Automating the mine
This edition of earthmatters demonstrates how Australian science and engineering is successfully pushing the boundaries of intelligent automation. What was once thought impossible or very difficult has been proven in the lab and is now being actively commercialised.

We have built intelligent machines and systems that are operated remotely at distances ranging from a few metres to more than 1,000 km. We are creating an immersive and interactive virtual environment that will be a research theatre and training centre for robotic mining equipment.

In the field, we are working with our industry partners to improve extant systems such as those that break rocks at a mine or load ships at a port. And we are developing unique systems that utilise modern sensors to accurately image the challenging conditions in the mine environment, allowing operators and supervisors to observe and interpret details of their surroundings that have previously been unavailable.

This ambitious drive for automation is aimed at solving two fundamental problems that have dogged the exploration and mining industry for decades: How to remove people from hazardous and inhospitable working environments, and how to increase efficiency, productivity and profitability in mining.

Teleoperation (remote control at a distance) delivers valuable answers to these problems by deploying mining equipment that can move quickly and cover long distances while being controlled remotely from the surface. Skilled operators can teleoperate more than one machine simultaneously while remaining in a pleasant and quiet environment. A future miner might well work in a comfortable office in street clothes instead of underground in coveralls, steel-capped boots and a hard hat. This safe and comfortable future world of automation is a striking contrast to the tough and dangerous conditions facing early Australian miners, who worked in crudely dug and unstable underground environments with barely a fraction of the procedures and protective gear we now are essential to the safety of mine personnel.

Perhaps in a decade or so, we will look back with some wonder at the way people once ventured below the surface with or without protective equipment, smart escape plans and adaptive communications and supervisory systems. Autonomous or at least semi-autonomous mining conducted and managed by skilled, safe, and secure people in a comfortable environment will be the norm.

Dr Michael McWilliams
Chief
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For details, call Lyndelle Broadfoot: +61 7 3327 4474, Lyndelle.Broadfoot@csiro.au
The message from the Director of CSIRO’s Minerals Down Under National Research Flagship, Dr Peter Lilly, (see pages 4 and 5) is a sobering wake-up call to all involved in the exploration and mining industry. However, possibly his most important point is also one of his most positive. He highlights the “powerful suite of technologies” being built by CSIRO, which includes intelligent machines, smart extraction solutions and futuristic production systems.

Regardless of the current or future economic position of the industry, there can be no doubt that when it comes to automation science, Australia is a leader, but how do we define such a seemingly vast discipline as automation? Where does it begin and end and how does industry benefit?

One of our featured scientists in this edition, Rio Tinto’s Head of Innovation John McGagh, puts it well: “Automation increases the level of control in what is inherently a chaotic process. It gains control by applying more stringent rules to decision-making processes, and removing the randomness inherent in isolated decision making. It is about applying a controlled process to variable mine geology and ever-changing topography.”

He added: “Automation allows for the management of disparate information flows in new ways to deliver unified end-to-end interlinked processes. Mining processes have traditionally been viewed as being stand-alone but much theoretical work has been done on how the processes should interact.

“Also, removing human intervention and running end-to-end with machine control allows for unparalleled levels of efficiency and repeatability: true process quality.”

Most scientists and miners would agree that “true process quality” is still some way off but these months, these years, as Dr Lilly stresses, are the ones in which we must build the automation platform to ensure we reach that goal.

There are other factors at play here too. We know mining is traditionally cyclical, but in a post-credit-crunch world, could those cycles be skewed? Could the peaks and troughs that the industry has known and predicted previously be, suddenly, nowhere near as predictable as before? Add the fall of the US economy and the rise of China’s and India’s into the mix and you have another untested dynamic.

In this chaos, could automation be one of our constants? Could it also, as John McGagh predicts, be a way of creating shared success and shared wealth?

“I am convinced that to exploit the opportunities in this new age will demand new management and organisational structures,” he tells earthmatters on pages 10 and 11 of this edition.

“We live in the time of the network/extranet. I see no reason why a group doing breakthrough innovative work on the other side of the planet cannot be as much a member of my team as the physical lab next door. Australia has capability in this area and can play on the world networked stage.”

In such turbulent times, it is encouraging to hear voices of reason such as Lilly’s and McGagh’s, and that of CSIRO Exploration & Mining’s Research Projects Engineer Chad Hargrave (see p18) who is one of those at the forefront of automation and who reminds us of the most constant goal of all - protection of our fellow human beings.

He said: “We have traditionally defined the benefit of automation to industry across three general domains: safety, productivity and sustainability. My hope is that the research that we do, when transferred to industry, results in a genuinely safer and better work environment that improves the lives of mining workers and benefits the companies that employ them.”
The next mining boom sta

The Director of CSIRO’s Minerals Down Under National Research Flagship, Peter Lilly, says now is the time to invest in skills needed to benefit from the next upturn.
Beneath the Australian desert sands lies another Broken Hill, Mt Isa, perhaps even another Kalgoorlie – several vast, world-class mineral deposits capable of generating centuries’ worth of national prosperity.

