The Network Control Revolution in Underground Rock Breaking

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ABSTRACT

Electronic detonators represent a significant breakthrough in the rock breaking function of the modern mine and have delivered numerous benefits associated with precise timing, including better fragmentation, reduction in the number of phases and increased advance per blast. Accompanying the introduction of these electronic detonator systems is the deployment of high technology networks, software and infrastructure systems all designed to give mines centralised blasting control. This paper explores the impact of blast control networks on underground mines and the challenges faced when implementing such systems.

Three key impacts from the deployment of networked blasting systems are explored, namely safety, centralised control and information benefits. From a **safety** perspective digital control networks deliver a more reliable centralised blasting capability than any other system available today. Blast control networks also enable **centralised control**, because they deliver to surface a wealth of pre and post blast data from the underground workings. These systems inform managers of potential safety and production problems, the scale, location and extent of the planned blast before the panels are centrally initiated delivering increased management and operating control. Lastly, these systems create **information transparency** in that they deliver to the surface in-stope information and communications such as when detonators are connected to the system, ventilation conditions, temperature levels, moisture levels etc. Digital blast management networks are therefore a major step towards continuous mining operations, which require real time information and control systems to be viable.

The **implementation risks** and realities of any new system are complex and are clearly articulated in this paper. DetNet Solutions (An AEL Company) have identified both the benefits and the obstacles that have to be managed for the effective adoption of these control systems. This experience base, both positive and negative, is explored with the aim of illuminating the path forward to a more integrated mining system that will continue to deliver new benefits, critical for the effective survival of the underground mine of the future.

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1 Introduction

The global mining industry has, over the last 40 years, undergone some fundamental changes in the technologies and methods used in the extraction of mineral wealth. Each of these changes has shifted the very nature of the mining function, delivering new benefits to mine managers and miners alike, and creating new management challenges. Within this context, this paper explores the potential business impacts of networked blast control systems in the narrow reef mining industry from both a management and a shareholder perspective. Before proceeding with the analysis however, a brief technology context is required.

2 The Electronic Detonator Revolution

Electronic detonators represent the outcome of more than a decade of research by numerous firms and the technology has now reached a stage of operational maturity with resulting high adoption rates in the African mining environment. Adoption has been driven by the significant breakthroughs in the rock breaking function that electronic detonators deliver. These benefits include better fragmentation and reduction of drilling costs in the surface arena; and the reduction in the number of phases; better hanging wall conditions; and increased advance per blast in the narrow reef and underground massive mining spaces. These benefits are well documented by both suppliers and mine management alike indicating that the technology has moved from an experimental stage to one where business benefits drive adoption.

3 Evolution from Electronic Detonator Control Systems to Blast Control Networks (BCN)

The emergence of Blast Control Networks (BCN's) as a new type of rock breaking can be understood by briefly looking at the evolution of electronic detonator control systems.

3.1 Conventional Electronic Detonator Control Systems

All electronic detonators are deployed on a wire bus system of some sort that is in turn connected to a piece of control equipment. A brief description of this is shown in Figure 1.

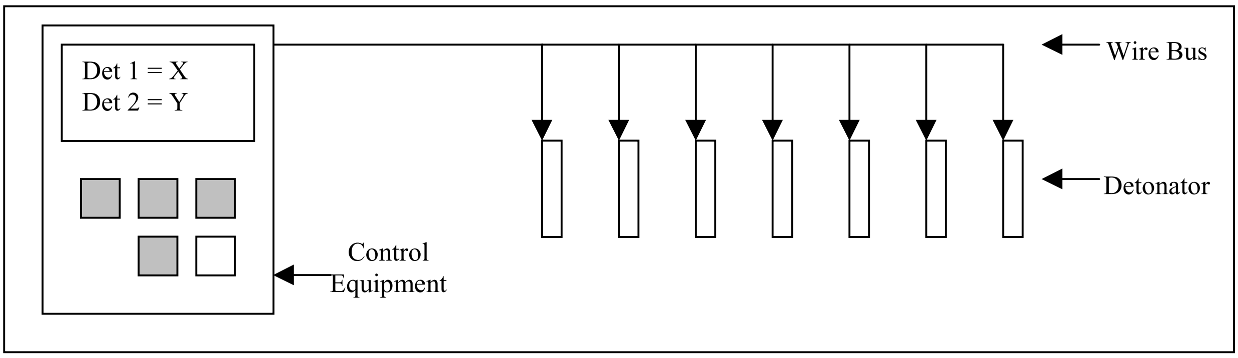

Figure 1. A Basic Electronic Detonator Control System

The control equipment manages control data, timing data and at blast time, blast energy along the wire bus to and from the electronic detonators. The control equipment is a computer driven device which inspired the next step in the product development cycle, namely the creation of computer networks, as clarified in the following section.

