Tailings Management, Meet Science Fiction

Amanda Adams, Debra Johnson and Kwestan Salimi, Stantec, USA,
explore how further steps can still be taken to better manage dam safety.

Science fiction fans can appreciate how easily characters in shows such as Star Trek and Doctor Who are able to diagnose every issue. There is no explanation of how the methods work, or what data they are collecting, they simply deliver exactly the right information the instant it is needed. Imagine if that were possible today for applications such as dam safety and tailings management.

What if everything one needed to know about slope stability, soil saturation, production rates, impoundment density, embankment deformation, etc. was available at one's fingertips? And not just the individual data sets, but a synthesised diagnostic that combines the design, construction and operation, along with inputs such as climate data, seismic readings, and real-time inspections? This sounds like science fiction, but the reality is closer than one might think.

Global Standard on Tailings Management

Tailings disasters have triggered an overhaul of global safety guidelines, leading to the introduction of the Global Industry Standard on Tailings Management (GISTM). In August 2020, co-conveners International Council on Mining & Metals (ICMM), United Nations Environment Programme (UNEP), and Principles for Responsible Investment (PRI) launched the GISTM with input from a multi-stakeholder advisory group. The GISTM aims to prevent catastrophic failure and enhance the safety of mine tailings storage facilities (TSFs).

Figure 1. Stantec engineers monitor many remote tailing storage facilities, like this one in the mountains of Peru. An all-encompassing, largely automated tool would be extra useful at sites that are difficult to visit.

Figure 2. Apollo 11 moon landing.

The GISTM sets a new, global benchmark to achieve strong social, environmental, and technical outcomes in tailings management. It also highlights that "while the mining and metals industry has come a long way in improving how it operates, there's still much more that can be done to safeguard lives, improve performance and demonstrate transparency."[1]

Data overload

Mines are working with ever-lower grade ore bodies, which means that the percentage of waste to mineral product is increasing. This translates to more and larger TSFs than ever before, although alternatives to TSFs are in various stages of development. Increased disclosure requirements, as well as more complex designs and monitoring systems, timely and accurate data collection and analysis, make reporting of TSF performance more critical than ever.

Types of data collected include:

- Production data from the mill.
- Grain size/grind of the tailings.
- Deposition locations and quantities placed in the impoundment.
- Construction quality control/quality assurance testing.
- Survey data including bathymetry.
- Piezometer or other instrumentation readings.
- Weather and climate data.

Data may be generated monthly, weekly, daily or even by the minute, depending on the collection system. Many mining companies are utilising satellite imaging and remote sensing data, which can generate millions of data points across a site. It is great to have so much data, but the sheer volume can be overwhelming. According to NASA, "Over the last years, the volume of SAR has grown to 9 PB, predominantly from the recent Sentinel-1 satellite with 7 PB of data. This volume is expected to grow at an unprecedented rate of approximately 86 TB per day with the launch of NISAR in May 2022."[2] Mine operators need sophisticated data storage and management systems, but they also need efficient ways to pull and analyse the data for it to be useful in practice.

Turning science fiction into fact

Tailings engineers and operators must be able to quickly visualise information and be alerted long before any monitoring points reach a critical level. Looking at datasets individually may not tell the whole story. Perhaps a piezometer reading appears to be below the trigger level, but if it is placed in a zone of finer grind material, the trigger is no longer accurate. Or perhaps the available stormwater storage is sufficient based on the original design, but not when the effects of climate change are considered.

This is where mines need a futuristic data analysis tool: a device so sophisticated that it can analyse endless data points instantly, as well as run countless scenarios to identify critical risks in a timely manner, faster than human engineers can currently create the analyses. It would understand and compare disparate datasets, extrapolating how the impacts of changes in one or more parameters could impact the entire facility. Furthermore, most importantly, it could also immediately warn stakeholders of impending risk based on situational and environmental changes so that relevant action could be taken.

Shoot for the Moon

In 1961, John F. Kennedy asked Congress to "commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth."[3] JFK created a vision and a challenge that Congress, NASA, and the American people could rally around.

No one company or technology made this moonshot vision a reality. It required collaboration, ecosystems of diverse partners (including companies who were traditionally seen as competitors), creativity, and a lot of hard work to solve both big and small challenges. There was a lot of incremental innovation that had to happen to achieve JFK's moonshot vision. Because of that 60-year-old vision, current space journeys (such as the highly publicised trips by Richard Branson and Jeff Bezos) continue to leverage the resulting technological advances.

Today, there is an opportunity for the mining industry's own moonshot vision – an application on the mining company CEO's phone that shows the status of every TSF in the company, enabling the CEO to sleep soundly knowing that everyone who could be impacted by TSFs will be safe tonight. As with JFK's moonshot, in order to achieve this vision, a lot of very 'unglamorous' incremental technologies need to be developed and matured. It will require creativity, collaboration and data sharing between the entire industry, including companies who may be competitors.

Incremental change to achieve the vision

Industrial Internet of Things (IIoT), data lakes, data fusion, predictive analytics, machine learning (ML), artificial intelligence (AI), Cloud and Edge devices – technology words that are tossed around every day – mean nothing if the right data is not available, the ML and AI models have not been trained with expert knowledge of the impact of diverse events and conditions, or data aggregation is delayed or corrupted due to unreliable communication networks or cybersecurity issues. A future state vision for TSFs needs to be embedded into the organisation at every level to be successful. The vision should also incorporate a clear technology roadmap. Without this level of dedication, the crucial foundational technologies that may lack standalone return on investment (ROI) will be at risk of ending up on the budgetary cutting room floor.

