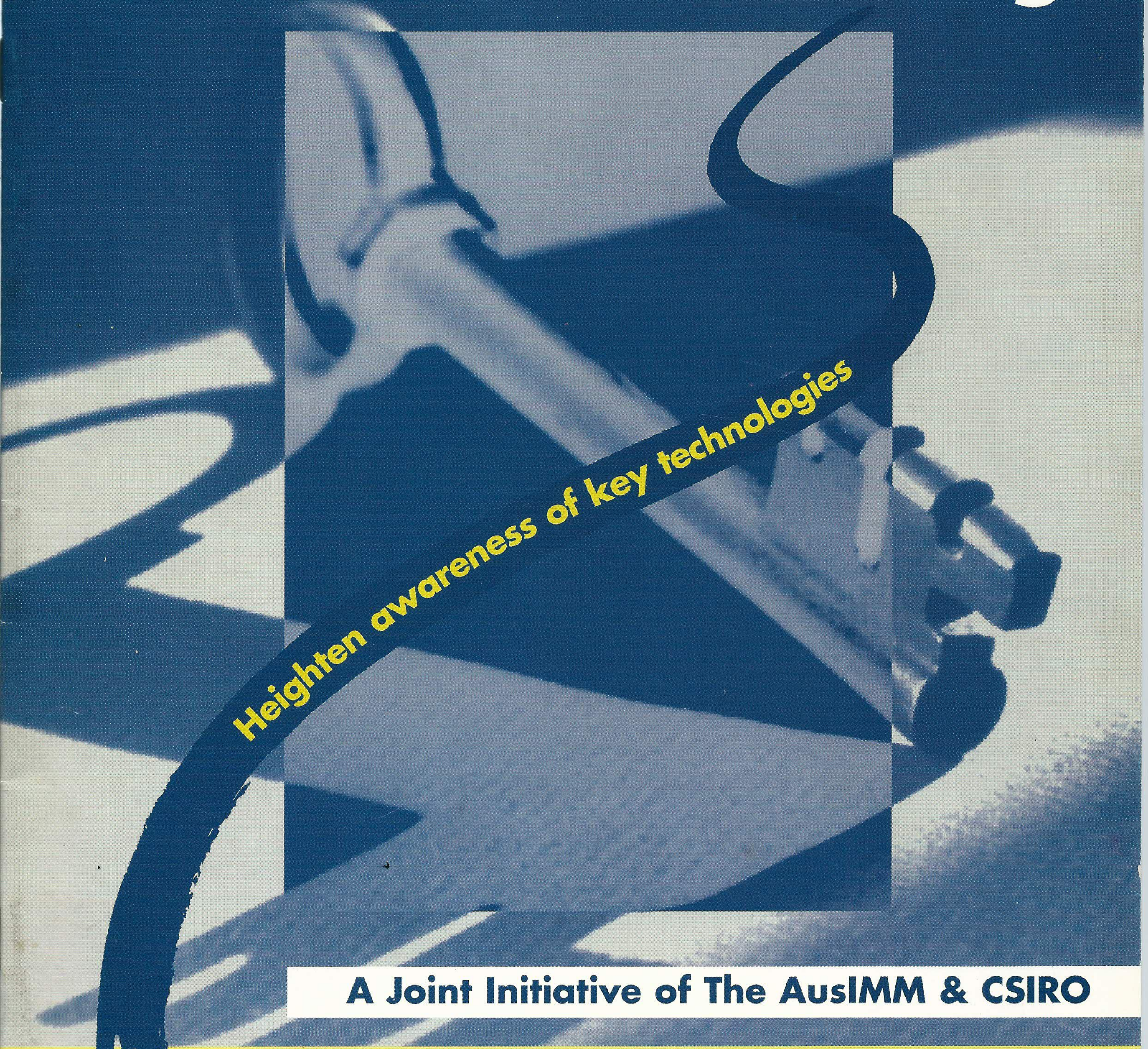
1997 AusIMM Travelling Technology Forum

Monday 17 to Friday 21 March 1997

Automation in Mining



A Joint Initiative of The AusIMM & CSIRO

SUMMARY OF PROCEEDINGS

Sponsored by

CSIRO, Western Mining Corporation Limited,
Aberfoyle Limited, BHP Coal Pty Ltd, Goldfields Limited, Novacoal Australia Pty Ltd, Pasminco Limited, RGC Limited,

and supported by the

Centre for Mining Technology and Equipment

THE AUSTRALASIAN INSTITUTE OF MINING & METALLURGY
FOUNDED 1893

CSIRO
AUSTRALIA

WMC

Automation in Mining

Proceedings

The 1997 AusIMM Travelling Technology Forum

A joint initiative of The AusIMM and CSIRO

Singleton, NSW
18 March 1997

The Australasian Institute of Mining and Metallurgy
Publication Series No 8/97

Published by
The Australasian Institute of Mining and Metallurgy
Level 3, 15-31 Pelham Street, Carlton Victoria 3053, Australia.

ISBN 1 875776 59 1

Printed by: Integrated Mailing Services, 4 Tullamarine Park Road, Tullamarine Vic 3043.

CSIRO
AUSTRALIA

CONTENTS

Introduction

In a technologically oriented industry, it is important to understand and apply technology very consciously to create competitive advantage.

Technology is not an activity which is simply restricted to CSIRO or the research and technology department. Technology improvement is a part of everyone's role. It is a way of life – the technology facet of continuous improvement.