How can I be sure? Well, we’ve really only searched a third of this continent thoroughly so far, and look what we’ve already found. Logic, as well as geology, suggests that there’s twice as much wealth still hidden under the sand and rubble that masks two-thirds of our land mass. And more wealth still, the deeper we go.

Yet just when we ought to be looking our hardest and smartest, to offset the effects of the downturn and build a platform for the next inevitable surge in world mineral demand, Australia is cutting back.

Companies are laying off the geologists, mining engineers and metallurgists they couldn’t hire enough of a year ago. Some university mining and geology schools are in deep trouble and may even close. The national research investment we make to remain leaders in the global mining and minerals business is miniscule when compared with the $159 billion return it will generate this year, and it is shrinking.

Our existing resources are becoming costlier to extract. We’ve run through most of the high-grade, easy-to-reach ores. We’re now onto the tough ones, where you have to dig deeper, crush more rock for less product, or use more energy, water and money to win the metal from a tricky ore.

Mining in Australia is becoming harder and more expensive at the precise moment in history when it needs to be more efficient, more expensive at the precise moment in history when it needs to be more efficient, more expensive at the precise moment in history when it needs to be more efficient, more expensive at the precise moment in history when it needs to be more efficient, more expensive at the precise moment in history when it needs to be more efficient.

After the longest period of sustained mineral prosperity in our history we’re repeating the mistake of draining the lifeblood of our industry – discovery and innovation – at the very time we ought to build it up, to ride out the hard times and get ready for the good ones when they come again.

It’s getting to be a habit: in the latest boom we lost five years in terms of technology and infrastructure, and it cost us almost $20 billion in global market share.

Australia isn’t so rich that we can afford to hand $20 billion to our competitors every time there is a cyclical upturn in the markets, not to mention all the jobs and skills. The time to invest in the technologies that give us a leading edge is now, today – not when it’s too late.

Hi-tech solutions

For example, CSIRO is developing a powerful suite of technologies to “see” into and through the regolith – the rubble that shrouds two-thirds of our continent – to predict and discover huge new ore systems, just below the surface or even a kilometre or more down. This will be vital as present quality ores are used up.

We’re inventing novel ways to mine ore and intelligent machines that can sense their way through the orebody to extract the richest deposits. We’re pioneering “keyhole mining”, the automation needed to exploit and process ores underground, leaving a minimal footprint at the surface.

We’re devising cheaper, cleaner and smarter ways to extract minerals, or process difficult ores, mineral sands and bauxite. Australia has hundreds of billions of dollars in known mineral deposits that cannot currently be exploited economically without these new processes. This is wealth for the taking, but first we need the science to take it.

CSIRO is developing some spectacular technologies that will enhance the production of aluminium and titanium and other products, reduce their environmental impact, recycle waste into valuable products and fabricate ultra-strong lightweight materials for the eco-cars, boats, buildings, aircraft and manufactures that are in such growing demand.

We are shaping the ‘industrial ecology’ of the future, systems where ‘wastes’ are recycled through various industries, to create new wealth instead of a disposal headache.

End to boom/bust

This endowment of resources and leading-edge technologies offers Australia an opportunity like no other to end the busts of the traditional minerals cycle, create hundreds of thousands of value-adding and high-tech jobs along with new industries and exports. First we have to invest in the knowledge that delivers them, both publicly and privately.

If we wait for the next boom to do so, it will be too late.

The horse that wins the Melbourne Cup is never starved by its owners. Indeed, they usually breed from it. Yet Australia is now starving its greatest winner of the past 150 years. It wouldn’t make a lot of sense to a horse owner, and it doesn’t make much sense for a nation.

We can end the minerals boom/bust cycle by applying our brains, and planning now for the next great phase of minerals demand.

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Australia’s minerals go on

Matthew Brace reports on the world’s first virtual mineralogy library

Explorers will soon have a new knowledge source at their fingertips to help them tackle the challenge of finding new mineral resources.

The AuScope National Virtual Core Library (NVCL) is a research network, which offers users a detailed and high-resolution portrait of the composition and more specifically the mineralogy of the top 2km of the Australian continent.

Core libraries have existed for many years but they have not been utilised to anywhere near this degree. The NVCL, which is part of the AuScope National GeoTransects Programme, has the goal of progressively building a novel high-resolution image of earth materials and properties, and facilitating world-class geoscience research.