3.2 The Evolution of a Network

Narrow reef mines are large-scale operations with many different sections blasted every day. Initially numerous stand-alone electronic detonator control systems were deployed. As the number of these control systems grew, it made sense to customers that all these discrete control systems be connected and integrated into one system. Out of this development emerged the Blast Control Network (BCN) (see Figure 2).

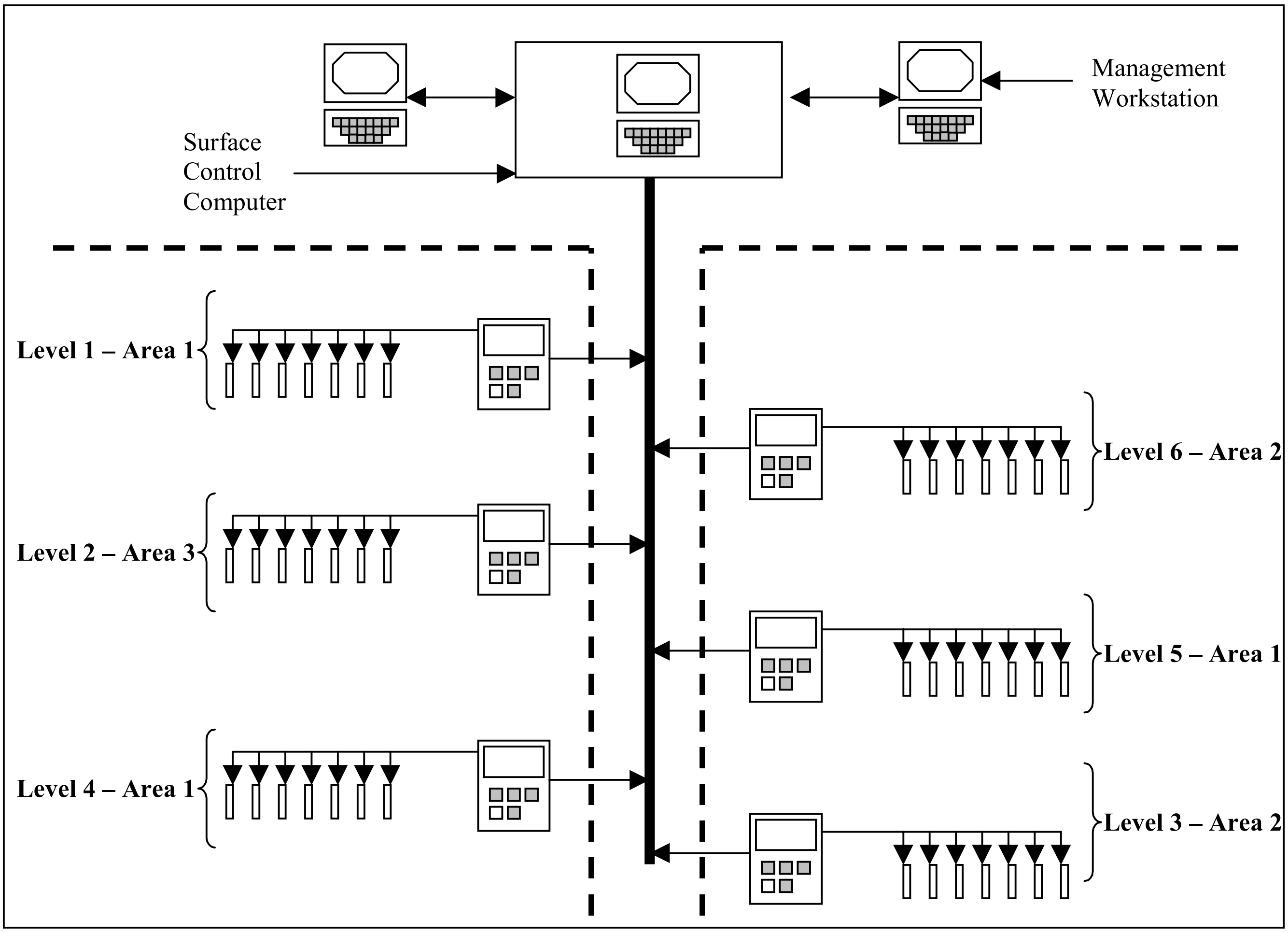

Figure 2. The Modern Blast Control Network

It is clear from the above diagram that a Blast Control Network (BCN) connects up a number of underground blast control computers to a shaft network. The shaft network in turn aggregates all these systems and connects them to one dedicated Surface Control Computer. A blast can be initiated from this machine, assuming each of the underground systems are armed, miners have authorised the blast, and the mining environment is secure. More importantly the Surface Controller can view, in real time, the status of all panels hooked up to it, and can communicate with miners at their control units.

The management benefit this delivers is immense because the Surface Control Computer, in turn is part of a surface network that is connected to Management Workstations that allow managers to see how their sections are doing during panel hook up, and to communicate with them to offer them support. These Management Workstations cannot initiate the blast ensuring that the central integrity of the system cannot be compromised.

In conclusion, in the narrow reef environment, control systems have been unified into one high technology network, seamlessly joining many working areas to a network that flows up the shaft to the mine control centre. This radical innovation has delivered to the narrow reef mining industry an opportunity to take a major technology step forward, driven by the Blast Control Network (BCN).

Attention can now be directed to the impacts of this new Blast Control Network Age.

4 The Blast Control Network Age (BCN Age)

