Automation is no longer just represented by a handful of isolated and idealised test areas of mainly conventional mines. It is becoming a full production reality at a number of key operations, both surface and underground. And if anything the market pressures, particularly in the form of cost scrutiny, are driving progress at a faster rate than ever before. But automation also brings unique safety and planning challenges, that are now also being addressed and considered.

**Multi machine capability**

*Atlas Copco* states that: “by enabling the strength of a common control system on our new generation mine equipment we can enable customer value with smart functions and features on a large range of mine equipment.”

The mechanisation era has been followed by the computerised or automated area for mining that has been around a couple of decades; and several improvements have been implemented thanks to on board computers and network based electrical systems. Oscar Lundhede – Atlas Copco Product Manager Underground Automation explained in a recent presentation the next generation impetus: “The operator has got help to control the equipment in the most efficient way and some operating tasks and routines have also been fully automated. Even the service and maintenance have improved helping the operator and technicians to solve problems and detect errors faster and more precise. But what about the control of the machine, isn’t it still one operator for one machine?”

Since 2012 the Atlas Copco Simba Multi Machine control system has been available for remote control production drilling applications and has been in operation in LKAB in Sweden. Together with ABC Total and the new generation Simba the operator can supervise up to six production drill rigs. But now thanks to the common control system the same function in 2014 is now available for Scooptram LHDs.

Atlas Copco started with teleremote functions on drill rigs in the 1990s in collaboration with LKAB in Sweden. It was a PLC based system with different supplier of the hardware and software. The Kiruna mine was working on wireless underground communication (WLAN) and Malmbetget was using fixed cables connecting each rig. The Simba W469 or BK rig was controlled from a cabin in a close remote location from the rigs.

Atlas Copco has for several years, been working on automated functions for repetitive routines. This is to increase the safety and working conditions but also to increase productivity. In 1998, Atlas Copco introduced the Rig Control System (RCS) to the market. The RCS made the equipment easier to use and made it possible to add different type of automation solutions, such as ABC Basic, ABC Regular & ABC Total. These functions assist the operator to control the drill rig with higher precision that leads to increased productivity. Still today Atlas Copco drill rigs have the most comprehensive automation package on the market with additional proven functions such as Underground Manager, Measure While Drilling, Rig Remote Access, and Drill Plan Generator. The company recently won an International Design Award (IDA) for the RCS 5.0 rig control system for Boomer underground drill rigs. In 2013, the same product also won a design award from IDA.

When it comes to the underground loaders and trucks there have been a number of steps towards automation for several years including vehicle monitoring systems, load weighing systems and several remote control systems. In 2005 Atlas Copco released a line-of-sight radio remote control for Atlas Copco loaders, the Scooptram RRC. The remote control was the first automation product developed for the Atlas Copco loaders. The company states: “The product has been a success when it comes to user friendliness, durability, cost efficiency and easy to support, and it is today operational in more than 30 countries world-wide.”

The first RCS loader to be launched was the 14 t loader, Scooptram ST14 with RCS, introduced in 2006. This has then been followed by a 7 t loader (ST7), an 18 t loader (ST18) and a 42 t truck (MT42), all being automation ready with RCS.

In 2009 Atlas Copco released the Scooptram Automation system, a semi-automated system for Atlas Copco RCS loaders. The package includes an ergonomic and easy to use operator’s station, an RCS loader with additional sensors, a safety system isolating the loader from other equipment and underground personnel and a standard wireless communication link (802.11) to the mine network (LAN). The loader adds features such as tele-remote control, auto-tramming, and auto-
Scooptram Multi Machine is designed to be efficient, reliable and easy to use. The remote operator station provides the operator with an ergonomic and safe working environment.

Scooptram Multi Machine is designed to be efficient, reliable and easy to use. The remote operator station provides the operator with an ergonomic and safe working environment. The Scooptram automation machines from the rest of the mine. This is achieved through the use of Light Barriers together with an Area Restriction Stop Light and a Check In/Check Out Area. Should a barrier be broken or breached, only the automation machine in that production zone will be safely shut down, allowing the remaining automation machines to safely continue operation in their respective automation production zones.

