EO4RM

Earth Observation for the mining of Raw Materials

D5.3 Executive summary

V1.1 FINAL VERSION]

Date: 09/12/2020

Contract No. 4000126894/19/I-EF

Submitted by:

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DOCUMENT RELEASE SHEET

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CHANGE RECORD

Version	Date	Page(s)	Change record	Release
0.1	28-10-2020		Setup of the report	
0.2	25-11-2020		Draft text completion	
1.0	04-12-2020	10	Final version after feedback ESA	
1.1	09-12-2020	10	Final version after final review	

EO4RM Objective

The objective of the EO4RM project is to fully unlock the potential of Earth Observation for the mining of Raw Materials and find new ways of exploiting the vast growing volume of EO data available today. The project is initiated and funded by the European Space Agency (ESA) in order to bridge the gap between the mining and EO sector.

The geoinformation needs, EO products available, and level of uptake for EO vary across the stages of the mining life cycle. Mining companies, consultants and other stakeholders were consulted by the project team during surveys, various expert interviews, a workshop and two webinars in order to study:

- The geoinformation needs of the raw materials mining sector.
- The current utilization of EO technology in the sector.
- Subsequently, for every geoinformation need the corresponding mature EO products were identified and validated in a gap analysis.
- The sentiment (opportunities and challenges) towards further uptake of EO technology.
- To showcase EO services and products in a virtual platform
- Development of a best practices road map.

Next to key project deliverables that were supplied as part of the project scope of work, the following activities were performed that contributed to strengthening communication and outreach of the project results:

- The project was promoted through several actions by the consortium partners using the partners' websites and social media (LinkedIn).
- The project and first results were presented on two occasions during the Raw Materials week (18-22 November 2019) in Brussels. Firstly, in the plenary program as part of the "9th Trilateral EU-US-Japan Conference on Critical Raw Materials" and secondly in the satellite event "Global Research Consortium on Tailings – Consultation Workshop".
- As a result of travel restrictions due to the COVID-19 pandemic, workshop 2 was replaced by two (identical) webinars held on the 23rd and 25th of June 2020. Timing was chosen to allow participation from all over the world and in total almost 200 participants were informed about the project and provided feedback to the prototypes and the EO4RM section at the EARSC portal. Video registration of the event has been made available at the EARSC portal[1] and was supplied to ESA for further usage.
- The project is published in the Tailings and Mine Waste 2020 conference and is selected for oral presentation on November 18th, 2020.
- Results of the project, including EO product sheets, are made available through the EARSC portal.
- Participation in the EOCafe, organized by EARSC, to communicate the project results to potential users and other stakeholders is anticipated early next year.

Geoinformation needs

The EO4RM project identified sixty-seven items of geoinformation that are required over the life of a mining project, it described how they are currently achieved and the associated measurement specifications that are required by the mining industry and regulating agencies. This list was developed

[1] https://earsc-portal.eu/display/EO4RawMaterials/Materials

by mining experts that were part of the EO4RM team. Table 1 provides a summary of the requirements for a selection of the identified geoinformation needs.