For this reason, The AusIMM has organised this Travelling Technology Forum – a series of presentations about automation in mining. To make the message more accessible, The AusIMM had originally planned to take the Forum to four regional mining centres: Mackay/Townsville, Singleton, Burnie and Kalgoorlie, but only one seminar was held, ie at Singleton in March 1997. Seminars at other locations were cancelled because of insufficient registrants. The presentation by Andrew Logan of BHP Cannington was not available for the Singleton forum.

The aims of the forum were:

- to heighten awareness of the key technologies and their impact in the minerals industry in the medium term;
- to foster creative thinking;
- to encourage people to broaden their technical and commercial skills and develop individual networks and linkages based on an interest in these key technologies;
- to share information on the application of these technologies in the industry;
- to promote an enhanced appreciation of the need for an innovative culture; and
- to encourage staff to consider post graduate courses in technology management.

The AusIMM wanted to not only raise awareness about 'automation in mining' issues, but also to get technology in a more general sense back onto 'centre stage'.

The Forum was generously supported by CSIRO, Western Mining Corporation Ltd, BHP Coal Ltd, Aberfoyle Limited, Goldfields Ltd, Novacoal Australia Pty Ltd, Pasminco Ltd, and RGC Limited. The program was endorsed by the Centre for Mining Technology and Equipment (CMTE).

Copies of the full papers are available from the authors, see 'References'.

Technology and Innovation in the Australian Minerals Industry

Angus M Robinson, Convenor, the Standing Technology Advisory Group of The AusIMM and General Manager, The Warren Centre for Advanced Engineering (presenter) and Alan Broome, Chairman, Austmine Ltd.

In his address, Angus Robinson highlighted the importance of innovation, and outlined some applications and barriers to technology and innovation in the minerals industry.

Robinson began by stressing the importance for mining industry professionals of exposure to new technologies so that they are empowered to deal with their introduction. He also stressed the importance of continuing education and skills training in this field. This approach, he said, would also foster creative thinking and encourage innovation.

Innovation

Robinson summarised a report by the House of Representatives Standing Committee on Industry, Science and Technology entitled *Innovation, A Concept to Market* written in November 1995. The Report defined innovation as *'... innovation is something that is new or improved done by an enterprise to create significantly added value either directly for the enterprise or indirectly for its customers'*. The Report provided a model to illustrate the innovation process which identified:

- *Drivers and catalysts* as R&D, CRCs, technology foresighting, and the innovative enterprise.
- *Sources of innovation*: educating for creativity, and vocational education and training.
- *Barriers to innovation* as the level of management skills, and insufficient linkages.

The *outcomes* included more satisfying employment opportunities for professionals.

Innovation in the minerals industry

Alan Broome highlighted the field of heavy equipment as an area where technology and innovation can be applied to improve Australia's performance, for example heavy dump trucks, excavators, and loaders and their ancillary equipment.

Some of the Austmine companies have had great success in developing medium, engineered units especially in the hard rock sector. However, there are many examples of Australia's innovative R&D successes being produced offshore because of the inability to complete the innovation cycle locally. For example in modern continuous miners for underground coal production, hard rock, tunnel boring equipment, and more recently, innovative, haulage truck technology for surface mining applications.

Broome estimated that in excess of $1 billion of heavy engineered capital equipment is imported each year for the minerals industry. There is no evidence of local manufacture of this equipment growing.

Robinson claimed that Australia is now in a unique position and could become the most significant exporter of heavy industrial mining equipment in the world by 2020. In addition, Australia can develop the 'high-tech' systems and components for use on the heavy equipment manufactured overseas.

Main barrier

The main barrier to innovation, said Robinson, is the market forces. 'Until mining companies encourage local engineering small to medium sized enterprises to build the results of their innovations and research and development locally, these opportunities will not be realised,' he said. Also, the potential individual producers – whether they be Australian companies or international companies – must see the market for their products if they are to establish manufacturing operations locally.

According to Broome, the Austmine group has set the following directions to address this emerging opportunity:

- promoting the production and use of the outcomes of Australian mining R&D within Australia and for exploitation as exportable products and technology for the future;
- encouraging and fostering the expansion of the heavy mining, equipment manufacturing base in Australia to develop import replacement capability, availability to the domestic industry, and the development of major equipment export potential;
- moving Australia towards a position of global significance in the supply of mining equipment, technology and services to the international mining industry; and
- fostering the 'Team Australian Mining' approach internationally to promote the sale of mined commodities with mining equipment and technology.

Automation potential

Primary industry and commodities supply – from mining, agriculture, stevedoring, through to transportation and construction – accounts for 65 per cent of Australian exports. Australia also has considerable world technical expertise and a natural advantage in these areas.

Automation applied to these sectors (either as automation applied to the production processes themselves or in the development and maintenance of the physical infrastructure and freight services that support them) has the potential to provide quantum changes in overall industry efficiencies.

In addition, systems-level planning of operations and the application of process automation techniques across all traditional domains will achieve larger efficiency gains.

More efficient primary sector processes have potentially great benefits for export trade, for the management of off-shore operations, and for improved performance in the global market in terms of price, quality and delivery.

The Warren Centre project

To maximise the benefits of automation, The Warren Centre for Advanced Engineering is planning a project to explore the technical, human resource and management implications of automation in the primary industries sector. The project planning is being led by former Group Executive of CRA Ltd and a Past President of The AusIMM, Jack Brady.

Aims of the Forum

A contribution from Dr Robin Batterham, Vice President, RIO TINTO Research & Technology and a member of The AusIMM Standing Technology Advisory Group.

Dr Robin Batterham is of view that the inevitability of automation in the minerals industry and the importance of addressing the human implications. He also outlined Rio Tinto's approach to automation.

The progressive introduction of automation into mining operations will be revolutionary in its effects. This is the experience in other industries and it will be no different in mining.

