Acid Mine Drainage Monitoring with focus on Sentinel-2 data integration. Veronika Kopačková-Strnadová, Czech Geological Survey

Mrs. Strnadová discussed the application of EO for monitoring Acid Mine Drainage (AMD), with a particular emphasis on using Sentinel-2 data. AMD is the outflow of acidic water from mining sites, typically occurring when water and oxygen interact with sulphide minerals like pyrite during mining operations. This reaction can produce sulfuric acid, leading to highly acidic water that can contaminate nearby water bodies and have detrimental environmental impacts.

They identified a current need for a robust approach to simultaneously monitor AMD indicator minerals and mine water quality, as well as to understand the interconnection between these two phenomena. Such an approach would enable more effective monitoring, management, and mitigation of AMD, provide early warnings about potential pollution, and understand drainage pathways and geochemical patterns between water and soil systems.

Strnadová highlighted the potential for multi-sensor fusion and data integration in remote sensing, which can combine data from various sensors and platforms to enhance AMD monitoring. She outlined the data requirements for mapping AMD, which include multi-temporal data, relatively high spatial resolution, and a spectral range covering the visible/near-infrared (VIS/NIR) spectral ranges.

They compared drone-based hyperspectral data and multispectral satellite data, noting that drone-based data offers higher spatial and spectral resolution, detailed scale, high accuracy, and high flexibility, but covers smaller areas and requires significant manpower effort. On the other hand, multispectral satellite data provides sufficient temporal frequency, global coverage, and requires no manpower for data acquisition and preprocessing. However, the 10-meter pixel resolution might be limiting for some sites, and there is low flexibility with no customization options.

She then proceeded to outline the current state of the art in two Technology Readiness Level (TRL) categories.

At the lower TRL (TRL3-5), she described the development of a detailed mineral map that requires validation through ground observation. This involves model up-scaling to match Sentinel-2 data in terms of spatial and spectral characteristics, as well as further validation with ground truth. The extended analysed area at this TRL ranges from local to regional scales.

For the higher TRLs (TRL 5-7), she presented a Sentinel-2 harmonized cloudless monthly composite that facilitates generic model training and validation. This approach allows to analyse extended areas from regional to global scales. The composite includes data from multiple years, starting from 2017, and incorporates Machine Learning (ML) and Deep Learning (DL) testing and validation. This advanced modelling enables accurate detection of hazardous materials that contribute to AMD and extends the model's applicability to other areas, scaling from regional to global levels.

In her conclusions, Mrs. Strnadová summarized the advantages and limitations of using Sentinel-2 data for Acid Mine Drainage (AMD) monitoring:

- Sentinel-2 data is accessible in a pre-processed format, which simplifies the creation of data cubes and cloudless composites.

- The temporal frequency of Sentinel-2 data is beneficial for monitoring AMD drainage, and this will be further improved with the launch of Sentinel-2C, expected to be in orbit from September 9th, 2024.
- While the spatial resolution of Sentinel-2 is appropriate for monitoring larger mines and is sufficient for regional to global studies, it may not be detailed enough for smaller, abandoned mines, especially those with considerable vegetation cover.

27. Sentinel-2 data is effective for mapping hazardous AMD on regional and global scales and can assist in identifying new areas at risk of generating harmful materials. However, for more detailed local analysis, it is necessary to integrate Sentinel-2 data with data from higher spatial and spectral resolution sources, such as drone-based sensors or additional Copernicus contributing or commercial satellite missions.

Session 1 discussions – Verbal and online chat interventions

An audience member directed a question to a MOSMIN project speaker, Mr. Bergström: Is the poll [within their project] used to gather data valid due to the fact that those in the mining sector will not know the environmental impacts that the project aims to cover (actual extend, reactive flows, cascades, etc.)? It was followed with the statements: isn't such poll as presented re-inventing the wheel? Different studies already identified much of the needs of the mining sector, including environmental monitoring. Mr. Bergström answered that the project continuously interviews various stakeholders of the sector (mining companies, environmental consultants, academia, governmental organizations, NGOs). Some of the findings probably overlap with existing findings from literature (perhaps especially those presented here, as we have generalized them to fit the context of the session). Many of the findings are however quite specific in relation to what we are trying to develop in the project.