As previously stated, the introduction of electronic detonator systems was coupled with the deployment of high technology networks, software and infrastructure systems all designed to give mines centralised blasting control. The impacts of this new type of Blast Control Network (BCN) have been profound, and are highlighted in this section. Three core areas of benefit are identified and explored namely safety, control and information benefits.

4.1 Safety Impacts and Risk Reduction of the Blast Control Network (BCN)

A centralised blast driven by a Blast Control Network (BCN) is by definition, initiated from a central, safe place. There are three key safety benefits to this type of digitally controlled blast. These are:

Firstly, because the system reports on the status of all the connected panels, people on surface and underground can see which panels are connected to their control equipment. Panels can only be made ready to blast once a sequence of checks and balances including inserting blast keys in safe areas have been met. The basic information delivered is:

Prior to Blast: - Managers have a clear picture as to which panels have connected up, which ones are ready to go, and which ones are having problems and need support.

Post Blast: - Post initiation, it becomes more transparent to operators on the surface which panels fired. After a blast is initiated, the panels that failed are transparent, making entry for the cleaning crew safer and more predictable allowing for better mine operation planning.

More importantly, blast energy can only be activated once the units underground have been activated and the surface control room verifies their status, and sends the blast signal. This adds a whole sequence of new checks and balances, unavailable on other systems, ensuring that miners can be moved to places of safety prior to blast activity.

Secondly, these systems can be used to initiate standard pyrotechnic systems such as shock tube and ignitor cord. This means mine operations can continue using existing pyrotechnics with which their operations are familiar. An example of a device that can plug into a networked blasting system to set off standard non-electronic devices is shown in Figure 3. These intelligent devices still give limited feedback to the control equipment in terms of their hook up status, and post blast status.