Mining companies most successful at implementing the new technologies will gain relative competitive advantage and those manufacturers who produce the most desirable automated equipment for miners will also gain market share.

Automation in manufacturing

The individual technologies required for totally automated manufacturing are largely available now. The real difficulties lie in technically integrating them to work as a whole. It is also still more economic, in many cases, to use human labour or involvement at the most complex and unpredictable points in the operation. So, most manufacturing operations consist of islands of automation linked by human effort. However, the number of areas where the human linkage is required has been decreasing progressively over the years.

For example, a modern, automotive assembly line typically has dozens of individual automated work stations, all linked through automation. Once installed, human intervention comes mainly in the form of programming and maintenance.

Automation in mining

The minerals industry is going down the same conceptual track as manufacturing but more slowly – mainly because the feedstock is much less controllable and the working environment is considerably more harsh. These factors are significant, but are being progressively addressed, so that total automation in time will be achieved.

However, this total automation scenario is not the major focus of the industry today. Instead, it is focused on 'islands of automation'. These islands – such as unmanned drills and haul trucks –are almost at the point where they can be economically introduced into real operations. Fully automated drills are effectively a reality now, and autonomous haul trucks will be commercially implemented in the next three-five year timeframe.

RIO TINTO's mine automation project

RIO TINTO has an active, mine automation project supported by all major open cut business units within the group. This project has identified major cost savings from the introduction of automated drill rigs and, more particularly, automated haul trucks.

The main component of these cost savings is not reduced labour, but increased equipment availability and utilisation.

Increased availability arises because of the reduced wear and tear with automated equipment. This reduces maintenance downtime.

For example with a haul truck, instead of the driver tramming at speed and then sitting in a queue at the shovel, the control system in an automated fleet will anticipate such a situation and slow the truck so that it arrives at just the right moment to stop and be loaded. This results in the fleet moving continuously and smoothly with potentially a lower average speed but higher productivity.

Improved equipment utilisation arises from the fact that vehicles need only stop for loading, dumping, fuelling and maintenance. There is no loss of productive time for shift changes, meals or any other need arising from human involvement.

Human implications

Batterham stresses the need to consider the human implications of automation as well as the technical aspects. Because people are effected, human relations and industrial relations are crucial, as is training since the skills mix required as automation progresses will be quite different to now. Safety per se, and also legal and statutory issues relating to safety, are also important, especially as they relate to staff in partially automated environments.

Technology – part of life

We live in a technologically oriented industry and those who are good at understanding and applying technology, use it very consciously to create competitive advantage. Companies operating within the industry must understand this and plan their technology strategies accordingly. However, it is not only corporate managers and their planners who have a part to play – every one of us working in the industry must be constantly aware of the contribution we can make.

Technology is not an activity which is simply restricted to CSIRO, the company research and technology department or individuals with 'technical' in their title. Technology improvement is a part of everyone's role. It should be seen as a way of life – the technology facet of continuous improvement.

Only in this way, can the industry reach a position where it is proactive with regard to new technology, rather than forever scrambling to catch up, which is so often the case.

Batterham stresses the importance of asking ourselves: 'What can I do to better improve my understanding of technology' and 'What can I do to improve technology in my business for bottom line effect'?

Introduction to Automation Systems Requirements

By Dr David Dekker, CSIRO Exploration and Mining

Dr David Dekker discussed the importance of a multidisciplinary approach to automation, the infrastructure required to support automation, and selecting the equipment for automation.

Dekker stressed that automation involves a number of technologies. The mining industry is currently about part-way through the evolutionary process of achieving a fully integrated automation system. He pointed out that the final stages require parallel development of infrastructure such as mine communications.

Technologies required for automation

Automation systems consist of three parts: the gathering of information, the processing of that information, and taking action.

Dekker outlined the technologies required for automation in the mining environment. See Figure 1.

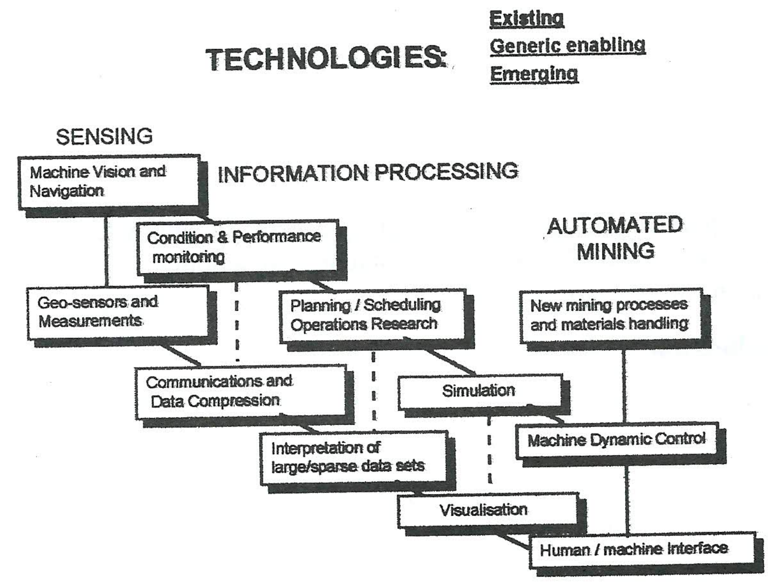


FIG 1 - Technologies required for automation.

A mine must acquire and apply the most appropriate aspect of these technologies to integrate into an automated system. Of these navigation (and location), monitoring, planning and machine control are key technologies; elements of which exist in other industries. (Navigation and location positioning relies on communications technologies.)