Additionally, if mining as an industry does not improve its ability to advance incremental technologies required to develop a holistic solution and achieve this vision, TSFs will continue to operate at unacceptably high-risk levels. Like those first steps on the Moon, this vision will only happen with collaboration between ecosystem partners who understand the bigger vision of responsible mining with exceptionally high expectations for timely, accurate visibility into TSF risks.

TSF tools of the future

Although this futuristic TSF tool is not yet a reality, many of the required elements already exist. For example, interferometric synthetic aperture radar (InSAR) is an effective technique to evaluate the stability and behaviour of earthen structures (e.g. TSFs) continuously. InSAR is capable of measuring and accurately mapping ground deformation through monitoring the changes in land surface altitude using radar images of the Earth's surface collected from Earth-orbiting satellites at high degrees of measurement resolution.[4] Radar signals are reflected off a target area to produce images at different times, then two images are combined, resulting in maps called interferograms that show ground-surface displacement between the two time periods. InSAR techniques can, for example, help determine if the drainage system works properly and, if not, where the additional drainage wells should be installed.[5]

InSAR data, when harnessed and fused with other data sources in a holistic solution, will greatly extend the ability of TSF engineers and operators to:

- Rapidly and accurately monitor any potential deformation of a TSF, such as embankment movement or sinkhole development.
- Identify those conditions that require subsequent manual onsite investigation.
- Provide a reliable early warning system with millimetric precision.[6]

Building the tool vs trusting the tool

Another way to think about the journey to getting to an automated, smart TSF safety tool is to think about the development of self-driving cars. People have dreamt of self-driving cars for decades. Developing the concept from the initial idea through to a fully autonomous, safe passenger vehicle requires many iterations, with continuous testing in countless scenarios conducted in low-risk environments, before the vehicle is ever trusted to navigate in real-time on an operational road. To be successful, a self-driving car must be 'intelligent': it must sense obstacles, react to changing road conditions, and, above all, preserve the safety of passengers, pedestrians, and other vehicles.

The mining industry is in the early stages of defining how an intelligent TSF safety tool would work. It will likely be a long road to developing a 'self-driving' TSF. TSFs are currently monitored by people assimilating information from numerous sources. Even when the best datasets and information dashboards are available, that information is still reviewed, analysed, and verified by an operator or engineer. Stability analyses, trigger alert systems, and critical failure mode assessments are ultimately the product of people, not computers. The future of tailings management will be an intelligent system, informed by the site engineers, but smart enough to extrapolate information, make recommendations, identify problems, and suggest modifications without human oversight and constant input. The key will be to address the unique barriers to developing this system and effectively leveraging the expert knowledge of engineers.

While self-driving cars must be able to react to stimuli and conditions, their job is distinctly different from the role to be played by a TSF tool. No two mines are the same, and no two TSFs are the same, each with quite unique physical properties. All cars have wheels and engines and can drive on asphalt, concrete, even dirt roads. Training the ML and AI models for a TSF tool must rely on engineering calculations, since repetitive scenario testing is not feasible. At what point will a 'self-driving TSF' be trusted? What level of testing and validation will be required to be confident that every analysis and recommendation output by the tool does not still need to be duplicated and validated by a person? These questions will need to be answered sooner rather than later as ecosystem teams work together to build this tool.

Conclusion

Although the diagnostic tools of TV science fiction do not yet exist, there have been advances light-years beyond the technology that existed at the time of the first Moon landing. Catastrophic TSF failures, and the associated outcry from the public, have resulted in the GISTM. This standard strives for nothing less than "to achieve the ultimate goal of zero harm to people and the environment with zero tolerance for human fatality". The technology step-change which will be required, in order to get from current design and monitoring practices to fully utilising sophisticated ML and AI models, will not happen overnight. However, many foundational elements of a tool like this already exist and the use of InSAR and other automated sensing and monitoring data grows daily.

There is more collaboration and innovation happening in the mining industry today than ever before. Now is the time for the entire industry to set the goal of an 'intelligent' TSF tool to better manage dam safety. With this unified goal, the industry will be able to achieve not only the technological vision, but more importantly, the goal of ensuring that everyone who could be impacted by those TSFs will be safe. GMR

References

1. *Global Tailings Review*, https://globaltailingsreview.org/
2. 'Enabling Cloud-Based InSAR Science for an Exploding NASA InSAR Data Archive', *EarthData*, https://earthdata.nasa.gov/esds/competitive-programs/access/cloud-based-insar
3. 'May 25, 1961: JFK's Moon Shot Speech to Congress', *Space.com*, https://www.space.com/11772-president-kennedy-historic-speech-moon-space.html
4. COLOMBO, D. and MACDONALD, B., 'Using advanced InSAR techniques as a remote tool for mine site monitoring', *The Southern African Institute of Mining and Metallurgy*, (2015).
5. HU, X., et al., 'Consolidation settlement of Salt Lake County tailings impoundment revealed by time-series InSAR observations from multiple radar satellites', *Remote Sensing of Environment*, Vol. 202, (2017), pp.199 – 209.
6. THOMAS, A., et al., 'Earth observation data and satellite InSAR for the remote monitoring of tailings storage facilities: a case study of Cadia Mine, Australia', *Paste 2019: Proceedings of the 22nd International Conference on Paste, Thickened and Filtered Tailings*, pp.183 – 195.