Each Area Isolation System can have a total of 30 Automation Production Zones and a maximum of 90 Barriers. Each automation production zone can have one automated machine, giving a total of 30 machines running simultaneously in one Area Isolation System.

Set-up of production zones is done through the easy to use Master Touchscreen PLC Cabinet which allows a customer to assign any barrier to any production zone, providing a truly flexible system.

For every Automation Production Zone, a Check In/Check Out Area allows one automation machine to safely enter and exit the Automation Production Zone. This is achieved by using a unique key which can only be connected to one operation at all times.

A Safety Barrier consists of a Safety Box, a Light Barrier and an Area Restriction Stop Light. Multiple light barriers can be added to create multiple automation production zones, or to safely isolate a single automation production zone. For local regulations physical barriers might be required and could be integrated to the safety system.

The Area Isolation System is connected through Ethernet, connecting the production area including one or several zones, the operator's station safety module and the machine's safety PLC. Additional to a reliable Ethernet network 110/230 power is also required. For the machines to operate in semi-autonomous or tele-remote mode, WLAN coverage is required throughout the Automation work area. A communication panel, a monitor, server cabinet, desk and chair. The operator handles the vehicle and the system with the control panel and gets visible feedback from strategic on-board cameras and a lasers-view, which is displayed at the operator's desk monitor. Full vehicle data information is displayed along with remote on-line diagnostics.

With Multi Machine control the operator can operate several loaders from one or several operator's stations. The system is flexible to operate any from a single loader up a large numbers of remote controlled loaders. How many depends on what is possible to manage by the operators and the cycle time of the operator.

“The Tactical Display will give the user a good overview of the entire system. The current status of the machine, Area Isolation System and infrastructure will be visible and easily monitored by the operators, production management, maintenance management or any other party that could benefit from this information. The Tactical Display will be tied to a map of the mine, with assets like draw points and dump points visible as well as machines with their current location and assignment status.”

The semi-autonomous system includes Tele-Remote control, Multi Machine control, Auto-Tram and Auto-Dump functions. This makes it possible to avoid human exposure in unsafe areas such as unsupported stopes, or in any other load, haul and dump applications.
network is installed, normally controlled and maintained by the mine itself. The Local Area Network (LAN) and Wireless Local Area Network (WLAN) must be compliant to the Ethernet standard IEEE 802.3 as well as the Wi-Fi standards IEEE 802.11 a, b or g. The network requires a reservation of 20 fixed IP addresses to be able to use a dynamic host configuration protocol (DHCP) server. One vehicle utilises a bandwidth of approximately 2 Mb/s while in operation. The Access Point (AP) has to be set up as a single channel network, using one of the three orthogonal channels 1, 6 or 11. The WLAN cannot be encrypted in any way and must broadcast its Service Set Identifier (SSID). Signal strength should not drop below -60 dBm to the vehicle. The AP needs to be complemented with power and Ethernet and requires bandwidth of at least 2Mb.

When a smaller production area for one or two vehicles is required, Atlas Copco can provide the communication hardware needed. The number of access points or switches required is dependent on the size and layout of the automation production area. Atlas Copco can assist with a communications audit to determine the infrastructure required.

On the new offering Lundhede states: “The functionality of Multi Machine gives new possibilities to increase safety and productivity. It is today available for Simba production drill rigs and Scooptram underground loaders and will extend with time to additional Atlas Copco equipment.”

The semi-autonomous underground loaders are traming in high speed without required supervision by an operator. For fulfilling mining regulations the area needs to be sealed off from personnel. With Multi Machine a safe and flexible safety system has been designed that allows several loaders to operate in several production cells. Though these cells are divided from each other maintenance of a vehicle in one area can safely be performed without affecting the other vehicles.

To gain increased productivity the mine will though need to plan for implementing Tele-remote equipment as follows:

- A stable network is the foundation of high availability of any Tele-remote system. It also needs to be planned to seal off parts of the production areas for the semi-autonomous loaders.
- During its operational hours any interruption to its isolated production area will affect the operation. Area inspections, maintenance or traffic through the area needs to be planned to not interfere.