Table 1. Selection of geoinformation needs per mining cycle phase

Cycle	Information type	Current technology used	Area assessed	Min. measurement requirements	
				Resolution (various)	Refresh rate
Exploration	E1. Topographic mapping of surface expressions	Digital Terrain Modeling / Optical Satellite imagery / Drones (LiDAR) / Field mapping surveys	Variable. Can be <1 km^2 to >1,000 km^2	1 m^2	Annual or greater
	E2. Geological mapping of sub-surface expressions	Maps / Previous exploration data / Geophysics	10 km^2 to 1,000 km^2	Minimum depth 30 m and up to 1000 m	Annual or greater
	E3. Geochemical signatures / anomalies	Maps / Walk-over portable XRF / Airborne / Sampling & assaying of soils and rocks / Drilling & Trenching / Vegetation assessment	1 km^2 to 1,000 km^2	Various measurement resolutions are required.	Annual or greater
Permitting	P1. Water catchment	Desktop study and field work	Various, can be >100 km^2	1 in 50,000 (1 cm on the map equals 0.5 km)	Annual or greater
	P2. Population centres / social impact	National Databases / Site assessment / fly over / drive through	Regional - 50 km^2 Local – 1 km^2	1 in 10,000 (1cm on the map equals 0.1 km)	Annual or minimum of every 10 years.
	P3. Characterization of flora and fauna	Published data / Biological Surveys	1 km^2 to 10 km^2	1 to 10 m^2	Monthly
Construction / Operation	O1. Site design and layout of infrastructure	Drones / LiDAR / Surveys	10 km^2	1:1000 (1cm on the map equals 0.01 km)	Weekly
	O2. Ground / Structural / Infrastructure / Stability	Surveys / Drones / LiDAR /	10 km^2	0.001 to 0.5 m	Continuous to annual
	O3. Stockpile measurement	Drones / Surveys	10 km^2	0.005 - 0.5 m	Daily to monthly
	O4. Groundwater monitoring	Published data / borehole monitoring	10 km^2 to 100 km^2	1 m^2	Monthly
Closure / Aftercare	C1. Demonstration of rehabilitation / revegetation	Fly over / Aerial photography / walk-over / Optical satellite imagery	1 km^2 to 10 km^2	1 m^2	Quarterly
	C2. Demonstration of infrastructure removal	Fly over / Aerial photography / walk-over / Optical satellite imagery	10 km^2 to 100 km^2	1 m^2	Monthly
	C3. Demonstrate long term structural stability of key infrastructure - Water Retaining Dams / Tailing Storage Facilities / Pits	Surveys / Water level monitoring	10 km^2 to 100 km^2	0.005 to 0.01 m	Continuous to annual

Geoinformation within the mining sector is acquired and used by many different organizations such as mining companies, regulatory authorities, consultants, academic institutions, community groups and other stakeholders. The techniques and methodologies used by different organizations will not vary significantly, although academic organizations and consultancies will often lead the way in terms of the development of new techniques to attain geoinformation. During the interaction with actors in the raw materials sector the following barriers in relation to advancements in geoinformation acquisition were identified:

- General unawareness of the potential of EO services and its related business rationales.
- Lack of knowledge of availability and capability of EO products by smaller companies.
- Lack of procurement procedures with commonly accepted terms of references.
- Availability of services and products that provide tailored information for the mining sector.
- Costs of product and services usage.
- Skilled personnel in EO technology at mining companies.
- Lack of well communicated, proven success stories on application of the EO products.

Gap analyses between EO products and geoinformation needs

The EO capability evaluation has been focused on mature EO technologies with standardized processing of the satellite data into a tailored outcome presentation. An expert panel, made up of remote sensing specialists, evaluated the capability of the mature EO products in relation to the geoinformation needs of the mining sector. This evaluation was reviewed by the International Industry Board (IIB). The IIB is a group of experts from mining and remote sensing industry, part of the EO4RM project, that offers support and feedback to the project. Next to the ability to fulfill the geoinformation need, spatial resolution, the temporal resolution (refresh rate) and costs were taken into account during this evaluation. The following classification of EO capability was used:

1 – Low capability. The EO product can address the needs in a limited way. Long-term development of new sensors will be needed to fulfill the need.

2 – Medium capability. The EO product can often fulfil the demand, but there are some thematic content, accuracy, or delivery limitations to address the needs.

3 – High capability. The EO product meets the current and anticipated needs of the mining sector. Initiatives such as standards, training, and integrations tools can still benefit the industry.

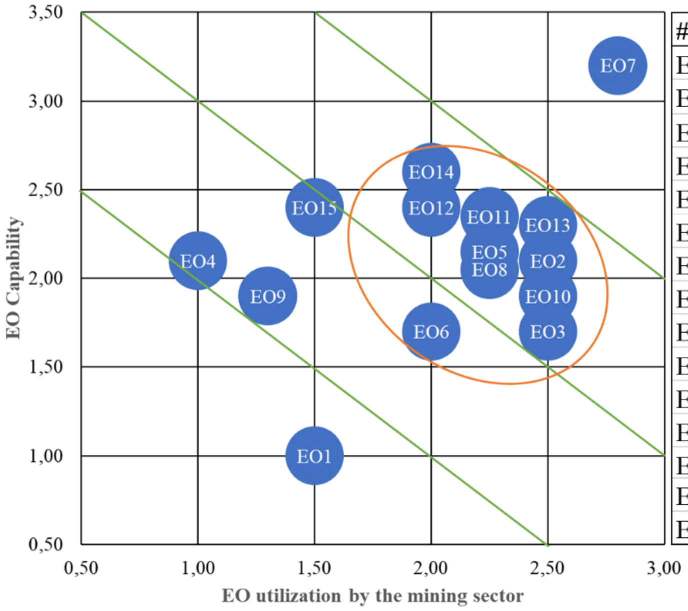
Likewise, the utilization of EO was evaluated using the following classification:

1 – Low utilization. The mining sector is using only freely available satellite information sources.