The NVCL will contain both mineralogical and image content describing geology of the core contained in these libraries. It will significantly increase the value of existing core libraries by scanning hundreds of thousands of core samples using CSIRO’s robotic, automated spectroscopic machines (or HyLoggers™) and then publicising the detailed mineralogical data derived from that process.

This reveals new geological knowledge that is not readily evident to the naked eye.

According to the Programme Director, CSIRO Exploration & Mining’s Chief Research Scientist, Dr Jon Huntington, “never before has such a comprehensive and accessible mineralogy map of Australia been available”.

“Most government core libraries and company core ‘farms’ are large repositories for rocks and core samples that people can visit and examine but no-one has taken it to the next stage of developing a wholesale value-adding process to use those core assets, certainly not using hyperspectral techniques to derive mineralogy. Neither has anyone put the results online for all to use either for research or more practical exploration activities,” he said.

“One goal of the NVCL is to encourage people to use knowledge from the past to drive ideas, exploration concepts and understanding, leading to future exploration and new resources.”

Library content

The raw data for the library is based on the rich legacy of drill cores already held in roughly 18 core libraries or informal core repositories in the seven State and Territory Geological Surveys.

Thousands of cores - some recent, some many years old - are already stored in these libraries and are publicly available. They have been drilled by State Governments or donated by private companies.

The new virtual online library will offer users the chance to examine detailed mineralogical results remotely before deciding to spend money on a formal visit to physically inspect the core.
The hyperspectral infrastructure is made up of seven HyLoggers, one in each of the State and Territory Geological Surveys. Each HyLogger consists of sensitive visible and infrared spectrometers, a very high-resolution digital camera, a laser profilometer, a robotic x/y table, power supplies, lighting, control software, and a control and data management computer.

The HyLogging™ systems are being built with funds from CSIRO and the National Collaborative Research Infrastructure Strategy (NCRIS). The Geological Surveys will own the HyLoggers, maintain them and provide operational staff as their co-investment in this project.

**Wealthy data bank**

The sheer mass of information to be scanned and published is remarkable. According to the team, the project is producing roughly 3MB of processed data per metre of core scanned (the raw data also has to be stored).

“If a State Geological Survey manages to scan 100,000 metres in a year that would be 300,000MB or 300GB, and that’s just one Survey,” said Dr Huntington.

“This might amount to 4 terabytes over the life of the current NVCL project. Moving this amount of material around on the internet is not trivial. Not everyone has internet speeds we in CSIRO are used to so we have to be clever and offer alternative strategies to publish and deliver data. We are developing these as we proceed.”

**Open for business**

Explorers will be able to start viewing scanned results from about mid-2009.

Dr Huntington explained that the NVCL team is building an Oracle database, a version of which will be provided to each State Geological Survey to implement.

“The AuScope Grid will access those databases, extract data and publish simplified versions to the internet for all to examine. Full resolution copies of the data will be available from the Survey NVCL contacts called ‘custodians’ and maybe some of it over the internet,” he said.

According to Executive Director - Minerals and Energy – for the Department of Primary Industries and Resources of South Australia, Dr Paul Heithersay, NVCL “allows for a totally new way to interrogate geological data from core. It has shown us, for example, that alteration zones can be much larger than previously recognised. It also allows for geologists to scan core remotely so that a visit to the core library is more targeted and cost effective”.

“The state governments make a very significant investment in storing and maintaining core for the use of explorers. I see this as adding a lot more value to an important asset,” he said.

The view from Queensland is equally positive. Acting Manager of the Geoscience Information Unit at the Geological Survey of Queensland, Ian Withnall, told earthmatters that NVCL’s role in providing a better understanding of mineralising and alteration processes in a mineral province should “lower the risk associated with mineral exploration and increase the chance of discovery by both those companies already active and those that we would like to attract”.

“Discovering a resource not only provides direct royalties to a government but provides employment and wealth that flows through the community and sustains our economy,” he said.

Explorers wishing to get research access should begin by contacting the NVCL custodian in the relevant Geological Survey.

**Building a legacy**

The publicly-funded NVCL will be built progressively as more and more core sample data are added over the coming years from government and private sources.

A rough estimate puts the total length of core scattered around the country’s warehouses and libraries at roughly 8 million metres. Even discarding core which has decayed over the years, the amount of work involved in scanning this resource is vast, which is why the HyLoggers will be active for many years to come.

Prioritisation of cores to be scanned will be made on the basis of creating representative transects through important metallogenic provinces and mineral deposits, and to support research being undertaken in other AuScope components.

Donations of scanned cores from the private sector are also invited and will augment the value of the growing database of earth composition knowledge for future generations.

**Acknowledgement**

The NVCL project is funded via AuScope (www.auscope.org.au) and the NCRIS programme via the Australian Federal Government’s Department of Industry Innovation Science and Research (www.diiis.gov.au). CSIRO Exploration & Mining would like to acknowledge the Directors of each State and Territory Geological Survey without whose unilateral support the NVCL project would not have happened.