[In reference to the MOSMIN project] an audience member asked where all use cases are concerned, are these driven/designed primarily by what EO technologies can accomplish rather than what is required? For example, mining companies in their environmental statements specify the monitoring criteria for specific mining domains. How are these attempts matching the expectations of these use cases? An audience member asked what data the machine learning models are trained with, is the data based on labelled data with proved AMD against the background. The speaker mentioned that the source of the training data was points of geochemical information.

Another audience member also asked what machine learning method was used and the speaker answer that many were tested.

Session 1 round table discussion continues – Eric Ronne

Eric Ronne, the Research Manager of Sustainability at Boliden, introduced the greatest challenges faced by users. The speaker explained that many people have heard of EO services and information but not many people have the knowledge to use it. The second greatest challenge to the uptake of EO is that the current process of measuring and collecting relevant data with field work is still in effect and stakeholders are reluctant to change. Mr. Ronne explained that EO is cheaper and more efficient than field work, but that stakeholders lack the knowledge to apply EO and are not interested in changing due to their comfort with the current system.

The speaker was asked about the main challenges of adopting this technology and how it can be integrated into the industry. They explained that one of the biggest barriers is the lack of remote sensing education in universities, as few professors teach it, leaving many without the necessary skills or background to work with remote sensing data. Another key challenge, according to the speaker, is the difficulty in convincing people of the effectiveness of EO solutions and data, particularly when it comes to the application of machine learning.

Another speaker intervened regarding the challenges that were noted stating that firstly, the issue of data fusion, having multiple data points in a single platform or EO is not readily available, the second challenge is the expensive pricing of high-resolution data, and that a large barrier to the uptake of EO services in this sector is cost both for the service providers and users. Another obstacle the speaker noted is proving to the mining and exploration companies that the satellite data processing results are reliable.

EUSPA posed the question to the audience: What are the trends that are observed in your industry relating to EO data?". A user member explained that there are many gaps between having data and being able to use the data, the speaker noted that the greatest trend they have seen is that people (users) want to use available data to get better results. Similarly, they mention that a barrier to the application of space data is building trust with the client, educating customers about why the provided data is valid and meaningful.

A follow-up question was asked about how to achieve this understanding. The speaker responded that it's important to teach users how EO works and to demonstrate the process in a way that demystifies it, preventing it from being seen as a "black box." This approach helps increase users' understanding of the technology.

Another follow-up question addressed how Copernicus could be improved to better meet industry needs and overcome current challenges. The speaker noted that Sentinel-2 data wasn't specifically designed for mineral mapping, which is why it lacks the ideal spectral bands for this purpose. However, a hyperspectral satellite is planned for launch, which will represent significant progress. While the resolution of the current data is adequate for now, additional spectral bands would enhance its utility.

Audience members also expressed interest in having a satellite capable of monitoring topography. It was suggested that the Copernicus browser interface be improved to make it more user-friendly, with one speaker proposing it be designed similarly to Google Earth. This would enable users to select specific application layers and access legacy data, helping to create tailored, application-specific solutions.

Round table: Mining Site Exploration

Agenda Item 5 - Lorenzo Solari (EEA): EGMS for monitoring soil movement in mines.

Mr. Solari from the European Environmental Agency introduced the European Ground Motion Service (EGMS). He explained that EGMS is an important component of the Copernicus Land Monitoring Service (CLMS) portfolio and is derived from data gathered by the Sentinel-1 radar satellite mission. EGMS provides high density, continental scale map of ground motion, and each measurement point has a value of ground motion velocity and a time series. An example of ground subsidence was displayed.

Highlighting the key features of EGMS, Solari noted that it encompasses all Copernicus participating countries and it is updated annually. It provides a five-year time series and generates approximately 13 billion measurement points with each update. The service is guaranteed until at least 2028.

An example of ground movement from an iron mine was given. It was reviewed that EGMS measured the millimetric scale motion over time of ground reflecting features, it can measure land subsidence, landslides and slope phenomena, uplift, and movement of larger-scale infrastructure.