Systems integration

Dekker stressed the need for a multidisciplinary approach to technological development. This allows innovative contributions from team members in areas outside of their field. It is also important as systems become more and more complex. Dekker cited the importance of an inter-disciplinary approach in the development of fail-safe braking systems of remote controlled equipment. For a fail-safe operation to be guaranteed, there needs to be a clear overview of the total system which is well documented. This overview must be available for anyone considering changes to any of the interrelated components.

In another example, Dekker pointed out that launching a miner in the wrong direction in a typical highwall mining application can result in roof collapse. Optimal management involves a knowledge of geomechanics, surveying, guidance technology and the economic and operational consequences of 'getting it wrong'.

Infrastructure needs

Communications makes possible the automation, scheduling and operational management of a modern mine. The extent of the mine infrastructure and the level of automation affect the communication systems required.

In addition, strict electrical safety regimes in coal mines limit the types of communications systems and the power levels that can be used. In case of failure of automated systems, teleoperation will remain a key feature.

Underground conditions

Mine design is one of the most significant restrictions on implementing underground communications systems. Factors such as the tunnel structure, cross-section, and the complex geometry all limit operation. Although systems that allow communication through the earth exist, they offer only very narrow bandwidth and hence, slow information transfer.

To overcome this, Dekker outlined the need to develop signal processing technology and novel approaches such as advancements of the terrestrial cellular radio systems. Systems based on distributed communications of a large number of very low-cast modules may also be appropriate.

He summarised a number of different communications technologies and their approximate capabilities. He stressed that a future mine will depend on all existing systems – PED (through the earth), power line, medium wave, cellular, FD4, hard-wired, leaky feeder and broadband cable/fibre.

According to Hainsworth and Gurgenci, the approvals process is one of the greatest impediments to the transfer of advanced other-industry technologies to underground coal mining. The cost of development to satisfy the testing requirements and the small market dissuades manufacturers.

Economics of automation

Dekker highlighted the importance of selecting the right processes to automate. These might not always be obvious, so careful analysis is needed. One of the main outcomes of automation is improved productivity. This results in a higher return on capital employed.

Automation of data collection

Automation also covers office automation and the automatic collection of data. Examples are using photogrammetry for geotechnical evaluation, survey total stations for blast hole position measurement or structured light to automatically and rapidly collect information about pit wall structure and stability. These techniques, along with new laser ranging and imaging technologies, will ultimately allow remote determination of a 3D image of pit and plant operation in real time.

Future goals

Dekker presented his vision of future industry capabilities and their time frame (subject to appropriate R&D and technology transfer funding). In addition, there will be new mining methods made possible for the first time by automation technologies.

Highwall miner navigation	1997
Dragline wing/hoist/dump automation	1998
Shovel payload and diggability monitors	1998
Robust underground communications	1999
Fully automatic shearer horizon control	1999
Underground vehicle navigation system	2000
Autonomous surface trucks	2000
Underground haulage automation	2001
Fast automated analysis of rock conditions	2002
3D real time pit photogrammetry	2003
Automation of u/g roadway development	2004
Full automation of dragline operation	2004

The End of the Line for Roadway Development

By Michael Kelly, CSIRO Exploration & Mining

Michael Kelly highlighted that roadway development performance remains one of the threats to expansion of Australia underground coal exports to the growing Asian market. In a recent industry study, automation was highlighted as one of seven strategies for roadway development improvement.

Growing Asian markets

The expansion of the Asian coal market is a long term driver for expansion of the underground coal industry in Australia – if significant productivity improvements are made.

Imports of steaming coal by Asian APEC members are predicted to rise by from 150 MT to 190 MT. Australia is one of the few countries which has a potential capacity larger than predicted internal needs.

Predictions are for exports of black steaming coal from Australia to increase from 50.3 MT in 1992 to 106.3 MT in 2010. To meet this prediction, an investment of $10.7 billion (in 1992 dollars) will have to be made in mining and transport facilities. This is equivalent to the opening of a major new mine each year until 2010.

Many of these mines will be underground operations. However, much of Australia's capacity to respond to increased Asian demand will depend on its ability to develop underground technologies and improve productivity.

The inability to make sustained improvements in roadway development rates has to date been one of the main reasons why new underground projects have failed to deliver the expected returns.

Roadways and longwall mining

Roadway development rates are a critical issue for longwall mines. Automation is one of several industry strategies to cause a sustainable long-term improvement in these rates. For the last decade, rate of driveage for roadway development has been unable to keep pace with improvements in longwall extraction rates and average development costs are high – around $2000 per metre.

Collieries have responded in different ways: some introducing 'super-panels' where two miners or more are concentrated into the prime development panel. Others have reduced the amount of 'outbye' (away from the face) work to allow more face unit shifts. The results have been to increase the complexity of face operations and decrease 'outbye' standards. Shortening longwalls is at best a short-term advantage, with a net negative effect.

The financial results for many companies have been disappointing. Problems with longwall continuity, increasing manning numbers to catch up development, and implementation issues with new technology or management changes have all affected the 'bottom line'.

In spite of substantial technology advances in mining equipment over the last ten years, improvements in roadway development rates have not followed for the industry.

In 1994, the industry reviewed this problem through a series of workshops and studies and developed a roadway development plan.

Roadway development strategy

The result of the plan was to take a systems approach to roadway development. This recognises the complexity of the system and manages it as a whole rather than as individual processes. The components of roadway development have been said to be 20 per cent technology and 80 per cent systems and people.

The plan also developed two simple models to bring the various components together. These components included: mining systems, organisation factors, machinery supply and support, the human element, maintenance best practice, systems support, strata support and gas control, and safety systems.

