Advanced Mining Technologies
Greg Rowan
Director Mining Research
Theme Leader Mining and Specialist Services

Introduction

The Mining and Mineral Process Industry (covering exploration, extraction and processing) is a critical part of the Australian economy, representing approximately 5% of Gross Domestic Product (GDP). When combined with the Quarrying Industry (clay, sand, gravels and crushed rock) it represents 6% of GDP and employs over 1% of the workforce.

The minerals industry itself is Australia's largest export earner contributing $57.7 billion to Australia's commodity export earnings in 2005-06[1]. It also contributes annually $1.9 billion in high-technology exports and accounted for 19% of the value of Australia's fixed assets and natural capital. The industry has added around $500 billion to Australia's wealth in the last 20 years.

Whilst Australia is currently enjoying the global increase in commodity demands, it is clear that many countries have lost their mining and associated support industries and primary resource industries continue to play a less significant role in first world economies. Europe and the USA have both been through this transition and both have seen steady declines in mineral production, exploration and the associated knowledge industries. Key drivers are a declining role of minerals in wealthy (developed) nations and the ability and expectation of the minerals industry to play a role in managing social and environmental impacts.

In this international context, there has been a climate of global decline in R&D in the sector. In other developed economies, where mining represents a smaller proportion of GDP, R&D in the sector is being all but abandoned. For example, efforts in mining technology and automation research in the following international organisations have been terminated.

- USA: US Bureau of Mines (closed). OH&S research through DOE and NIOSH

- UK: British Coal Technical Services and Research Executive (TSRE) (closed)

- France: Cerchar (Centre d'Etudes et Recherches des Charbonnages de France). (ICT and Automation research terminated)

In 1994, as a prelude to privatisation, the British Coal Corporation closed its Technical Services and Research Executive (TSRE), ending 47 years of state research into mining problems[2].

In 1995, the US Congress voted to abolish the United States Bureau of Mines as a budget saving measure. Contracts to continue the work of the USBM have been awarded to NIOSH (National Institute for Occupational Safety and Health), US Department of Energy, US Geological Survey and the US Bureau of Land Management[3].

Australia has opposed this trend.

Over the period 1994-95 to 2003-04, R&D expenditure by the mining industry more than doubled from $303m in 1994-95 to $783m in 2003-04. As a result, the mining industry's contribution to all industries R&D expenditure rose from 9% in 1994-95 to 11% in 2003-04.

Australia's premiere national R&D organisation, the CSIRO, invests approximately $35m per year into R&D through its Exploration and Mining Division which employs around 200 full-time researchers, scientists, engineers and support personnel based in three major centres across Australia (Brisbane, Perth and Sydney).

Additionally, the creation of a new CSIRO National Research Flagship, known as Minerals Down Under, is in direct response to the major challenges confronting the minerals industry in Australia. As

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[1] Australian Bureau of Statistics, 5368.0 International Trade in Goods and Services, Australia

[2] (*Mine Monitoring for Safety and Health,* TSRE)

[3] http://www.mtech.edu/CHEM_330/Government_Documents/USBM.htm)

recently announced in the federal budget, this new Flagship will receive $A34.6 million from the Australian Government over the next four years, allowing it to collaborate with industry, universities, institutions and others to coordinate research which will help Australia unlock key commodities in our underground mineral reserves.
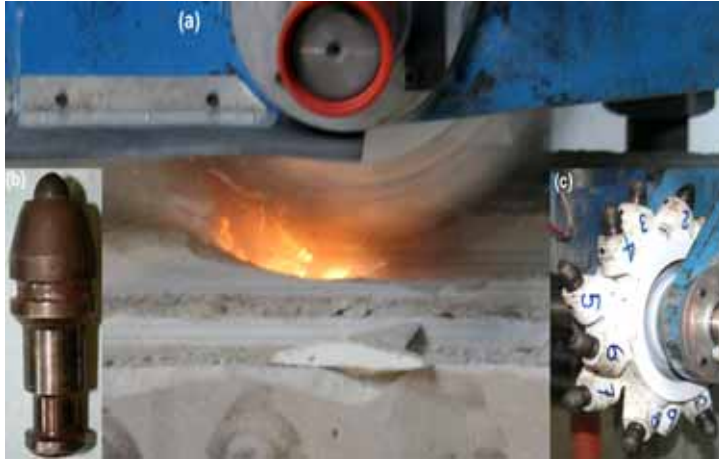