New maintenance skills need to be implemented in the service organisation.

Network support is new for most underground mines. A reliable network is key for any remote operation.

Hardware updates

Earlier this year, power management company Eaton announced the release of its new OMNEX multi-function two-way radio remote control with high resolution colour display. The new OMNEX TD3200 is a robust, next generation radio remote control designed for smooth operation and precise control of vehicle mounted equipment and mobile industrial machinery, including mining equipment. The multi-function radio remote incorporates state-of-the-art design, integral two-way communications and industry-leading ergonomics into a “robust and lightweight portable control unit.”

The TD3200 offers a 3.5 in transflective color LCD display that provides extensive status monitoring, diagnostic information and controls capability. Two-way communication delivers useful machine status information to operator via the display’s exceptional graphics, readable in day and night conditions for increased productivity.

Safety features include an operator alert buzzer, drop/tilt detection as well as sensing inactivity detection. Critical safety features are integral to the design with redundant signalling and emergency stop functionality. Eaton states: “The TD3200 is ergonomically superior, with a lightweight design that minimises operator fatigue and maximises productivity...the radio remote accommodates a wide variety of controls including: two and three axis joysticks, paddles, toggle switches and potentiometers.” OMNEX Trusted Wireless FHSS technology provides “superior range and exceptional reliability.”

“Our team has created a breakthrough design for OEMs and high value machinery builders who want to leverage wireless control to achieve greater safety and productivity for hydraulic machine operators,” said Steven Toteda, Vice President and General Manager for Eaton’s...
wireless business. “The TD3200 remote control provides feature and function richness, and ergonomic advantages that are coupled with a modern aesthetic for the next generation of mobile control.” Other features include durable, weatherproof construction, internal and external battery design that offer long life and waist belt and shoulder harness attachment points.

Eaton’s OMNEX brand is the industry pioneer and leader in developing rugged radio remote controls for heavy machinery and field operations. OMNEX remote control products are used extensively in the mining and construction markets, as well as in material handling equipment.

In July 2014, Laird, the global technology company, announced the release of two new intrinsically safe operator control units (OCUs), the LRC-M1-IS and the LRC-L1-IS. Both units are approved for use in highly explosive environments and are part of the CattronControl globally compliant family of remote control systems for cranes.

The company stated: “Adding these intrinsically safe units to the CattronControl line of products enables users in hazardous environments to benefit from the freedom of movement and associated increase in productivity and safety that remote control brings. An operator is able to safely position themselves to best advantage without being tied to a manual control station or wired pendant. Both OCUs employ advanced dual processor electronics and safety critical software which are protected in an ergonomic and robust housing that is well-suited for use in demanding industrial environments.”

New features include an external memory button, allowing facilities to quickly deploy spare units by simply swapping the memory button between the operating unit and a spare. This minimises downtime and the number of spares required to support the overall operation. Additionally, the units are approved for Zone 0 use which allows continuous exposure to the explosive atmosphere. This approval requires the products to tolerate two concurrent faults without causing a condition that could create a hazardous situation. The battery will last for 12 hours of continuous use, but can also be changed while in the hazardous environment which minimises downtime.

“Our customers safety and productivity were the top priorities in developing intrinsically safe remote controls for use in these hazardous environments,” said Rick Morse, Senior Vice President for Laird. “To meet the needs of a variety of customers, we were able to design multiple models for a range of applications that not only deliver safety, but increase efficiency and reduce costs for our customers as well.” The LRC-M1-IS is a mid-sized OCU, while the LRC-L1-IS is a full sized unit. Both are available as engineered units to suit specific application requirements.