Development of automation priorities

Automation was identified as one of the strategies to improve roadway development and was seen as a long-term activity – between five and ten years. Priorities will come out of identifying the bottle-necks which are amenable to mechanisation and automation.

Kelly cited automating roofbolting as an example of the long development time. The focus should be on key areas where the industry has some maturity in approach while the other areas will require long-term priorities for development.

This strategy recognises that automation has a tremendous potential to improve safety, consistency and productivity, but has historically been associated with issues of over complication and poor implementation performance.

Current status

Kelly reviewed the current status of roadway development processes:

Cutting	remote
Roof bolting	mechanical/manual
Rib bolting	manual/mechanical
Coal transport	mechanical
Ventilation - tubes	manual
pumping	mechanical
cable	manual
direction - azimuth	mechanical (laser)
direction - horizon	manual/mechanical
stonedusting	mechanical
ventilation - stoppings	manual
services extension	manual/mechanical
belt tensioning	mechanical/auto
belt extension	manual/mechanical
man transport - face	manual
man transport - outbye	mechanical - mainly
material transport	mechanical/manual
road construction	manual
secondary support- bolting	manual/mechanical
secondary support- timber	manual

The future

The future of automation depends on the development of driveage systems which are conducive to automation as well as assessing automation opportunities in current mining systems.

Mining Automation

By Professor Hugh Durrant-Whyte, Australian Centre for Field Robotics and Centre for Mining Technology and Equipment, Department of Mechanical and Mechatronic Engineering, The University of Sydney

Professor Hugh Durrant-Whyte summarised why the mining industry needs to automate and reviewed the current automation technology – its risks, costs and benefits.

Why automate?

The drivers for automation include: safety, productivity, quality control and reduced manning,

equipment utilisation, maintenance, and organisation and planning.

Durrant-Whyte recommended starting out with a picture of a fully automated mine and working backwards through a systematic analysis of benefit and risk. This also involves looking at the impact of the total automation on current mine design, and identifying the key technologies.

Automation technology

Durrant-Whyte categorised the various automation technologies as:

Sensing and navigation:

- position sensing: inertial, RF tag, RF beacons, Global Positioning Systems (GPS), microwave, millimetre-wave and lasers;
- position estimation: triangulation, Kalman filtering, set methods and reliability;
- environment sensing: scanning lasers, ultrasonics, vision, millimetre-wave and picture compilation.

Control of motion and contact:

- wheeled vehicle control: electric, mechanical, drive, engine and traction control;
- tracked vehicle control: motion modeling, position and traction control;
- contact control: hybrid position-force control, and bucket and soil modeling.

Safety and condition monitoring:

- collision detection: sensing, discrimination and reliability;
- condition monitoring: vital-sign monitor, fault prediction and maintenance;
- safety system design: fault tolerant, specification, verification and certification.

Planning and logistics:

- route planning: kinematics, trajectory generation and trajectory execution;
- route scheduling: dispatch, sequencing, traffic control and docking;
- logistics: tasking, resource allocation and maintenance.

Sensing and navigational systems

Navigational systems allow the users to find out where they are. The advantage of GPS technology is its wide user base, simple off-the-shelf components, and that it can be used in almost any situation, at almost anytime. However, there are problems with line of sight. Sometimes the satellites drop out, and with large structures or systems underground, obscuration can occur. GPS alone is not the solution for autonomous vehicles.

Inertial aids give extra information and can be used as an adjunct to GPS. Durrant-Whyte cited solid-state gyroscopes which can be purchased for less than $1000.

Laser sensors are generally low cost (around \$5000) and are widely used. Whilst they are accurate, they are easily affected by dust and other environmental factors, so reliability is a problem.

Radar is another option which is increasingly being used in automotive applications. With high frequency, they have good range, accuracy and less attenuation than laser. However, they are costly and complex to use.

Other sensor options include: short-wave radio triangulation, sonar, optical markers, radio tags, capacitive/inductive proximity and visual marking.

Vehicle control

Durrant-Whyte outlined the different models that are needed for positional control and trajectory generation. These include kinematic models for planning and tracking at slow speeds; dynamic models for prediction of slip and skid, traction control, and effects of terrain; and contact control for force and position control, and control of contact with a rigid environment.

Existing technology

Durrant-Whyte presented the existing technology in autonomous haul trucks:

Komatsu's autonomous haul truck project

Navigation is via dead-reckoning with steer and drive encoders, fibre-optic gyro, and side-view laser beacon reset. They are now moving to GPS. Long-range laser collision detection and short-range ultrasonics are used. There is no condition monitoring. The truck is operated on a 'teach and play-back system'.

Caterpillar autonomous haul truck project

Navigation by 'drive and steer' encoders, fibre-optic gyroscope, trimble differential GPS system, and dead reckoning and reset. Safety and condition monitoring system is by radar and patch antenna, with VIMS condition monitoring. Planning and pilot is by 'teach and repeat'.

Conclusions

There are three technology phases:

Phase 1 is solvable and involves getting process and mining people to talk together. It includes: material transport, haul trucks; drill rig automation; and drag line cruise control.

Phase II is in the development stage and includes contact control, control of loaders and shovels, and local terrain pictures.

Phase III is in the research stage and includes picture compilation – building up a picture of the mine globally, autonomous loaders and ancillary equipment, and remote operations.

Case Study: Dragline Swing to Dump Automation

By Peter Corke, CSIRO Manufacturing Technology/CRC for Mining Technology and Equipment (CMTE)

Peter Corke presented a case study of a project to automate the dragline swing to dump operation. The project is funded by ACARP, BHP Coal, Pacific Coal and the CMTE and is being carried out on a dragline at Pacific Coal's Meandu mine near Brisbane.