Fig 1 SmartCut Technology

Although our minerals industry is booming, exploration investment has fallen by half a billion dollars a year since 1998. Where we once thought we had centuries of reserves, we may have only decades. The future of our major minerals houses is no longer linked to Australia's future. They have a global choice, Australia does not, and we must be proactive to retain our most important export industry.

Risk, specifically *technical risk*, is seen as being higher in Australia than elsewhere and is traded by the industry against the *sovereign risk* it incurs when operating in less stable areas overseas. But technical risk can be reduced by new technology and this paper addresses some of the R&D activities being undertaken by CSIRO to overcome some of the technical challenges facing Australia's mining industry now and in the future.

In order to grow, the Australian mineral industry will need to:

- Maintain a steady supply of economically exploitable mineral resources
- Increase the rate of discovery of mineral resources
- Improve the economics of mining and processing of existing reserves
- Increase the conversion rate of resources to reserves
- Increase the value added proportion of the metal production cycle
- Maintain an investment friendly political and fiscal environment
- Develop technologies that allow socially acceptable mining in an environment of increasingly scarce consumables (notably energy and water) and increasingly intense scrutiny of mining as a valued contributor to the national triple bottom line
- Improve OH&S performance
- Reduce environment impact of operations
- Meet community demands and expectations about social interaction

Mining Geoscience
CSIRO Exploration and Mining is developing new technologies and systems to characterise, predict and monitor minerals and energy resources, ground conditions and material behaviour through the mining value chain. Activities span brown-fields exploration, feasibility, planning, operations, utilisation and rehabilitation.

Coal Characterisation
Optical microscopy is being used to characterise individual grains of coal and rock from cores, stockpiles and on-line sampling. This information yields quantitative characterisation, providing new information for predicting and monitoring coal beneficiation that is currently unobtainable by other methods. In addition, research into coal handling conditions arising from coal properties is delivering substantial improvements to coal rail wagon loading and unloading

Bore-hole Logging
We are a global leader in the development and application of new borehole logging technologies aimed at measuring rock properties important to mining. We are also extracting additional data from conventional borehole logging methods through the development of new techniques for the analysis and interpretation of the full range of borehole logging data.

3D Data Imaging and 3D Data Processing

CSIRO's proprietary Sirovision® is the world's leading technology to generate and analyse high-precision 3D images of rock mass surfaces using digital photography. New versions of Sirovision® for open pit and underground environments are being developed. It is also gaining mine mapping, slope stability analyses, blast optimisation and real-time input abilities.

Fig 2 3D Photogrammetry

Microseismics

Our research is aimed at understanding, monitoring and predicting rock integrity and ground condition associated with mining processes through microseismic analysis. Significant advances have been made in the fundamental understanding of rock fracture mechanisms and roof caving processes associated with longwall coal mining. New data processing algorithms are being developed to support the automated event classification and interpretation that is required for the implementation of real-time microseismic monitoring.

Integrated Geoscience Data Analysis

Geologists generate huge data sets during exploration, feasibility assessment and mining. We are developing new systems for processing, analysing and interpreting complex and disparate, spatial and non-spatial geoscience data sets. This capability is also being used to generate greater understanding of deposit formation and response to mining. We have developed the CSIRO Self Organizing Maps (CSOM) method to define relationships not evident through the use of traditional statistical and GIS based data analysis procedures. In addition, new algorithms have been written to integrate borehole data with 2D and 3D seismic data.

Mining Systems

CSIRO has developed world-class expertise in mine equipment and drilling technologies with a focus on low cost, high tonnage mining systems. Our metalliferous team is making improvements to open pit design methods; in coal mining the focus is to improve gas and strata control; and the rock engineering group is developing capabilities to improve the understanding of rock behaviour.

