One of the issues the mining industry needs to resolve over the next five years in working towards an understanding of “What the industry will be like 50 years from now?” is the extension of digital technologies from surface to underground. No matter which methods of mining will be applied in future, one thing is certain – the mine of the future will be digital.

The building of a digital mine laboratory (Digital Mine) has the potential for integrating the mock-mine at the School of Mining Engineering with the rest of the Chamber of Mines (CoM) building, the Genmin Laboratories on campus and in fact the rest of the Wits campus. This will allow further integration within Wits, extension to Joburg City, its communities and surroundings – especially areas affected by past and current mining operations. A laboratory of this nature is therefore of long-term benefit to both mine- and urban planning as one integrated activity. It is also a key component of the mining engineering teaching and learning experience at Wits University and a vital division of a future and leading Wits Mining Research Institute at Wits University, along with the Centre for Sustainability in Mining and Industry (CSMI) and Centre for Mechanised Mining (CMMS).

Aim and objectives

Through research, development, testing and implementation of smart decision-making technologies, mine designs and processes can be optimised. The purpose of Digital Mine is to create a platform to action the existing strategy of the mining industry to continuously improve working conditions and mine economics. Digital technologies are fundamental for an efficient and safe mine where all systems are optimised. This requires clarity of multiple sources of underground data communicated to a surface control room and back to the workplace in real time. The objectives are:

- **Financial:** To work with lead sponsors and to explore more and different sources of funding (work in process).
- **Customers:** To build a world-leading facility to benefit our staff and students with their teaching, learning and research goals; and to assist our industry with real time monitoring, data processing, management and control using a digital mining platform.
Operational: To develop digital research capacity and enable fundamental mining research and development for better safety, worker health and economics.

People: To demonstrate that we can do it, we have taken the initiative and indeed the first steps towards attracting multidisciplinary students/researchers locally and internationally into mining research.

Who are currently involved?
The Digital Mine project was conceived by the author, who secured initial funding, implemented and managed the initiative to date. Individuals who have made significant contributions are:

- Sarfraz Ali (PhD candidate): Design and facilitation of ground behaviour monitoring system for Digital Mine, with an extension to Sterkfontein caves.
- Dave Borman (Snr Lecturer): Building of a 3D model for integration with camera systems.
- Prof. Fred Cawood (Professor of Mine Surveying and Interim Director WMRI): Strategy and implementation.
- Prof. Grant Cawthorn (Professor of Geosciences): Design, planning and layout of all geological features.
- Prof. Turgay Celik: Fundamental research for Sensing Mine (SEMI).
- Tariq Feroze (PhD Candidate): Digital Mine Secretary.
- Bekir Genc (Snr Lecturer): Computer and IT systems and the School of Mining Engineering’s representative looking after School Digital Mine research projects.
- Prof. Beatrys Lacquet (DVC): Making space available for the mock-up in her role as the responsible person for Wits Facilities and Infrastructure.
- Wynand Marx (BBE): Advisory capacity and design of ventilation system.
- Barry Prout (Snr Lecturer): Visualisation systems, Mock-up Project Manager and the School of Mining Engineering’s representative looking after the teaching and learning objectives of Digital Mine.
- Desmond Subramani and Stephan Fuchsloch (Leapfrog): Development of the geological model for Digital Mine using Leapfrog Geo Software.
- Russel Scott (Sculptor): Sculptor, model building and feature design.
- Francois Stroh (Horts Solutions): Precise, high-density laser scans and visual analysis.
- Ruud van Nieuwenhoven (Mine RP): Initial design steel arch section of the mine tunnel, with WiFi specifications, in addition to facilitating the MineRP software donation and partnership.

Who are our funders?
The dream of building the Wits Digital Mine laboratory became real after we received three substantial donations, i.e. a financial donation from Gold Fields in 2010, an in-kind donation from Aveng Mining in 2013 and a capital injection from Sibanye Gold in 2014. These three companies are the main partners to date. The first phase, the building of the mock-up hosting our digital mine, which starts on the 4th floor of the CoM building in the Mine Design Laboratory (MDL) and ends at the mock-up area in the basement with an extension into the Genmin laboratories, is at an advanced stage of completion. The MDL and basement is linked through the west stairwell of the CoM building, which is equipped as

Note 3: Many individuals, vendor companies and mining companies have indicated that they are interested in partnering with Digital Mine. This discussion is restricted to funders whose support had already been received at the end of December 2014.
a vertical shaft. The components\(^4\) and their funders are:

- Anglo American (Chairman’s Fund) – Space for the Mine Design Laboratory (see Fig. 4).
- Gold Fields (Nick Holland) – Equipment for the Mine Design Laboratory (see Fig. 4).
- Aveng Mining (Martin Hobbs) – Equipment of CoM West stairwell as an equipped and sinking shaft (two components), along with graphic visuals down the shaft and floor passages. This facility will host research projects that require a vertical facility e.g. communications, shaft design and surveying methods (see Fig. 5).
- Gold Fields (Nick Holland) – Building of the 70 m tunnel\(^5\) with crosscut breakaway (stump allowing for one rail switch). The tunnel has a separate ventilation system suitable for research. To be equipped with a monitoring system and wireless communication. (See Figs. 7 and 8.)
- New Concept Mining (Brendan Crompton) – Building of platinum stope panel\(^6\) with complete support and safety system. To be equipped with a monitoring system and wireless communication. (See Fig. 9)
- Sibanye Gold (Neal Froneman) – Building of Lamp Room for research into lamp room design taking account of security and health management. To be equipped with a monitoring system and wireless communication. (See Fig. 10.)
- Sibanye Gold (Neal Froneman) – Building of rescue bay for research into rescue bay design. To be equipped with a monitoring system and wireless communication. (See Fig. 10.)

Note 4: Starting at the top floor of the CoM building, working towards the basement and then the extensions to Digital Mine.

Note 5: Financial contributions were also received from the Dean’s budget and the Mineral Education Trust Fund (METF).

Note 6: Financial contributions were also received from Gold Fields and Sibanye Gold. Anglo American Platinum (School of Mines) hosted the visit required for the design of the facility.
• Sibanye Gold (Neal Froneman) – Building of control room (in early stage of implementation) for research into Campus/City GIS design; data processing; remote visualisation; health, safety and environmental monitoring; data analysis; and hosting of a research group on preventative control measures.

• Sibanye Gold (Neal Froneman) – Funding Sterkfontein caves extension (in planning stage of implementation) for research into remote visualisation, health and safety. To be equipped with a monitoring system with ability to communicate with the control room on campus. (See Fig. 11.)

What kinds of research are being undertaken?
The first PhD students (on suitable wireless technologies for mining and on mine ventilation engineering) have been registered and will install current (SMART) systems as part of their research. Over time these will further be integrated with:

- Smart surveying and mapping (visualisation) systems.
- Smart climate control systems and (energy) savings.
- Smart rock engineering systems.
- Smart data processing for smart mine design, mining planning and decision-making.

How is the project expected to assist the mining industry?
Digital Mine has the same values as the mining industry, namely a partnership approach to knowledge generation and skills, which are key to a safe, healthy and thriving mining industry; and a deep commitment to South Africa and its mining industry.

We are passionate about education and skills and want to do more on fundamental mining research.

Benefits to the mining industry include the following:

- Access to a safe, smart mine laboratory reaching into the surrounding community on a multi-sensor GIS platform.
- Relevant (not vendor-driven) knowledge to collect appropriate and accurate information to optimise mine designs and processes.
- Reduction and clarification of multiple streams of data. Clarity is required more than ever in a system capable of receiving continuous data from unlimited sources resulting in an overload of information and significant noise. Misunderstanding of information is counterproductive and clarity brings information to a state of "readiness-for-decision-making".
- A positive impact on security and mining sector efficiency.
- To bring operations in a state of proactiveness by being predictive and continuous.

Note 7: "Clarity is the ability to discern the factors that make a difference and act on them productively, without being distracted by the 'noise' in the system." J Smart (2013).
• Mine-to-order (or demand mining) becomes a real possibility, contributing to productivity, mine bottom-line and transforming the mining industry through information technology.
• The mining industry has adopted a zero-harm philosophy when it comes to worker safety and health. A digital mine will accelerate the process of reaching this goal.

Innovative technologies under development (some have been implemented) and their purpose
Technologies under development that have the potential to be incorporated in the mine of the future are:
• Underground communication systems – real-time intervention to manage all types of risk.
• Lamp room camera (MultiCam) systems – environmental, health and safety monitoring for security, preventing illegal access, monitoring worker health and face/action recognition.
• Underground drone – a floating technology that sees, maps, collects data, communicates and decides. It has significant potential for reconnaissance-type work, pillar mapping in abandoned mines, use whenever the risk does not justify sending a person, inspections after a blast, rescue services, etc.
• The ultimate aim is to do the fundamental research required for manufacturing the smart underground monitoring station, i.e. a complete stationary sidewall-mounted measurement station that meets the accuracy requirements for mine surveying, mapping and environmental monitoring. Such integration of systems will allow for intelligent decisions, improved safety and health, and cost savings through real time monitoring, data processing, management and control using a digital platform. Researchers from various backgrounds will be required and include all Schools in the Faculty of Engineering and the Built Environment, Geography, Geology, Computer Science, Mathematics, Health- and Environmental Sciences, and the Humanities.

What is the progress to date?
Digital Mine has four phases, namely:
• To build a mine mock-up for teaching, learning and research.

Note 8: Agreements that were at an advanced stage by the end of 2014 include contributions from Schaunburg, MineRP and Esri.