Line of sight in China

Eldorado Gold’s target is to double the output at its Jinfeng gold mine over the next two years. In order to achieve their production target, the company needed to identify a way in which it could continue to mine, safely and efficiently. The solution is to incorporate a change to the current mining method of over-hand cut and fill and to include long-hole open stoping, which requires remote loader capabilities to recover the ore from large unsupported areas. The Carlin type ore deposit mined in Jinfeng is commonly associated with poor to fair rock types and high grade areas that self-mine, this can jeopardise the safety of the operators and machines. The ability to continue to mine in these unstable conditions without jeopardising the safety of the operators is the key factor to increasing productivity at the mine. Jinfeng recently took the first, significant step...
towards teleremote control with the implementation of RCT's Line-of-Sight control of their Caterpillar R1700 LHDs.

Where an area is unsupported, such as long hole open stopes, removing the operator from the hazardous area and allowing them to control their machine from a safe location some distance away, allows continued production without exposing personnel to any risk. The significant safety improvements available through remote control of equipment first caught the interest of Jinfeng mine management resulting in the installation of two ATX2200 Line-of-Sight remote solutions at the gold mine. This allowed them to control their R1700 LHD vehicles from a safe distance and to continue to operate in the unsupported conditions. RCT states; “The successful implementation of RCT’s ATX2200 Line-of-Sight Solutions at the Jinfeng operation heralds the beginning of remote control operation at the mine which is one of the largest foreign owned gold mines in the People’s Republic of China.”

RCT’s team installed the remote control systems at Jinfeng on two underground loaders (LD002 & LD005) and trained 14 Jinfeng staff (including underground operators, underground trainers and maintenance personnel) in safe operating techniques, fault finding and diagnostics of the Line-of-Sight remote system. Successful completion of the training enabled the operators to control the underground loader LD005 from over 400 metres away using Line-of-Sight control. The comprehensive operator training included classroom theory and practical operation of the loader on remote control.

Eldorado maintenance staff underwent RCT’s Level 2 training which allowed them to not only operate the remote loader but to identify potential faults and understand the internal diagnosis software functions and settings. “Remote control loaders are essential for safe long hole open stoping, and to ensure the safety of the operators,” said Jackie Bock, Underground Foreman at Guizhou Jinfeng Mining ; adding “this commissioning and training will enable us to recover ore from places that are considered too high-risk for exposure to our operators.”

RCT states: “The comprehensive support and training provided to operators, training and maintenance staff at Jinfeng has empowered them with the skills necessary to gain the most from their Line-of-Sight equipped machines. With machine maintenance now possible, immediately or as required and on site, machine downtime is minimised and production can continue with minimal interruption. This, together with the ability to continue to operate in the unstable environment, has a significant impact on production with an increase in operations.”

With the successful installation and the achievement of positive outcomes from the Line-of-Sight control systems, Jinfeng are now looking at implementing teleremote control to approved machines. While the benefits of RCT’s Automated Mining Solutions were already well known to the Underground Foreman, from his own experience at another operation, its application at Jinfeng provides significant opportunity to increase safety for the operators prior to the operation moving to a new and more productive mining method. “I have seen the benefits of RCT’s remote control solutions in other operations so am confident in achieving positive outcomes at Jinfeng,” said Bock. “To further lift our production, we are looking to change our mining method to long hole open stop mining,” said Bock. “We have seen the success of RCT’s solutions at a sister mine, so we have confidence in achieving successful outcomes here at Jinfeng with the Teleremote Solution.”

Hard-Line advances TELEOP

Hard-Line has had a high degree of success in regard to its TELEOP (Tele-Operated Remote Control System), which enables the operator to control any machine from a remote location. The company told IM: “We recently used this system in New Mexico for a demolition company that was decommissioning a military base. The system enabled the heavy equipment to be operated from a safe location while excavating dangerous commodities from the site. In another
application, a mine in northern Quebec uses
Hard-Line's TELEOP system in their open pit
operation, removing operators from risk zones.
We are also currently commissioning seven
large mining vehicles of various types and
brands in South America that will remove the
operators from risk. Because TELEOP can be
customised for virtually any heavy industrial
machine, and so mixed fleets made up of
various manufacturers are not a problem. It is
this flexibility and safety component that
makes it a very attractive solution to the
operation of these machines.” In underground
applications, TELEOP has been used for multiple
rock breaker sites operated by one remote
TELEOP station, resulting in greatly improved
efficiency. It has also been configured to operate
drills, LHDs and a host of other equipment. Shift
changes in underground operations result in lost
productivity, but with TELEOP production can
continue during these periods resulting in
increased productivity in the mine. Hard-Line's
market position is “we can TELEOP any machine
you run” and states that this holds true based on
the breadth of real applications. In the very near
future Hard-Line will be launching its Operator
Assist system, which will allow the operator to
run an LHD transporting ore without steering
using laser technology to guide the machine.
Load and dump would still be manually
controlled from the TELEOP site, but the