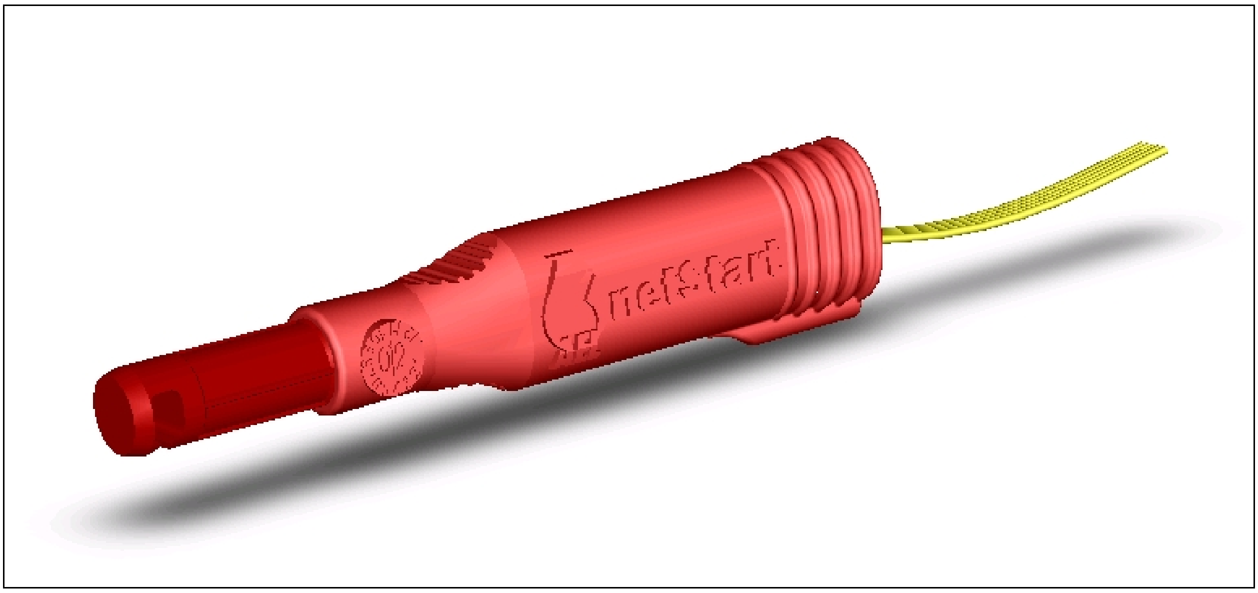

Figure 3. The NetStart, an Intelligent, Network Driven Standard Fuse Initiator

Thirdly, because the blasts are initiated in a very limited time frame (using electronics almost all panels are initiated simultaneously if so desired) the geological stress in the mine occurs in a narrow time frame. In certain geological conditions this has been shown to be beneficial to the overall stability of the mine, and therefore to the improved safety of those working underground. Furthermore post blasting fumes are somewhat more predictable which could potentially lead to quicker entry periods.

In conclusion, from a safety perspective, Blast Control Networks (BCN's) being digital, deliver a safer, more reliable centralised blasting capability than any other alternatives.

4.2 Information Impacts of the Blast Control Network (BCN)

Information from Blast Control Networks (BCN) provide day to day operational data and therefore represent a major step towards continuous mining operations, which require real time information and networked control systems. These systems can create **information transparency** to the surface of in-stope information such as detonator status, ventilation conditions, temperature levels, moisture levels etc. The benefits of computer delivered management data are well known, and include advanced reporting, graphing and case analysis.

4.3 Control Impacts of Blast Control Networks (BCN)

Blast Control Networks (BCN) also enable **centralised control**, because they deliver to surface a wealth of pre and post blast data from the underground workings. These systems inform managers and surface operators of potential safety hazards and production problems, the scale, location and extent of the planned blast before the panels are centrally initiated delivering increased management and operating control. Current measuring tools and procedures often result in key information becoming understood days or weeks after key events when the opportunity to implement preventative remedies has been lost. Blast Control Networks (BCN) deliver real time information on the status of the workings, giving managers more robust information with which to control their operations. It is this control benefit that allows Blast Control Network (BCN) driven mines to be safer and more optimally managed.

4.4 Conclusion

Blast Control Networks (BCN) clearly deliver many benefits to the modern mine. However, there are some real management challenges that these systems present, that if not addressed lead to the non-delivery of these benefits. These challenges are now explored.

5 Implementation Realities

The **implementation risks** and realties of any new system are complex and have to be effectively managed if these system are to deliver real value to the narrow reef industry. DetNet Solutions (an AEL Company) has identified both the benefits and the obstacles that have to be managed for the effective adoption of these control systems. Each implementation risk is looked at in this section, with the aim of sensitising mine management to the reality of owning a Blast Control Network (BCN).

5.1 Resistance to Change

The implementation of new technologies in the narrow reef mining environment has historically had varying degrees of success. Given the strenuous and high-risk nature of the narrow reef environment, resistance to fundamental changes in operating procedures and technologies is a reality. All new technologies pose challenges to organisations, and these new blast management technologies are no different. Experience suggests that resistance to change manifests in two key forms, namely:

Resistance to process change: - changing the processes in an operation is a challenge because people are familiar with the operating procedures and methods in place, and any new system involves training, follow up and a teething period where the new system does not appear to deliver as promised. It is the apprehension of this process of change implementation that in many cases drives resistance to these systems.

Resistance to management change: - these systems change the way that mines are managed because they deliver new types of management information, especially control information, that were not available in the past. If a panel fails with these new systems, management will know almost immediately. Conventional initiation system never delivered this data in real time. Management have to therefore embrace a new metric in the day to day running of the business. It is also a challenge to convince line management of the benefits of this new metric as they are under pressure to deliver against existing systems and metrics.