Corke began by highlighting that the minerals industry makes extensive use of large, mechanised machines. However, unlike other industries, mining has not adopted automation and most machines are controlled by human operators on board the machine itself.

Choosing an automation target

The dragline automation was chosen because:

- draglines are one of the biggest capital assets in a mine;
- performance between operators vary significantly, so improved capital utilisation is possible;
- the dragline is often the bottleneck in production;
- a large part of the operation cycle is spent swinging from dig to dump; and
- it is technically feasible.

There has been a history of drag line automation projects, none with great success.

Sensors required

The dragline bucket behaves like a simple pendulum. To control the bucket's natural tendency to swing like a pendulum, the operators have learnt the skill of estimating the bucket's velocity and controlling the swing accordingly. This skill can be derived mathematically and encoded in a control program on computer.

The key to success is the ability to measure the bucket location with respect to the boom continuously, ie 24 hours per day in almost all weather conditions. After investigating machine vision, radar, radio transponders and GPS, the team chose scanning laser rangefinders mounted at the boom tip, as the sensing system.

Equipment manufacturer

As the research is only of value if the technology is transferred to industry, the project has worked closely with Bucyrus-Erie, dragline manufacturer, and Tritronics, a Brisbane-based manufacturer of dragline performance monitors. Tritronics monitors are fitted to all Australian draglines and are well positioned to service a growing export market.

The Tritronics monitor continuously measures the state of the dragline using many sensors. Performance data such as bucket weight and cycle time breakdown for every swing can be extracted. The automation system, like the monitor, reads data from many sensors. However, it has an additional sensor to measure bucket swing angle, and is able to drive the dragline, whereas the monitor is entirely passive.

The system consists of a control computer, sensors and a radio data link so that commissioning, testing and development can be done in a caravan 1 km away rather than having to climb on and off the dragline, and interfere with the operation of the machine. The initial aim is to have the control better than the average operator.

Keeping the operator in the loop

The project provides partial automation of the machine, so it is important to be able to pass control smoothly between the human operator and the computer. For safety and initial confidence building, it is also essential that the operator can take control of the dragline at any time. To achieve this, the team developed a user interface that operates something like a 'cruise control' system. The computer controls the dragline by moving the operator's

joysticks and pedals. At any point the operator can override the computer by exerting a moderate force on the control – the computer will then return control to the operator.

A couple of extra buttons are fitted to the operator's control pod which allow the digging and spoiling positions to be taught to the computer, as well as intermediate points that the bucket must move through in order to clear the high wall and spoil piles. Another button is used to engage the automation system once the bucket has been filled.

Current status

The team conducted a demonstration in 1995 on a one-tenth scale model dragline to demonstrate the project's practicability. All equipment housing cabinets were fitted to the full scale test machine during a major overhaul last year. The sensor package has been installed at the boom tip and has passed preliminary checks. Performance over a long period and through all weather conditions will commence shortly.

The control computer system was run in the laboratory for software development and was due to be installed during April/May. This will enable the team to collect data in order to characterise the machine's performance prior to commencing automated motion sometime in the fourth quarter of 1997.

Corke mentioned the importance of handling relationships with operators, managers and electricians to help get the project up and running.

Future work

This part of the project is the first stage. With the automation system operating, the team can use it as a platform to investigate:

- automated bucket filling;
- dumping directly into a hopper or truck;
- optimally tub placement; and
- online planning based on laser or radar sensing of immediate pit geometry.

Corke also presented the work of a colleague on heading and horizon control for a continuous mining system.

Modern Management Systems for Higher Margins

By Malcolm Roberts, Catalyst for Corporate Performance Ltd

Malcolm Roberts put the case for changing systems in order to change behaviours and attitudes and improve productivity. "The key to lifting margins is changing systems."

A system is anything that drives ways of doing things. Sometimes these are formal, and documented, and sometimes they are not.

Improving productivity

The way to dramatically improve performance is to use the systems. Roberts stressed that if systems and processes are under control, the benefits of automation are huge. If they are not, the benefit of automation will be lost.

To improve productivity, you need to:

- identify what to change in the process,
- use the proven methodology to systematically improve the process, and
- change what people do – change work practices.

Roberts stressed that improving productivity is not like 'squeezing juice out of a lemon', or 'yelling louder' – this won't get higher productivity. The biggest influence on productivity is culture – the combination of behaviours and attitudes. Unfortunately, the common approach is to rely solely on communication and training to try to change attitudes and behaviour. But this does not work.

Instead, because people's attitudes are developed through experience, to change people's attitudes one must first change people's behaviours. This is done through using systems that drive the desired behaviour. This even applies to pockets of entrenched practices in traditional industries.

Effecting change is much easier once managers understand that systems drive human behaviours and that behaviours then shape attitudes.

Systems

Key systems for driving behaviour include:

- performance measurement, analysis, communication
- organisation structure
- performance reporting
- personal performance evaluation and development
- planning
- budgeting and forecasting
- accounting
- management processes
- communication processes
- systematically involving people
- pay recognition
- promotion

- safety management and reporting
- recruiting processes
- methodology for improving production processes
- core work processes
- supporting service work processes
- marketing and sales
- policies and procedures.

Methodology

The methodology for systematically improving processes and productivity is based on reducing variation to bring the process under control. This eliminates special causes and then reduces natural variation. As variation decreases, waste decreases – and productivity increases.

Roberts presented the methodology which initially involves stablising the process to reduce variation, and then works on improving the basic factors that determine productivity.