transport to and from the muckpile would be on
automated steering. “The benefits of less
machine damage, higher speed, and increased
efficiency make the system a profitable option.
The Operator Assist System will launch Hard-Line
toward the goal of automated mucking of ore”
the company told IM.

AngloGold Ashanti and SmartMineUG
In the operation of underground mines, all steps
of the production cycle are equally important, as
they depend on one another for development as
well as production. The sequencing and
prioritisation of the activities are fundamental
just like the progress and follow up of every task.

Hexagon group company Devex states:
“Due to that complexity, until recently the
solutions that existed for the management of
underground mines were mere adaptations of
systems designed for open pit mines, which
are more focused on loading and ore haulage
related activities thus giving higher priority to
that type of operation. The scenario only
started to change in 2011, through the
partnership between Devex and AngloGold
Ashanti for the development of a Dispatch
system specifically focussed on underground
operations.”

This is how Devex system Smartmine UG was
born. “The product was designed considering the
specificities and challenges of that kind of
operation which combine process control logic,
data communication, safety norms and
environmental hardships, amongst other
factors”, says Underground Product Director Julio
Alves.

According to Alves, the objective with
Smartmine UG is being able to plan and control
all the tasks carried out in underground
operations, regardless of the type of assets,
whether mobile or fixed. “That way, it is a
solution that goes way beyond a Fleet
Management System and thanks to its open
platform, it allows for integration with other
systems. One example is the specific set of
modules for the monitoring of the timeline on the
mining faces, which makes it possible to control KPIs such as availability and utilisation for that type of asset.”

Devex signed a partnership with AngloGold Ashanti to implement the SmartMine UG system at the Lamego gold mine in Sabara, Minas Gerais back in 2011, and now in 2014 the whole fleet of the mine is monitored by the system. Corrego do Sitio Mine Manager, Renato Queiroz de Castro, who initiated and followed the project until the end of 2013 as Mine Manager at Lamego, told IM that the transformation of the scenario within the unit of the mine started four years earlier. “We start to work by acquiring the communication system, since we did not have any radios in the mine. Then we created the Operational Control Centre (OCC) but the tasks were still being manually inputted into an Excel spreadsheet, until we signed the partnership with Devex for the development of the dispatch system and the platform for the automation of the all the other mining processes.”

Renato also stated that operators started to use the Tracker UG (onboard computer) to input data into the system and send information online to the system. “It is now possible to know the availability, utilisation, productivity and lack of productivity in real time, which guarantees an assertive decision making process at the OCC.”

Truck operator Alisson Magalhães points out that with SmartMine UG, controllers send all the operational information via the online system, so that they are spoken through a synthetic voice to the operators underground. “This was a real breakthrough in safety, since it allows us to remain focused on executing the task while we listen to the incoming messages, which are also registered into the Tracker UG so they can be read at a later stage. Not so long ago, we were in the mine without knowing exactly how many pieces of equipment were in each area. Now the data is made available in real-time for the OCC and in case of an emergency, we can be warned and safely leave the underground mine.”

Lamego Mine Controller, Elmo Franco Júnior, says that with SmartMine UG, the data started to be sent to the OCC with more accuracy. “The system reads every activity that the operators execute at all the different mine levels. I believe that this communication efficiency which is already effective in all the areas of the mine, accounted for the rework rate to have decreased by 80 to 90%.”