EGMS is capable of measuring millimetric-scale motion over time of ground reflecting features, which can be either natural, such as bare rocks, or man-made structures. This capability is essential for measuring and mapping various geological and infrastructural movements, including land subsidence, landslides and slope phenomena, uplift (whether natural or anthropogenic), and the movement of larger-scale infrastructure.

Mr. Solari detailed the portfolio of the EGMS covering L2a, L2b, L3.

He also addressed the limitations of EGMS and InSAR technology:

- Discontinuous coverage, meaning there may not be measurements in the desired locations.
- Measurement point positioning, which has metre-scale uncertainty regarding their precise location.
- Spatial resolution, with each measurement point derived from a 20x5 meter ground cell.
- Motion orientation, as EGMS does not provide measurements in the north-south direction.

28. Type of motion, where fast or instantaneous motion cannot be captured by the service.

An audience member asked about the minimum detectable magnitude of movement and speed, as well as whether the technique used is InSAR. The speaker responded that, in theory, the minimum detectable movement is 2 mm per day for continental-scale processing. They confirmed that the technique used is InSAR, specifically multitemporal InSAR.

Alba German from EUSPA asked "How will the current data on the EGMS be updated? Will the previous data still be available?" The speaker explained that the data will be updated for the past five years, and that the previous datasets will be still available by specific request.

Agenda Item 6 - Dr. Ignacio Marzan (CSIC-IGME): Tharsis tailings dam case study.

Dr. Marzan presented a case study on ground stability monitoring at the Rio Tinto mine using Sentinel-1 data. He explained that ground stability is a significant hazard in mining and that InSAR technology can measure ground displacements at a millimetre scale with a wide coverage. In 2018, under the RawMatCop Program, the capability of Sentinel-1 to monitor ground stability at the historically significant Rio Tinto mine, which has over 5,000 years of history and contains both active and abandoned sections, was assessed.

The first step in monitoring involved characterizing the deformation field, starting with a historical review using catalogue data from European radar constellations: ERS, Envisat, and Sentinel-1. The Sentinel-1 constellation has provided free access to global Earth coverage with medium resolution and high revisit frequency. Despite not being designed for high-resolution studies, Sentinel-1 has delivered remarkable results at the mining scale.

The main monitoring characteristics of Sentinel-1 include small spatial and temporal baselines, open access data, continuous data acquisition, high data quality, a C-band radar sensor, and medium resolution of approximately 5x20 meter pixels.

For the deformation field, both ascending and descending geometries were processed for the period 2015-2017. Combining both geometries provided a complete characterization of the deformation field, with observed displacements projected onto a common reference system, assuming projections along the maximum slope for steep topographies and the vertical direction for flat topographies.

Focusing on passive mining elements, four main anomalies were detected:

- Two anomalies in rock dumps, previously unknown, with displacements up to 5 cm/year.
- An anomaly consistent with surface collapses caused by failures in old, abandoned galleries.
- An anomaly consistent with block slide-type displacements observed in the Atalaya open pit, showing subsidence of more than 11 cm/year, constrained by a fracture zone and a geological contact, with minor displacements on the south wall related to debris slides from collapsed terraces.
- The subsidence in the Atalaya open pit correlated well with a local GNSS network, with mismatches explained by scale differences.

The next step in the monitoring process was to create a web service that automatically downloads new Sentinel-1 acquisitions, reprocesses data, alerts on trend changes, and provides updated data at the end-user level. In 2020, a web prototype operating on a local server was created as part of the RawMatCop Program.

Marzan then discussed the European Ground Motion Service (EGMS), describing it as the most important deformation monitoring system ever developed, providing millimetre-scale displacements across a continental scale on a free-access, user-friendly platform with high-quality, high-density data. It combines Persistent Scatterer (PS) and Distributed Scatterer (DS) techniques, overlapped tracks, Line of Sight (LOS), and geodetic-projected products with a temporal window of 5 years, updated annually, and a 1 to 2-year delay from the present.