New Mining Methods

A hard rock mining method called ROES™ is being developed that uses a new generation of remote controlled equipment to dramatically reduce mine development costs. One or more vertical or inclined shafts are driven through an ore body, with access only at the top and bottom. It is estimated that ROES™ will reduce mine operating costs by up to 20 per cent. This could result in savings of up to $200 million a year in 18 target mines alone. In addition, the method may make economic at least $100 billion of metal currently in sub-economic ore, creating new reserves.
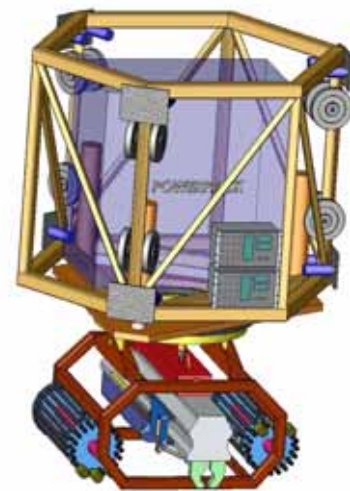

Figure 3 Remote Controlled Automated Mining Method

Mineral Sands
Mineral sands valued at about $80 billion will remain economically unviable without the technology to decrease mining costs by up to 15 per cent. We are developing keyhole mining technologies, new processing technologies, remote sensing and modelling technologies to help unlock this vast resource.

Coal Mining
Cosflow is an integrated simulation software package that couples fluid (gas and water) flow through a porous medium with rock deformation and stress. It is the only product of its kind in the world to simulate ground deformation and water/gas flow. Other developments include dust control technologies and the evaluation of longwall top coal caving methods in Australia and a new collision avoidance system for mine haul trucks based on radar proximity detection systems. We are building new knowledge about the strength and deformability of rocks and the mechanisms that lead to failure of rock slopes in large open pit mines. Simulation of dust behaviour around a longwall shearer is leading to dust control technologies including a shearer scrubber

Microsiemics
Microseismic analysis has allowed us to reach new levels of understanding of rock integrity and ground condition, with a real-time microseismic system for longwall coal mining currently under development.

Gas
Improved gas characterisation and control techniques have enhanced underground coal mining productivity at the face. We have also improved the efficiency of goaf gas drainage systems by more than 50 per cent, saving tens of millions of dollars. Additionally, we are developing advanced gas drainage technologies specifically for deep mining conditions. A new understanding of mine gases has led to techniques to utilise inert gases to combat fires. We have reduced the risk of heating and fire development in longwall goafs through proactive inertisation techniques, and have developed techniques for pinpointing heating in longwall goafs.
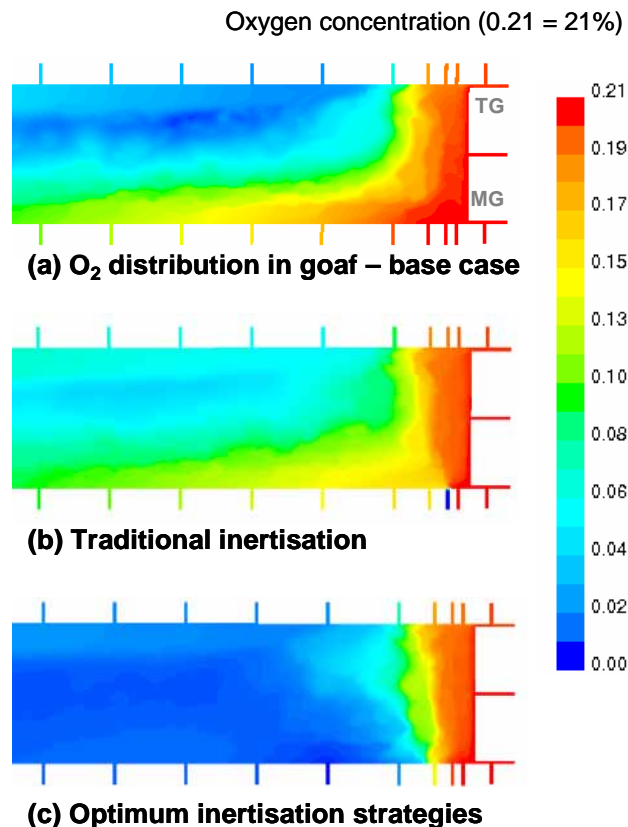