Dealing with resistance to change: - there has been much written about the management challenge of introducing new technologies to an operation. However, much of this theory is not useful in the day to day real world management of the introduction of new systems into mines. It is clear that the most effective mechanism to deal with this resistance to change is senior management buy in, and continuous training and support of end users. Once people have the means and ability to run a system, mine management has to then commit and hold them accountable for using it. Only a well-structured project and hand over plan, drawn up in consultation with labour, management and the technology provider can create the necessary forces to ensure the smooth adoption of these systems.

5.2 Levels of User Skill

Narrow reef mines have a broad range of skill bases in their operations. An effective Blast Control Network (BCN) has to be designed and tested by users to ensure that the technology is both simple and safe to use. Blast Control Networks (BCN) are not an attempt to deploy high end, complex computing power to the end user, they are systems that deploy easy to use and understand operating benefits. By using computational power, the right level of usability and complexity is deployed to the right level within the mine structure. For example, advanced reporting systems linking data to business variables are made available to mine management, whilst more specific operating reports are given to the miner underground such as how many panels are connected, whether their upstream network is connected, and confirmation of the sequence of events leading up to a safe successful blast.

Literacy is also a key issue and challenge to the adoption of these systems. Technologies must be easy to use, by for example using pictures, for the various degrees of basic language and technology literacy found on today's mines. Experience shows that Blast Control Network (BCN) failures, more often than not, are end user driven making the training and associated management challenges critical variables to effective system utilisation.

5.3 Transparency Issues

Perhaps the most striking impact that Blast Control Networks (BCN) have on the mining world is the fact that new levels of visibility of underground activities are created for surface managers. This creates a twofold challenges:

Firstly, it places the burden of proof on the miner, not management when it comes to the operational day to day activities of the mine. Daily logs of what was hooked up and blasted are known and can be relayed to relevant managers. This changes the dynamics on many of South Africa's narrow reef mines were data reliability and transparency are difficult to confirm and prove with existing methods. Transparency is a complex management issue, particularly in very large scale operations such as today's modern underground mine.

Secondly, it exposes day to day management to a new level of performance benchmark, daily failures of panels become clear, and the metrics for addressing these are different from those used before.

5.4 Support and Maintenance

Blast Control Networks (BCN) represent a new technology to mines, one that they have not had to maintain or use traditionally. Whilst today's narrow reef mines do maintain many types of control systems, the support and maintenance of this Blast Control Network (BCN) is critical to their continued operation. It is therefore essential that people are trained and committed to maintaining the integrity of these systems if they are to gain all the benefits of the systems. The logistics, maintenance and manpower issues have to be dealt with up front before such systems are implemented, if the systems are to deliver. The trend appears to be one where network and system support is paid annually as one would pay for any other type of IT support function. However, because the blast function is critical, the mine should retain ownership of the system.

5.5 Reliability and Redundancy Issues

Blast Control Networks (BCN) are mission critical and it is essential that they are not only reliable, but that the right levels of redundancy are built in. What happens if the shaft network fails, will the blast process continue in a safe way? The issues of redundancy and backup are paramount if one considers aspects such as power failures, rock falls and the general day to day unplanned realities that sometimes characterise narrow reef mines. Most systems are designed to withstand adverse conditions, but it is critical that the underground control equipment can blast in a stand alone fashion and that miners are prepared and trained to do so.

5.6 Conclusion

The Network Blasting Age has arrived, and will transform narrow reef mining. However, the real challenges of implementing such systems are human driven because these systems do change operating practices. New levels of information transparency create management challenges, however given the inordinate benefits of this new safer level of control of the blast, coupled with the real time management benefits these systems make business sense. Given that these systems deliver clear management benefits, coupled with the fact that there is a continuous drive in the narrow reef space for improvement, addressing the implementation constraints is paramount. These systems can be effectively introduced into mines provided there is strong management buy in to the process of not only introducing new systems to the operation, but also a strong commitment to addressing head on all the real implementation challenges. The most successful implementations of these systems have been in environments where management, vendors and the workforce co-operate in delivering value.