He concluded by stating that while the EGMS cannot be improved upon, there is room for tailored monitoring, including automated "real-time" reprocessing, adjusting the processing period to mining activities that cause decorrelation, monitoring of critical mining elements, trend change detection, forecasting, alerts, and detection of accelerations in areas with loss of coherence.

Agenda Item 7 - Dr. Sean Salazar (NGI). MINEYE presentation, focus on exploration results.

Dr. Salazar from the Norwegian Geotechnical Institute, representing the MINEYE project, discussed the application of Earth Observation Techniques for Mine Life Cycle Monitoring using a Machine Learning Data Fusion Approach. The MINEYE project, part of the HORIZON Innovation Actions, has a total cost of EUR 5.77 million, involves 13 partners across 9 countries, and is a 4-year project starting in January 2024, aiming to reach TRL6 – TRL7.

The expected outcome of the project is to contribute to increased access to primary and secondary raw materials, particularly critical raw materials for EU industrial value chains and strategic sectors. The main objectives include developing a commercial services web-based platform with associated modules, increasing the efficiency of mineral explorations, valorising mine waste and enhancing mine safety during mineral extraction, demonstrating technology at European pilot sites with varying mining contexts, and facilitating knowledge sharing and uptake.

Pilot site locations include Tharsis Mining in Spain, Norrbotten County in Sweden, and Soricom Mines in Albania. The critical and strategic raw materials under study are the iron ore deposit in Norrbotten, which has high levels of phosphorus and rare earth elements, apatite (an important resource for phosphate, CRM), the VHMS deposits in Tharsis, La Zarza, and San Telmo mines in Spain with target elements like Cu, Pb, Zn, Ag, Au, and Co, and the Ternove Cr mine in the Bulqizë area of Albania.

Dr. Salazar introduced the MINEYE platform and modules, showcasing a visual representation of the IPOP (Interfacing, Programming, and Optimization Platform), which includes modules for Mineral Prospectivity Maps, the Liquid Earth EO Plugin for 3D modelling, an Inventory Map and Mining Residues Package for environmental analyses, and a global stability assessment.

He detailed the European EO data types used in MINEYE, which encompass VHR optical and panchromatic, multispectral, hyperspectral, SAR, and InSAR, along with derivatives such as Ground Motion Services, classification maps, and elevation models.

Upcoming activities for the project include geophysical measurements at pilot sites, petrophysical measurements on core samples, environmental monitoring, and grade-tonnage modelling of potential secondary raw materials within mining residues, as well as ground stability monitoring to identify the size and growth of areas influenced by mining.

The expected outcomes of the project are to develop commercial services and products for the mining industry, including IPOP and modules for 3D modelling, mining residues, and prospectivity mapping, publish a free online thematic mining residues map for an EU country (to be determined), and provide courses and training materials.

The anticipated impacts are to increase the success rate of explorations in Europe and the supply of critical raw materials, enhance stakeholder access to EO-supported decision-making tools, and increase mine waste valorisation while reducing environmental impacts.

An audience member asked the speaker if LiDAR data is being used. The speaker responded that derivatives of LiDAR data are indeed being utilized.

Agenda Item 8 - Marco Bianchi (Tre – Altamira). Measuring ground and structural movement from space

Mr. Bianchi discussed the application challenges and current solutions for open pit mines, focusing on the risks posed by various geotechnical phenomena to operational continuity and personnel safety. These risks include surface displacement patterns with strong temporal and spatial variations, slope failures, and impoundment failures such as Tailings Storage Facilities (TSFs) and water ponds. Geotechnical monitoring tools like SSR, ATS, GNSS, and geotechnical sensors are typically used to manage these risks.

He presented a case study on monitoring ground instability over a coal mine area affected by strong surface changes due to mining activities, dense vegetation, and heavy rainfalls that compromised the stability of mine slopes. The main challenges for InSAR in this context included dense vegetation cover, fast movements, surface changes, collapses, flooded areas, and atmospheric effects during the rainy season. Bianchi explained the techniques used in the case study, contrasting Bulletins and SqueeSAR. Bulletins were effective for tracking rapid displacement and maximizing information coverage in highly active environments, while SqueeSAR delivered accurate measurements of persistent targets and identified non-linear trends and slower displacement patterns. He compared the effectiveness of C-band and L-band radar, noting that C-band has higher sensitivity for measuring surface displacements and detecting slower movements, while L-band can better penetrate vegetation to measure ground deformation and is better for faster displacement detection.