Figure 4 Operational Control: Mine Gas & Fire Control

Sustainability

As a global player in the coal and metalliferous mining industries we are meeting the challenges of more efficient recovery of ores and societal concerns around sustainability. We are developing approaches to reduce the environmental impact and utilise waste and emissions generated by mining methods. Using catalytic combustion techniques CSIRO hopes to deliver step-change technology in emissions management by turning ventilation air methane that is currently a source of greenhouse gas emissions into energy. We are looking at developing integrated waste management systems which will utilise two or more waste streams in one process.

We have developed expertise in understanding the social impacts of mining and our research enhances the sustainability of the resources sector. Projects are aimed at analysing social issues that enable a triple bottom line (economic, environmental and social) assessment of the minerals and energy industries. Environmental impact is assessed and changing public perspectives of mining are analysed

Drilling and Cutting

CSIRO is developing drill monitoring technology to provide an automatic assessment of rock condition and strata identification during drilling. The drill also automatically adjusts to find the sweet spot and feedback can be used to identify the rock type.

Figure 5   Cutting Harcourt Granite

SMART*CUT is a revolutionary new tool technology based on thermally stable diamond composite for cutting and drilling hard and abrasive rocks. SMART*CUT has a much deeper cut and wears hundreds of times better than traditional tools.

Water

Reliable prediction and management of mining induced water inflows and aquifer interference is a major emerging challenge. CSIRO has developed an integrated hydrogeological assessment process for mine ground water inflow prediction.

Underground Coal Gasification (UCG)

UCG allows us to extract previously unminable, low quality and hard to reach coal. The UCG process burns coal underground thus generating a gas that is captured on the surface. The gas can be used for synthesis of liquid fuels at costs competitive with the current oil supply. It can also be used for environmentally friendly power production.

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Mining Automation

Integrated, real time information systems and the automation such systems makes possible, is about to transform mining. We are developing intelligent network systems that will streamline the decision-making process, remove people from hazardous environments and make production more consistent.

Longwall automation

Our world-first longwall automation system works with existing face equipment to deliver accurate automatic longwall face alignment and horizon control. The system uses an inertial navigation unit to measure the 3D position of the longwall shearer as it moves across the face. Specially developed software provides a realistic 3D visualisation of face equipment conditions that allows control and monitoring of the automated face.

Real-time risk management

CSIRO has developed a system, *Nexsys™ Realtime Risk Management System*, that draws data from the thousands of sources and proprietary monitoring devices in an underground coal mine and integrates them into a single database. Using Ethernet enabled communication systems, selected safety critical data is analysed and presented in a clear, easily understood format, particularly critical in emergency situations. The system includes the *Nexsys™* software package, which presents a three-dimensional view of the mine and a realtime risk profile graphic. The communications system includes an fully managed, fast, fibre optic IEC Ex.ia (approval pending) Ethernet Switch and a separate IEC Ex.ia (approval pending) Serial to Ethernet Protocol Converter.

Future developments to the system will allow for anomaly detection, pattern matching and recognition capability and the first application of predictive realtime risk profiling to allow pre-emptive actions to be taken prior to a Trigger Level being breeched.