1. Make a flowchart of the process and give it an owner.
2. Determine whether the process is stable and if not stabilise it.
3. Reduce natural variation – tighten control of the process.
4. Further increase productivity by reducing variation of sub-processes and attacking productivity components to directly increase operating hours, hourly rate and labour utilisation.
5. Attack 'out-of-process delays' – especially upstream.
6. Continually improve the process.
7. Introduce higher capacity equipment where appropriate.

The benefits in accountability, discipline, metreage, tonnage, throughput, yield, recovery, purity/quality, and costs in mines and mills go straight to the 'bottom line'.

Simple statistical process control (SPC)

The key to correctly understanding processes is the correct measurement, control and communication of process performance. Use simple, statistically sound process control and improvement tools.

True continuous improvement is possible only after people understand and use correct performance measurement principles. SPC is not complex. It relies on very simple techniques underpinned by thorough understanding of variation. A leadership development tool, it enables and develops true accountability.

Roberts recommended the book, 'Understanding Variation – the Key to Managing Chaos' by Donald Wheeler, 1993. ISBN 0-945320-35-3. Available from SPC Press, Knoxville, Tennessee, USA fax (615) 588 9440.

Follow a plan

To change the work practices and culture, there is a need to develop and follow a plan. That plan will schedule changes to systems which drive behaviour and attitudes for higher margins.

How is Automation Relevant to Cannington and Other Remote Mines?

By Andrew Logan, Manager Technical Services, Cannington Project, BHP Minerals

Andrew Logan's paper outlined the Cannington mine project, and the trends in remote mining, and challenged whether mining automation R&D groups are in touch with current industry needs.

Cannington Mine

The BHP Minerals' Cannington project will mine a very large silver-lead-zinc deposit, located 190 km south-east of Mount Isa in Queensland.

The underground mine will process 1.5 million tonnes of ore a year to produce 24 million ounces of silver.

Main access and the orehandling system is currently being developed by the mining contractor. BHP Minerals mine labour will be phased in during 1997. Production mining of ore was due to commence April-May 1997.

Cannington is part of the recent trend to small-medium sized underground Australian base metal mines. Characteristics of the mine include the deposit's smaller geometric size making economies of scale limited, poor ground conditions, and remote location which means operations are 'fly-in/fly-out'.

Automation fits into the project in that it is consistent with the project's goals of:

- safety – best practice safety performance and lowest industry hazard exposure;
- environment – reduced impact on environment, and minimised personnel numbers;
- people – attract the best people, flexibility in equipment and personnel, reduction of repetitive tasks;
- achieving goals – increased productivity of processes;
- consultation – efficient and effective communication of mine performance internally and externally; and
- quality – maximise knowledge and extraction of economic resources and mineral processing recoveries, minimise mining dilution, and delivery of agreed concentrate grades.

Cannington's approach

Cannington's approach is to invest in and adopt technologies which have:

- a cost-effective entry price;
- a high likelihood of delivery by using existing technologies, transferring from other industry sectors or implementing undelivered R&D;
- a high degree of uesability;
- an incremental implementation – evolutionary rather than revolutionary approach; and
- the ability to be developed in partnership with the mine, supply groups and/or R&D groups.

Current research

Logan acknowledged the research sectors work in information management systems and the current CMTE projects into mining robotics, 3D perception, electro-hydraulic equipment, and autonomous underground vehicles.

He outlined Cannington's interest areas:

- Personnel: production management systems.
- Geology: cross hole seismic assessment; remote sensing applications; conditional simulation of resources with applied mining constraints to estimate and optimise reserves.

- Rock mechanics: assessment of excavation stability and ground support integrity, 3D seismic, stress change and ground movement monitoring.
- Ground support: remote stabilisation of ground to minimise personnel exposure to hazardous ground conditions.
- Production planning: 'smart' ring and blast design able to be used by operators.
- Development drilling: auto calibrating parallelism for repeatable drill patterns, automated drilling of development faces, real-time penetration recording and input power optimisation.
- Production drilling: hole location using seismics generated by drill string, performance maximisation by operating through traditional shift downtimes, real time penetration recording and input power optimisation, measuring drill performance and correlating with assay data.
- Ore handling: sustainable and maintainable telemucking, crusher operations, conveyor belt tramp steel pickers, role combination, ore pass monitoring and control.
- Backfill: monitoring system flow and pressures, modelling flows and performance, cheap and effective binding agents, and pipe wear.
- Ore testing: automated laboratories.
- Mineral processing: leaching of concentrate to produce metal.
- Information systems: production reporting and ore accounting systems.
- Environmental: use of 'cemented paste' to replace the need for tailings dams.

Cannington's interest

Cannington will sponsor and adopt technologies which best meet its project goals and approach. Generic technology groups are shown in Table 1 rated against Cannington's goals and criteria to get a ranking.

TABLE 1

Technologies Ranked Against Cannington Goals & Other Criteria
(1=lowest score, 5=highest score).

		GOALS						OTHER CRITERIA		
TECHNOLOGY	TOTAL SCORE	SAFETY	ENVIRONMENT	PEOPLE	GOALS	CONSULTATION	QUALITY	PRICE	LIKELIHOOD OF DELIVERY	USE
Weightings		5	5	4	5	3	5	3	4	5
1 Ventilation Management Systems	101	4	3	3	4	3	5	4	5	5
2 Improved Geological Interp	88	4	2	4	5	3	5	3	4	5
3 Improved D&B Practices & Quality	92	5	2	3	5	2	5	3	4	5
4 Production Reporting Systems	82	1	1	5	5	5	5	4	5	5
5 Ground Assessment & Remote Support Systems	57	5	2	3	3	1	3	3	3	5
6 Mining Robotics	55	3	3	2	5	1	4	1	1	2
7 Autonomous Underground Vehicles	51	1	3	3	4	1	3	1	1	1

Logan has observed that Australian research and its priorities appears to be in the reverse order to this listing. For Cannington, the highest ranking technologies are related to soft systems for information collection and use to better manage the mining process, rather than mechanical systems, and systems with a high likelihood of delivery.