Mr. Bianchi highlighted TREA's value proposition in ground movement detection, where InSAR monitoring of the slope showed deformations starting in July 2022, with increasingly large movements observed, until cracks were found in December 2022. Mining activities were halted for safety reasons. After a slope improvement plan was implemented, which included cutting back material at the top of the slope and implementing outer drainage, InSAR monitoring showed no further movement, allowing mining activities to resume safely.

In conclusion, Mr. Bianchi highlighted that InSAR is a highly effective early warning tool for decision-making in unstable mining areas. By using both satellite geometries (ascending and descending orbits), it provides more comprehensive coverage of pits with steep slopes, while 2D analysis offers greater insight into the actual direction of movement. InSAR plays an important role in improving risk management by supporting plans to reduce hazards associated with mining activities. Additionally, it can be used for post-event analysis, helping to reconstruct historical displacement data and assess whether the failure could have been predicted. Various techniques can be applied to monitor displacement across a wide range of rates.

Agenda Item 9 – Conclusions. Sara Kasmaeeyazdi **/ University of Bologna**

Mrs. Kasmaeeyazdi concluded the presentations section and initiated the roundtable discussion for session 2 by stating that EO data, particularly the free-access Copernicus, is revolutionizing various aspects and perspectives of the mining industry. Final remarks were made about how access to Copernicus is changing the life cycles of mining, from exploration, extraction, post-mining and tailing managements, environmental monitoring, mining hazards and ground deformation monitoring.

She highlighted that EGMS stands as the most significant deformation monitoring system ever developed, providing millimetre-scale displacements across a continental scale with high-quality data on a free-access and user-friendly platform. The EGMS has a temporal window of 5 years and is updated annually, with a delay of 1 to 2 years.

Mrs. Kasmaeeyazdi acknowledged there is still considerable work to be done in terms of developing tailored monitoring solutions for the mining sector. The goal is to monitor as close to "real-time" as possible, to adjust processing periods according to mining activities such as dam raising or new waste deposits, and to process sub-products that are specifically designed for mining applications. She then opened the floor for the roundtable discussion on these topics.

An audience member asked how often mine sites need to perform this type of analysis. The speaker responded that most mines now use real-time sensors to monitor changes in water levels, relying primarily on ground-based sensors.

Another audience member inquired about how the cost of EO services for the mining industry can be reduced. The speaker explained that if Copernicus data is used, cost is typically not an issue. However, if additional data is required, costs can become a challenge for both the service provider and the user. The key to reducing costs, the speaker noted, is ensuring continuous data availability and developing a deep understanding of the client's objectives while managing their expectations.

When asked how satellite data can improve mineral exploration and the benefits of using both high- and low-resolution datasets, the speaker replied that a diverse range of datasets is essential for robust mineral exploration, and EO plays a role in enhancing this diversity.

Agenda Item 10: USER REQUIREMENTS VALIDATION

Conclusions and closing remarks.

The session was closed successfully, thanking the audience for their participation.

2 Conclusions

Key results of this working session were highlighted during the plenary UCP session on 14th October, 2024 at the International Astronautical Congress (IAC) in Milan.

These results are summarised below:

Challenges related to the MOSMIN Project

29. Environmental and safety risks: Mining residues pose significant environmental and safety challenges.
30. Lack of comprehensive monitoring systems: Current systems for geotechnical and environmental monitoring lack adequate spatial and temporal data coverage and integration protocols.
31. Underutilization of EO technologies: There is a lack of awareness, technical expertise, and standardized processing methods for EO data in the mining sector.
32. Technological constraints: Limited development of novel, non-invasive geophysical techniques for monitoring subsurface and surface environments.