According to Mine Engineer Luiz Fernando Zanotti, SmartMine UG made the operation more dynamic: “The change was significant as we now get the daily data in a much faster way than we used to before. Today we have almost all the data online and centralised. Fleet control is more assertive, people have more information regarding location, productivity and the mine’s logistics got much simpler than not so long ago.”

According to Zanotti, centralising the information in an underground mine bring many advantages. “The first one is safety, since any piece of information that we lose underground translates into a risk. We will be able to reach a level of data management that will considerably reduce rework in all processes. Consequently, we will have more benefits in complying with planning, productivity and grade control.”

He explains that in underground mine operation, uncontrolled interferences cause changes in planning, but with Smartmine UG they are managed in a more efficient way, which makes it possible to accomplish working activities according to planning and consequently improve the adherence. “It is hard to measure precisely, but within a few weeks, we managed to reach 100% of the adherence with development and more than 80% of the adherence with excavation. These are milestones that we would never reach before implementing SmartMine UG.”

At Lamego, the use of eControl, the Devex system for the control and monitoring of electrical equipment, is also fully integrated with SmartMineUG for controlling secondary ventilation. The open platform also allows the integration with other third-party system, such as people tracking, MES, ERP etc.

The current implementation project between Lamego and Devex will run
until December 2014 and until then new features will continue to be added to SmartMine UG, such as Telemetry, Optimisation and Maintenance Control.

**Reasons to automate**

**Autonomous Solutions, Inc (ASI)** specialises in driverless vehicle technology and it develops the hardware and software that convert vehicles from manual to robotic control. ASI highlights that the first and probably the most compelling reason to automate a vehicle is safety. “Many of our customers started their investigation into automation because they had some sort of safety concern. For example, the well-known pit wall failure at the Bingham Canyon mine in April 2013 created a significant safety hazard. The landslide left a massive amount of unstable terrain too dangerous for human operators. ASI supplied the automation technology for six remote control excavators that could be operated from a safe distance, allowing cleanup to commence while also keeping the operators safe.” The excavators have since moved millions of tonnes of material as part of the clearing efforts that are scheduled to extend into 2016.

The second reason to automate a vehicle is productivity. Machines excel at maintaining productivity in precise, repetitive tasks over long periods of time. But ASI says that its technology is designed in such a way that it is not possible to completely eliminate human interaction. “Even considering our new artificial intelligence systems that choreograph vehicle interactions in a robotic ecosystem, humans still play an important role. Operators create vehicle paths, troubleshoot issues, analyse report data, and make the complex decisions that the robotic technology is not capable of. In this way, automation doesn’t eliminate jobs, it shifts the nature of jobs. Dull and mundane tasks are placed in the hands of robots where they can enhance productivity; tasks that emphasise human strengths, such as critical thinking and decision-making, are given to operators.”

The final benefits of automating are accuracy and repeatability of tasks. While humans are “fantastic at critical thinking and decision-making skills”, they are not as good at repeating very precise activities over long periods of time.

Dru Brown, ASI Marketing Manager also told *IM* about the company’s new haulage solution for autonomous fleets: “Mines of the world looking for the best way to improve productivity need look no further than the Haulage AI – the first installment in ASI’s new line of artificial intelligence software modules designed to enhance efficiency, yield, and operator capacity. Integrating seamlessly with ASI’s Mobius Command & Control software system, the Haulage AI manages vehicle pathways, traffic patterns, and progressive dump locations for multiple haul trucks operating in an autonomous haulage system. Maximum efficiency is achieved as the system automatically tasks vehicles to the next dump area and returns them to the appropriate load zone with no involvement from an operator required. The Haulage AI also manages vehicle interactions such as vehicle queuing outside the load or dump zone, proximity monitors to maintain safe distances, and obstacle detection.”

He adds: “The Haulage AI is designed to enable rapid scalability of an autonomous haulage operation, evolving personnel from single-vehicle operators into multi-vehicle facilitators. This one-to-many relationship enables mines to combat labor shortages, experience improved vehicle utilisation, and enjoy economies of scale as they gain higher yields with existing workforce levels.”