6 The Future – The Mine Area Network (MAN)

Blast Control Networks (BCN) are the first step in the creation of a narrow reef mining network revolution as they deliver computing power into the workings. Once the computing power is deployed in the workings, the systems will evolve into a real time information platform, delivering key operating data to miners at the face and managers in different parts of the operation. This integrated Mine Area Network (MAN) will deliver one unified blast and rock breaking critical data and control platform to the modern narrow reef mine. Attention can now be directed to the areas where future developments are likely to occur.

6.1 Safety Impacts Mine Area Networks (MAN)

The Mine Area Network (MAN) will deliver unprecedented safety features to the modern mine. Key areas of research are:

Stope Condition Monitoring: - temperature, air quality and humidity measurement systems are being prototyped. These systems will integrate into a secure Mine Area Network (MAN) that cannot be compromised, ensuring this occupational health and life critical data is available 24 hours a day 7 days a week and 365 days a year.

People Tracking: - Computer power in the face allows mines to know where people are thus protecting the workforce from potential hazards.

6.2 Information Impacts of the Mine Area Networks (MAN)

Mine Area Networks (MAN) will communicate data and information to both miners and mine managers that previously were unavailable in real time, if at all. A number of research projects are already underway to deliver services via a Mine Area Network (MAN), a brief overview of this work is presented below:

Real Time Accurate Production Information: - projects are underway to integrate ore flow data and other resource data sources to deliver target and benchmark tools for mine's continuos improvement programs.

Real Time Inventory Ordering Systems: - because these systems will report on actual production underground (blasts and ore flows) on a daily basis, systems are being designed to offer mines the ability to track and order in real time the materials and inputs needed for continued operation.

Real Time Stope Condition Reporting: -a key safety integration opportunity is being explored by integrating multiple environmental characteristics in the stopes, including air quality, temperature, humidity, stope closure etc.

Mine Planning Integration: - by delivering real time information for scenario planners and integrating this with their planning models, software developers are aiming to enable better mine planning and decision making.

Ore Flow Analysis Integration: - these systems exist right up to the face and are in a powerful position to integrate ore flow metrics from the moment of blast to the processing plants, giving managers a real time view of operational efficiencies and potential bottle necks.

Miner Communicator: - The more computational power in the hands of the people in the workings, and the greater their system adoption, the more information can be provided to these workers and throughout the mine. The safety and operating benefits of communications are immense, and systems are being prototyped to deliver smarter communications in stope and throughout the mine.

Simply put, Mine Area Networks (MAN) will deliver to the right people, the right information in real time. But what is the business case for this inevitable paradigm shift?

6.3 Control Impacts of the Mine Area Networks (MAN)

Mine Area Networks (MAN) ultimately enhance **centralised control**, because they deliver to surface an integrated view of the mine, covering environmental, people and other mining data. This integrated, secure environment allows for a far greater operating certainty by delivering to the right management level automated checks of the mining process and the real time flagging of potential hazards, bottlenecks and production flows.

6.4 The Business Case for Mine Area Networks (MAN)

Detailed financial models indicating the impact of Mine Area Networks (MAN) on narrow reef mines have provided some interesting insights. Most striking is the fact that these systems are critical if the dreams of continuous mining are to be realised. Any continuous operation requires real time, reliable data about the state of operation, and by delivering this data, Mine Area Networks (MAN) become the enabling factor in this process. The key driver for this is synchronisation – for any continuous operation the real time synchronisation of various inputs, labour and systems have to be managed. Real time synchronisation of complex operations can only be achieved in a large-scale mining by using technology systems.

From a shareholder perspective, the integration of the modern mine, via a Mine Area Network (MAN), translates into one benefit - **greater production.** Production is driven by information because information allows managers to do more with less. Mine Area Networks (MAN) translate into increased production at lower costs because they deliver to management all the benefits system integration have given to modern factories, namely increased efficiencies. Mine Area Networks (MAN) are therefore critical in the realisation of value out of narrow reef mining assets.

7 Conclusion

The benefits of Blast Control Networks (BCN) are clear – they offer safer, more predicable results for today's modern narrow reef mine. These systems represent the step towards a complete Mine Area Network (MAN) environment with all the benefits such environments have long delivered to large surface operations. The operating benefits of existing systems do and will continue to give mines of the future key competitive benefits. The real challenge is a managerial and cultural one, one in which mines will transform into more technology driven businesses. As a world leader in the mining sector, South Africa has the management talent, operational capability and business will to continue as a dominant player in the field. In short, the modern mining network revolution has started and will transform the character of the modern mine over the next few years and South African narrow reef mines are at the forefront of this production revolution.