Research needs to be in touch

Logan has challenged whether the research industry is in touch with its customers. He asked whether more industry user surveys should be conducted, and whether there are enough researchers with practical mining experience steering the research in the right direction.

His paper stated: efforts need to be refocused given the changing nature of the underground metal industry to smaller remote mines, to focus on industry needs rather than 'pet topics'.

He has also warned of the 'begging bowl' approach to funding saying that the research industry needs to get out of the mentality that if you deliver something useful your funding will dry up. 'This may be because it is easier to ask for additional money for the same research project again and again, than it is to deliver a product, disband a project team, and then sell a new concept.'

The Key Issues – An Overview

Minerals industry needs

Mining companies want technologies which are

- cost-effective,
- high likelihood of delivery (ie transfer existing technologies from other industries),
- highly useable,
- an evolutionary rather than revolutionary approach, and
- to be developed in partnership with the mine, supply groups and researchers,

For example, 'soft' systems for information collection to better manage the mining process rather than mechanical systems.

Human aspects

- Mining professionals must be exposed to new technologies and empowered to deal with them.
- Technology is part of everyone's role – it is a facet of continuous improvement.
- Mining professionals need to improve their understanding of technology and how to use technology.
- Human implications of automation are important – human relations, industrial relations and training.
- Multidisciplinary approach to mine automation is required to benefit from innovative approach of all parties.

Automation benefits

- Automation offers competitive advantage, improved safety, reduced environmental impact, improved quality control, improved job quality, reduced personnel numbers, better equipment use, improved maintenance, and improved communication, organisation and planning.
- Automation has the potential to provide quantum changes in overall industry efficiencies across mining as well as other primary industries including agriculture, stevedoring and transport.
- More efficient integrated, primary sector processes will have great export benefits.

Automation challenges

- Automation is inevitable in the mining industry; however, it is happening more slowly than in the manufacturing industry.
- Important to select the right processes for automation – economic analysis is required.
- The current focus in mining industry is on the individual islands of automation.
- It is harder to automate in mining industry because feedstock is less controllable and the environment is harsher.
- Communication systems and infrastructure, critical to automation, is heavily restricted in underground mines by mine design and safety considerations.

Automation technology

- Automation can be used in ventilation management system, improved geological interpretation, improved D&B practices and quality, production reporting systems, ground assessment and remote support systems, mining robotics, and autonomous underground vehicles.
- Automation technologies include: sensing and navigation; control of motion and contact; safety and condition monitoring; and planning and logistics.
- Strict electrical safety regimes limit the types of communication possible.

Mining automation research

- Australian research and its priorities need to be more in keeping with the changing nature of the underground base metal minerals industry.
- Researchers must complete projects and not be afraid that their funding will dry up.
- Important that technology is transferred to industry; this requires support and involvement of equipment manufacturers.

Equipment suppliers

- Opportunities exist to develop locally high-technology systems and components for use on heavy equipment manufactured in Australia and overseas.
- Mining companies need to encourage local engineering small to medium sized enterprises and provide the market opportunities.

Management systems

- Improving productivity requires changing systems; this changes people's attitudes.
- Reducing variation to bring the process under control allows the systematic improvement of processes and productivity.
- Statistical process control is the key to correctly understanding the process.

Appendix

Austmine Ltd

Austmine is an organisation of 115 exporters of Australian mining technology, goods and services who sell their products to over 42 mining nations worldwide. It started in 1988 with exports totalling $40 million and 30 company members. Austmine companies currently employ some 330 000 people. It hopes to achieved $990 million of exports in mining goods and services in 1996/97 year with $1 billion expected in 1998.

Austmine tends to export more services and equipment that it does consumables and technology. Over 60 per cent of Austmine companies export services, whilst around 50 per cent export equipment and technology.

Austmine's strategy is to expand market opportunities for its members and assist in the development of export capabilities. It also works with Austrade to improve exports.

References

The full papers are available from the authors:

- **Keynote Address**
  Angus M Robinson (presenter), The Warren Centre for Advanced Engineering and Alan Broome, Chairman, Austmine
  Contact: Angus M Robinson, tel (02) 9351 4048; fax (02) 9351 2012
- **Aims of the Forum**
  A contribution from Dr Robin Batterham, RIO TINTO Research & Technology, tel (03) 9287 7287; fax (02) 9287 7289
- **Introduction to Automation Systems Requirements**
  Dr David Dekker, CSIRO DEM, tel (07) 3212 4567; fax (07) 3212 4566
- **The End of the Line for Roadway Development**
  Michael Kelly, CSIRO DEM, tel (07) 3212 4612; (07) 3212 4566
- **Automation Technology**
  Professor Hugh Durrant-Whyte, The University of Sydney/CMTE, tel (02) 9351 5583; fax (02) 9351 7474
- **Industry Case Study**
  Peter Corke, CSIRO Manufacturing Technology/CMTE, tel (07) 3212 4584; fax (07) 3212 4455
- **Modern Management Systems for Higher Margins**
  Malcolm Roberts, Catalyst for Corporate Performance Ltd, tel (07) 3374 3374; fax (07) 3374 3004
- **How is Automation Relevant to Cannington and other Remote Mines**
  Andrew Logan, Cannington Project, BHP Minerals, tel (077) 692 100; fax (077) 692 222