**Western Australia guidelines**

A not often covered aspect of automation in mining is the requirement of legislation, detailing of good practice and means of compliance with standards. This has been laid out in some detail in Western Australia by the Department of Mines and Petroleum, in two reports, namely a code of practice covering **Safe mobile autonomous mining in Western Australia** and a set of guidelines covering the **Introduction of mobile autonomous mining systems**. Both were recently issued as drafts and distributed for industry feedback.
and public comment up until August 22, 2014 and can be read in full at www.dmp.wa.gov.au

The guidelines were issued by Resources Safety under the Mines Safety and Inspection Act 1994, and have been endorsed by the Mining Industry Advisory Committee. They were developed by the Department of Mines and Petroleum in collaboration with industry representatives, including the operators of autonomous mining systems and OEMs. The guidelines do not apply to remote controlled or base tele-remote systems, but parts could be relevant to tele-remote systems if they incorporate additional functionality that takes autonomous control of machines.

The draft guidelines state: “The decision to automate parts or all of a mining operation is a commercial decision based on perceived future gains in productivity, efficiency and safety performance. Many large mining companies and equipment suppliers have been involved with pilot projects in Western Australia for a number of years and are introducing autonomous and semi-autonomous mining equipment such as loaders, trucks, drills and dozers into production activities in surface and underground operations. While the decision to automate particular aspects of mining activities depends on the project’s financial and logistical viability, companies are also required to demonstrate to the regulator, through a project management plan, that they can effectively accommodate this new mining approach in their safety management system and manage the change.”

The report continues: “The addition of autonomous mobile equipment can introduce hazardous situations not normally encountered on a conventional manned mining operation. It is important that these safety challenges are addressed early in the planning cycle to maximise opportunities for solutions high in the hierarchy of control, such as elimination, substitution, engineering. This guideline will assist companies considering the introduction of autonomous mobile mining systems into their operations to achieve a safe and successful outcome.” The draft highlights the importance of mines:

- undertaking a comprehensive mine site risk assessment prior to making the decision to introduce autonomous mining
- a well-documented change management process, including roles and responsibilities of system builders and operators and development of strategies
- integrating autonomy into mine design and planning as early as possible
- putting in place project management plan (PMP) requirements
- having proper incident reporting

The authors continue: “The introduction of autonomous mining is not a trivial matter as its impact will be felt in many areas of a mining operation. Although automation provides opportunities, it may not be suitable for some sites. The benefits of autonomous mobile mining are most obvious for bulk mining because of the continuity and scale of operations. However, the extraction of geologically complex orebodies may be challenging. There needs to be a well-defined business case that addresses potential issues that may negatively impact desired outcomes. The business case should address questions such as: What are the expected safety and organisational benefits? What are the hazards and limitations of the introduced technology? If there is an existing operation, what hazards may emerge that need to be considered and managed during integration? What is a realistic lead time for full implementation, given the need for verification and validation trials as part of the risk management process? Companies should invest sufficient time and resources to ensure autonomous operations can start up safely and meet production expectations. Matters to be considered include organisational readiness, project management and site-specific risks. For a technology implementation project to be successful, attention is required in three key areas — people, processes and technology.”

The workforce will be affected by the introduction of automation, particularly in regards to training and skills development. Furthermore, roles and skill requirements will
change — new skills will be part of new organisational structures and some existing skills might no longer be applicable. Potential changes need to be identified and managed carefully for the implementation of automation to be successful.

Automation will also change the way in which the mine operates. It will impact many procedural aspects of mining such as traffic management plans, safety management plans, safe work procedures and work instructions. These will need to be identified and developed in a timely manner to ensure the introduction of automation has the best chance of success. The mine layout, mine design, mine plans and schedules will need to be tailored to accommodate autonomous mobile equipment and modifications need to be identified as early as possible to allow for sufficient time to incorporate any changes. The implementation of mobile equipment automation also requires the application of other technology such as sophisticated and robust wireless communications networks and control rooms. These will need to be identified and be part of the deployment process."

The ease with which automation can be introduced to a site will depend on the organisation's level of preparedness, at all levels, for the new technology. The greater the complexity of the proposed changes, the greater the importance of understanding whether there is a readiness for change and identifying the actions required to achieve the desired safety and performance outcomes.