Figure 6 Fully Managed Fast Fibre Optic Ethernet Switch

Virtual mine

Our capabilities in visualisation, spatial data integration and web-enabled 3D graphics have delivered a range of technologies. One of these is Virtual Mine. It transforms multi-dimensional data into interactive, web-accessible 3D models. This allows real-time data streams to be monitored and managed using a mine's own intranet to improve access to information and facilitate remote mining.
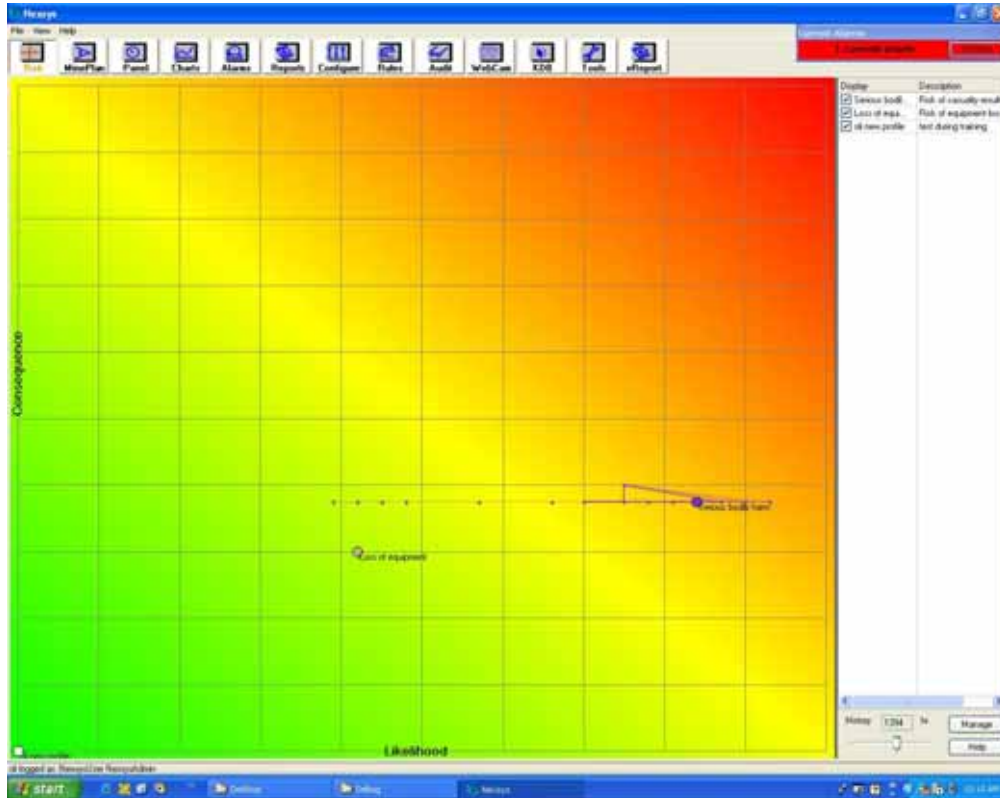

Figure 7 Nexsys Real Time Risk Management System

Multi-machine automation

Combining radar and laser scanning technologies with Wi-Fi communication networks is creating Simultaneous Localisation, Identification and Communication (SLIC) radar imaging. SLIC will eventually provide a globally coordinated approach to controlling the movement of multiple machines.

Working with CSIRO
CSIRO Exploration and Mining actively seeks partnerships and joint ventures with research organisations, governments and a wide range of industries. We can offer world-class people and facilities, leading edge technology, product development and project management to meet the needs of industrial, research and commercial partners.
CSIRO Exploration and Mining's attributes include: world-class expertise in cutting-edge exploration approaches using new technologies AND innovation of mining methods

Conclusion
Meeting these challenges, building on Australia's still significant comparative advantages and positioning it as competitive in a truly global marketplace defines the purpose for this initiative. It will require bold and highly challenging scientific breakthroughs from the united efforts of physicists, chemists, geologists, geophysicists, spectroscopists, bioscientists, mining engineers, environmentalists, metallurgists, IT specialists and others. Over the next 5 - 15 years, Minerals Down

Under will develop technologies that significantly increase exploration success rates in Australia, free-up major new resources and value-added products through new mining technologies, redefine "recoverable" ore and transform systems to realize this value to the national benefit.

Though the mining industry is a star performer for the Australian economy its future is not guaranteed. A healthy economic future depends on finding new resources to replace those we have already mined, and on mining those resources in a socially, economically and environmentally acceptable way.

CSIRO Exploration and Mining applies world-leading science and engineering know-how to raise Australia's competitive advantages in this vital sector