2 – Medium utilization. Using commercial services and products, but better specification products are available, or they could utilize more of the product if better integration tools were available.

3 – High utilization. The mining sector uses the best available, mature products.

In Figure 1 the result of the evaluation of EO capability and utilization is presented. When a product is low on the vertical axis, then we consider this a R&D gap, because the product needs further tailoring towards the geoinformation needs or even the development of new instruments or new data processing tools. When a project is low on the horizontal axis, then we consider this a utilization gap, the product may have good capabilities but barriers such as unawareness, lack of knowledge and cost may hinder full scale deployment. An example is Water quality (EO15). The product with the highest score both in capability and utilization is Weather forecasting (EO7). This product is widely recognized and used at full scale with many companies offering tailored services. The product with the lowest score is Shallow soil and chemistry (EO1), mostly because of physical limitations of the sensors



#	EO product
EO1	Shallow soil structure & Chemistry
EO2	Infrastructure stability monitoring
EO3	Stockpile measurements
EO4	Ground water monitoring
EO5	Structural geological mapping
EO6	Vegetation mapping
EO7	Weather forecasting
EO8	Surface water dynamics
EO9	Air quality TPM / Particulate matter
EO10	Lithology / Surficial geology
EO11	Topography / Elevation
EO12	Building / Settlement map
EO13	Orthophoto mapping
EO14	Ground stability monitoring
EO15	Water quality

Figure 1. Capability vs. utilization of EO within the raw materials mining sector

currently in use to fulfil the specific geoinformation needs by the mining sector. We have identified ten EO products (marked with the orange oval) that are already used by the mining sector at a certain level and show at least medium capabilities. These products are classified as high potential for wider uptake by the mining sector. Next to that, three products (EO4, EO9 and EO15) show a utilization gap.

For two of the high-potential products (section 3) mock-ups were developed. These can be used as an example to showcase to the raw materials mining sector the potential benefits and limitations. This provides insight and opens up the discussion on the barriers and challenges to application of the technology.

Product show case tailings dams

A selection process was completed by the project team to decide on showcasing stockpile measurement (EO3) and ground stability monitoring (EO14). These showcases were presented in two webinars broadcasted in June 2020. One webinar targeted the European sector, and another targeted those on different time zones (e.g. the Americas). In total, approximately 200 people attended the webinars and provided feedback, with a good cross-section across the sector including mine operators, consultants, regulators and researchers.

Tailings dams are used to store the residue or waste material after ore is processed. Given the relatively low proportion of minerals in ore and the high proportion of non-mineralized material, there are significant amounts of waste to be stored and tailings dams can be very large storage areas. Tailings dams must be monitored while the mine is operational and must also be monitored following the closure of a mine for a significant period thereafter. Various parameters are used to measure dam stability, EO offers the ability to be a technique to measure one of the key parameters, which is settlement or ground movement. The EO4RM project chose the 2018 tailings dam collapse in the Cadia gold mine in Australia as a test case. SAR data from Sentinel-1, with an acquisition interval of 12 days, was acquired and processed into settlement maps.

The results of this case study is presented in Figure 2 with data obtained covering the period December 2015 to March 2018. The dam wall was divided into polygons, with the movement of these polygons assessed over the time period. Data was presented with different colors being used to