Factors influencing organisational readiness include robustness of safety culture; commitment to change management; responsiveness to change; existing knowledge and understanding of autonomous mining, its risks and consequences; human resourceing including identification of new roles, responsibilities and reporting relationships and recruiting to address skill gaps; and the capacity of the workforce to transition between mechanised and autonomous mining in terms of ability to learn; adaptability of process and operation personnel; and awareness of the level of discipline required for autonomous mining.

The successful introduction of autonomous mobile mining also requires “commitment from the board and senior management to ensure but with equipment suppliers and service providers; as well as workforce acceptance of the implementation strategy.”

Risk factors to consider as part of a comprehensive risk management strategy for any autonomous system include access into autonomous area by unauthorised personnel or equipment; ergonomic or human factors that may lead to unexpected switching of operational mode with loss of control; autonomous equipment going into unauthorised areas; capture of changes to work areas, especially before switching work areas between manual and autonomous; loss of communications with autonomous equipment; system updates and changes to programming; and loss of control of movement of autonomous equipment (sliding or skidding). Other risks could include autonomous equipment deviating from its programmed path into the path of another vehicle or person.

On roles and responsibilities, the report points out that are two main groups involved in the introduction of an autonomous mining system: the system builders — those who design, manufacture, supply and construct the system; and the system operators — those who use the system, including operators, contractors and maintainers. The first group may comprise multiple parties, including OEMs, or the system may be built in-house by the principal employer, or by a third party. “Communication and cooperation are keys to a successful autonomous operation. The roles and responsibilities of those involved should be defined and agreed upon by all parties. While some roles and responsibilities have been assigned to certain stake holders, it is noted that many are dependent on information supplied by another party.”

On planning, the absolute crux of automation success, the report notes: “the introduction of an autonomous system is typically a staged process that takes time to design and implement. It should not be simply seen as a plug and play system due to the complexity of the system and layers of safety that need to be built in. Companies need to carefully evaluate why they wish to automate. They should evaluate their mine design and undertake a comprehensive risk assessment of the mining processes with support from site representatives and subject matter experts to satisfy the regulator that there are sufficient and robust controls. Controls should seek to minimise the start-up risks with new plant, such as starting small and simple and gradually building out; and creating a zone where the autonomous system is isolated or interactions with conventional manned mining systems are managed, as well as considering the implications in mine design, plans and schedules.”

Supporting infrastructure and area requirements need to be identified early in the project, as automation systems may have specific needs in terms of fuelling facilities, control rooms, communications network.

Finally, mining operations should be able to demonstrate that the hazards associated with mobile autonomous mining are being controlled so far as is reasonably practicable. “When considering the introduction of automation, the risk management process should address the following questions. What are the potential scenarios for mobile autonomous mining incidents? What are their potential consequences in terms of safety and health? What controls are available, how effective are they and how will they be monitored? Effective risk assessment for mobile autonomous mining may require input from a number of subject matter experts which will need to be identified and engaged before commencing the risk management process.”

A company proposing a new mine (including autonomy) must submit a PMP through the Department of Mines and Petroleum’s safety regulation system (SRS). The introduction of mobile autonomous mining to an existing operation is considered a substantial change to operating conditions and an addendum to the site’s PMP is required to be submitted to the Department through SRS.

“The introduction of mobile autonomous mining technologies to a mining operation, whether surface or underground, new or existing, can add hazards beyond those associated with a conventional manned mining operation. These additional hazards will require detailed consideration and risk assessment to ensure they are effectively managed. Submission of the PMP for mobile autonomous mining should be seen not only as a legislative requirement, but an opportunity to demonstrate an understanding of the risks associated with implementing autonomous technology. The PMP is an important tool in the development of a site-specific occupational health and safety management system.”

While mobile autonomous mining should be as safe, or safer than conventional manned mining operations, there are some incidents unique to the autonomous environment and their suggested reporting treatment as regards Western Australia is outlined in the attached table. IM