Market Research Insights (Alexander Bergström)

33. Negative bias toward remote sensing: Mining companies are reluctant to adopt remote sensing due to past isolated attempts with limited success.
34. Siloed operations: Limited collaboration both between different mining sites and within departments of the same company.
35. Data sharing constraints: Data sharing is restricted between companies and within organizations.
36. Regulatory compliance challenges: Monitoring needs are often tied to compliance with strict regulations and reporting standards.
37. High capital expenditures: Costs associated with adopting new technologies pose a barrier.
38. Limited progress in data visualization: While data quality has improved, there are insufficient tools to visualize and present data effectively.
39. Legal considerations: Contract, data acquisition, and storage challenges need to be managed for successful technology adoption.

Water Management Challenges (Luke Hopkins)

40. Complexity of water reservoir detection: Identifying water bodies in mining sites, especially those near tracks or under dense canopies, poses significant challenges.
41. Real-time data processing: Effective management of water requires rapid and accurate data processing capabilities, which many traditional systems struggle to provide.

Acid Mine Drainage (AMD) Monitoring Challenges

42. Integration of monitoring techniques: The need for a robust approach to monitor AMD indicator minerals and water quality simultaneously.
43. Multi-sensor data fusion: Difficulty in combining drone-based and satellite data to enhance the monitoring of AMD.
44. Spatial resolution limitations: Sentinel-2 10-meter pixel resolution may not provide enough detail for small or heavily vegetated mines.

- Scalability: Extending AMD monitoring solutions from local to regional or global scales requires further development of data fusion and machine learning techniques.

Business Development and Solution Flexibility

45. Adaptability to different stakeholders: Monitoring services need to be tailored to the unique needs of different market segments (e.g., active mines, closed mines, NGOs, government organizations).
46. Data security: Solutions must implement role-based access restrictions for secure data handling.
47. Modular solutions: Mining solutions need to be modular and customizable to fit the specific needs of various mines and locations.

- All speakers emphasize the need for improved data integration, technological advancement, regulatory compliance, and tailored solutions to address these challenges effectively.

Challenges in Ground Stability Monitoring

48. Ground stability hazards: Mining sites like Rio Tinto face significant risks related to ground stability and subsidence, posing safety and operational challenges.
49. Data limitations: Sentinel-1 is not designed for high-resolution studies, limiting the detail of the monitoring despite providing valuable data.
50. Complexity in monitoring different anomalies: Detecting and interpreting different types of ground movements, such as rock dump displacements, surface collapses, and block-slide displacements in open pits.
51. Data mismatches: Discrepancies between InSAR and GNSS data due to scale differences.
52. Need for automation: Developing systems to automatically re-process new Sentinel-1 data and alert users to trend changes in near real-time.
53. Long update delays: The European Ground Motion Service (EGMS) has a delay of 1-2 years, limiting its use for real-time decision-making.

Challenges in Exploration and Monitoring

54. Data integration: While LiDAR derivatives are used, there is still a need for integrating various data types to improve exploration results.
55. Cost of EO services: While Copernicus data is free, the use of supplementary data increases costs for both service providers and users, which can become a barrier for the mining

industry.

56. Stakeholder trust: Ensuring stakeholders trust the results from EO technologies and remote sensing data remains a challenge.

Challenges in Ground and Structural Monitoring

57. InSAR limitations: InSAR technology struggles in areas with dense vegetation cover and fast ground movements, which limits its effectiveness in certain mining environments.
58. Cost of high-resolution data: Acquiring high-resolution datasets to measure ground instability over complex areas, such as coal mines, can be expensive and technically challenging.

Challenges in Monitoring Ground Motion

59. Real-time monitoring: The need for improved real-time monitoring capabilities for ground motion in mining areas using advanced sensors.

General Challenges in Mining Monitoring

60. Life cycle integration: Monitoring systems need to adapt to different stages of the mining life cycle, from exploration and extraction to post-mining and tailings management.
61. Cost management: Cost becomes a challenge when supplementary data is required alongside Copernicus data, stressing the need for continuous data availability and managing client expectations effectively.

Finally, a few next steps were suggested:

62. Attract new users into the community by increasing stakeholder trust and decreasing costs.

63. Increasing education regarding the uses of EO in the Raw Materials sector, both upstream and downstream.

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