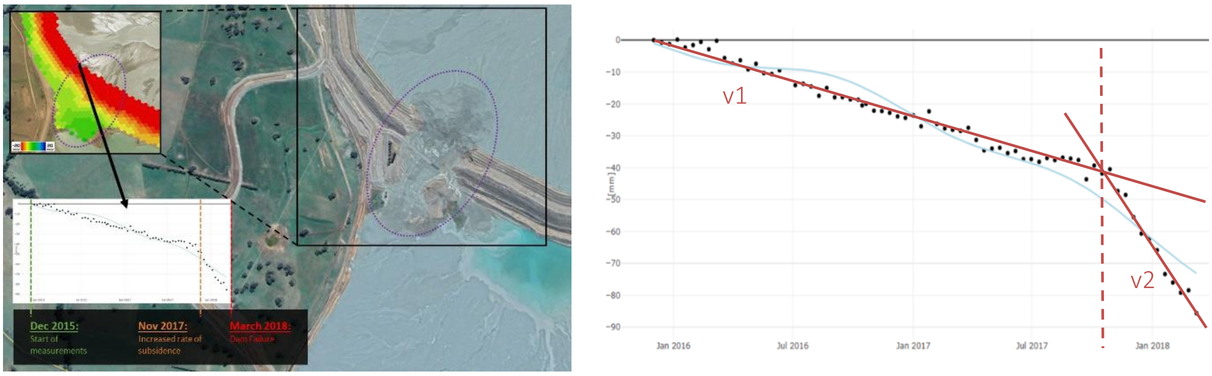


Figure 2 Cadia mine tailings dam failure in Australia

indicate the rate of movement. In the case of red, the dam is subsiding with more than 2 cm/yr, in the case of green the location is on average stable over time. To better understand these data, it can be inspected more closely from the underlying time series. Each polygon can be interrogated by the user to assess movement at each location on the dam wall. The picture in Figure 2.**Error! Reference source not found.** demonstrates how this section of the dam wall has subsided with more than 8 cm in 2 years. Depending on local conditions this can be a normal pattern for such a structure. However, when inspecting closely the area of the collapse in the InSAR time series data, a dramatic increase in subsidence rate from v1 to v2 was seen around November 2017. This was nearly 4 months before the collapse and was potentially a significant leading indicator that could have alerted the operator of an imminent failure.

The embankment failure was investigated in 2019 and the two small earthquakes that occurred the day before the event were ruled out as a root cause (Jefferies 2019). The investigation team divided the event into two phases. Phase 1 was a slow movement event, and this was followed by phase 2 which consisted of accelerated movements. The report concluded that Phase 1 terminated without triggering phase 2. However, the mechanics of phase 1 were a necessary condition for the occurrence of phase 2. SAR data was used by the team to help investigate the incident. These data indicated surface deformation prior to the collapse and in the months preceding the event were accelerating, the report states that this was particularly evident in the InSAR data that was discovered subsequent to the event.

The conclusions in the final report highlight the value that satellite based SAR data can provide. Having these data available on a continuous basis may allow an operator identify changes in movement prior to a failure taking place, which allows the operator to possibly intervene to prevent the failure or where this is not possible take steps to minimize the impact and loss associated with the failure.

Best practices road map

There are 3 possible ways to increase uptake of EO service in the RM sector:

1. Invest in individual downstream application developers.
2. Stimulate EO use in the sector.
3. Make access to EO service easier.

Ad 1. The gap analysis showed that there are already many technologies that can be readily adopted by the RM sector. A good example of this is the prototype service showcased in this project: both were based on existing technologies.

Investing in individual downstream application developers seems an obvious course of action to stimulate innovation, and it will of course increase the number of solutions for the RM market. However, the following number of arguments can be made against this course of action:

- Increasing the supply will not automatically increase the uptake. In fact, there is the risk that this will only further widen the gap between the technology on offer and the uptake by the sector.
- In the Copernicus program data and software tools are already made available on a free and open access basis.
- Tailoring a product to specific needs of clients in the mining sector should be performed by the private sector and IP becomes then part of their business model.

Therefore, we must conclude that this is not the most efficient way to increase use of EO information in the RM sector.

Ad 2. The gap analysis and webinars showed that there are many products that can meet the needs of the sector, but they are currently underused. This has multiple reasons. For starters, (part of) the mining sector could be unaware of the possibilities of EO. In addition, even if RM companies are aware, they may lack the knowledge and procurement procedures to ask the right questions to the suppliers (miscommunication). And finally, there can be guidelines or standards in place that inhibit the use of EO and regulating agencies can be reluctant to accept the outcome of EO based information.

Ad 3. Currently the market for EO solutions is very fragmented. There are many, often small, EO data providers that have solutions to specific problems. This makes it very difficult for the EO sector to find the right providers, but also for the providers to reach this new market. In addition, many EO providers are providing data products (rather than information) that are very diverse and difficult to understand or use by non-expert users. In other words, the connection between supply and demand is being impaired.

A solution to this problem is to develop common service platform to be used by all suppliers. This would provide a “one-stop-shop” for all products, making it easier for the market to *find* solutions. It will also make all information and data on offer uniform and therefore easier to *use* by the market.

Figure 3 provides a high-level development roadmap, highlighting the major phases of the roll out of the platform. It shows the main strategy, which is to gradually grow the platform, rather than to develop it all at once (“agile vs waterfall”).

	Mobilize Stakeholders 1	Implement infrastructure 2	Build community 3	After Care 4
Timeline	Within 3 months	Within 9 months	Within 12 months	Within 24 months
Objectives	Create operational team - Find relevant skill-sets - Acquire sufficient funding - Review goals and milestones	Expand the platform - Build the required features - Attract more content - Start with branding activities - Engage community to assess standards/guidelines issues	Secure initial user base - Focus on growing user base - Implement first feedback - Focus on quality content - Work with community to address guideline issues	Operations & growth - Focus on data to monitor goals - Implement lessons learned - Create additional value - Support community to implement new ways of working
Key activities				
Platform	Agree on implementation plan	Get EARSC Portal and web viewer operational	Integrate portal and viewer through API, set up marketplace infrastructure	Use feedback to continuously improve and evolve
Community	Re-engage already existing community	Set up community tools and forum within EARSC	Regular community contact through digital means	Further build community, explore other uses
Awareness	Set up social media and engage network	Start content writing and contact relevant partners	Run digital awareness campaigns	Focus on analytics for insight and improvements
Content	First 4 demo's	Increase demo count to 10	Increase demo count to 15	Have an average of at least 20 demo's
Recruitment	Recruit initial core team	Make use of freelancers to supplement progress	Add customer support, less focus on development	Install long term team composition
Funding	Initial budget provided by team	Get additional funding from third party	Get first funding through marketplace activities	Activities are self-sustaining

Figure 3 High level roadmap

Conclusion and recommendation

The EO4RM project resulted in a clear insight into the geoinformation needs during the lifecycle of a mine and the understanding of the common practice of utilization of EO in the mining industry. A selection of the geoinformation needs were studied in detail and connected to EO solutions that can fulfil the need. By plotting the EO product in a capability-utilization chart, the utilization gaps and R&D gaps could be delineated next to products with a high potential.

EO technology is being used by the mining industry. Although some EO products need further development to become of added value to the mining sector, many products show significant potential for increased usage given the need that this sector has for geoinformation. Several barriers for the wider uptake of EO have been encountered during interaction with the sector. For example, while many people within the mining sector are aware of EO, there are a significant number of people and companies that are not aware of the EO potential and its business rationale for their operations.

It has been demonstrated that there are already valuable applications where EO technology is of use to the industry. The EO technology will continue to evolve with improvements in resolution and coverage, which will open up more applications within the mining industry or provide additional assurance to branches of the mining industry who have yet to be convinced.

To realize the full potential of the technology within the mining industry the EO industry needs to engage more with the mining sector to educate the sector on just what is available. What is a resolution gap for one application may not be for another application. This engagement will need to be ongoing and the resolution gaps that currently exist will become less with time. Importantly, not only is it necessary to educate the users within the mining sector, it is also necessary to ensure that others who use and review information from mining companies, such as government regulatory agencies, recognize the validity of EO based information.

In the best practices road map report, we recommend two potential ways to increase uptake of EO service in the mining sector:

1. **Stimulate EO use in the sector**. The gap analysis and webinars showed that there are many products that can meet the needs of the sector, but they are currently underused. This can be due to a lack of knowledge, standardisation or guidelines in the sector. Addressing these issues will increase the use of EO in the mining sector.
2. **Make access to EO service easier**. Currently the market for EO solutions is very fragmented, making it difficult for providers and users in the mining sector to find each other. A solution to this problem is to develop common service platform to be used by all providers. This would provide a “one-stop-shop” for all products, making it easier for the market to find solutions. It will also make all information and data on offer uniform and therefore easier to use by the market.

Ground stability and environmental impact in the context of mining covers several areas related to the mining operation and the structures associated with the mining process, i.e. land use, vegetation, land subsidence, pit slope stability and tailings dam stability. The identified EO technologies are also potentially beneficial to other applications, especially in protecting society against geo-hazards, caused by failure of dikes and other flood protection structures, failure of water reservoir dams and occurrence of landslides and mud flows.