**View from AuScope**

The CEO of AuScope, Dr Bob Haydon, says the release of the first scanned results this year will be a major achievement.

“The NVCL is truly unique in its capacity to capture a range of important data from drill core. When established and populated with a range of data from drill core from the various States and Territories, the NVCL will provide remote access to ‘view’ drill core in a traditional sense but with the enormous benefit of viewing and displaying mineralogical data that will significantly enhance the ability of geoscientists to interpret drill core.

It’s the remote access to core that is so important and over time will be a viable alternative to physically storing and retrieving trays of drill core.

Any new technology that can publicise Australia’s geology and its potential to host undiscovered resources resulting in increased investment is very important and so there is financial benefit. However the NVCL also opens new opportunities for fundamental and applied scientific research that may have wide application in understanding of our earth resources and therefore have broad community benefit as well.”

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**VIEW FROM AUSCOPE**

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**Demonstration website**
http://nvcl.csiro.au

**www.auscope.org.au**
A fresh set of eyes

Modern sensors are delivering data for the creation of 360° digital maps for mine machinery in the harshest conditions

Anyone who has spent even the shortest amount of time in a working mine will know the adversity of the conditions that can exist.

An often hostile climate combines with the localised tempests of dust, heat and mist caused by the processes of digging or drilling into the earth to create some challenging environments.

Decisions made in such conditions where senses are severely limited (sight especially) have always been subject to significantly increased risk. There is a universal desire to reduce that risk.

Lasers have found regular but limited use in mining automation applications (such as Load Haul Dump vehicles) and applications of millimetre-radar are under trial with some promise. However, difficult mining conditions still threaten widespread use of both technologies.

CSIRO’s ICT Centre identified the need to extend the potential use of these tools by establishing the performance parameters of scanning range sensors under adverse environmental conditions.

The goal is to be able to prove that the much wider and more sophisticated sets of data that can be gleaned from such conditions could be used to construct accurate digital models of the mine environment and, subsequently, to make accurate and appropriate control decisions for operation of machinery.

Lab to field

CSIRO scientists, through the Minerals Down Under National Research Flagship, joined forces with CRCMining and the Australian Centre for Field Robotics (ACFR) to conduct a series of controlled laboratory experiments to examine the performance of three scanning range devices: two scanning infrared laser range finders and one millimetre-wave radar.

These experiments were undertaken as a requirement under an ACARP-sponsored Shovel Swing Loading Automation Project directed by CRCMining.

The performance of the devices was tested in rain, mist and dust-cloud conditions far worse...
than any ever experienced in nature. Then the sensors were sent into the field and installed on a P&H 2800BLE electric rope shovel at the Bracalba Quarry, near Caboolture in Queensland.

The aim of these tests was to establish the relative merits of lasers and radar technologies under the environmental conditions likely to be encountered in a working mine, in order to perform mapping operations and data segmentation into:

- the terrain surrounding the shovel
- trucks in the vicinity of the shovel
- relative location of dipper and truck tray

In other words, the researchers needed to know if these sensors could provide enough accurate data to build a clear 360° digital model of the environment around the machine so a remote operator could “see” clearly enough to make decisions for controlling the operation of the machine.

**First results**

According to one of the authors of a recent ACARP report on the research, Minerals Down Under Stream Leader for Geologically Intelligent Surface Mining, Dr Eleonora Widzyk-Capehart, “it was found that the lasers showed accurate and reliable target detection when visual targets were no longer discernible by passive means, such as video imagery”.

According to CSIRO ICT Research Scientist Adrian Bonchis, “there is a limit to the level of obscurity through which the lasers were able to provide accurate ranging information. This limit was similar for both the Riegl and SICK lasers at a transmission of 92.5% per metre for bright targets closer than 25m”.

Dr Widzyk-Capehart added: “The laser sensors can be blinded by build-up of obscuring media (such as mud or dust film) on the sensor lens. The radar return was unaffected by the generated conditions of the controlled environment testing, showing robust behaviour.

“However, as a sensing technology, due to its wider beam-width, radar provides low range and angular accuracy by comparison to the laser systems.”

The research results show that the two sensing technologies are complementary and should be combined to provide a more robust representation of the surrounding terrain using the following:

- radar returns to provide a rough draft of the surroundings in which significant obstacles (greater than 2m in size) are clearly identifiable as an obstruction (although not necessarily classifiable) and that is robust to adverse weather and dust
- laser information to provide the detail of the surrounds, and other information required for tasks such as volume estimation, segmentation and classification of objects and obstacles
- radar returns to determine when information provided by the laser sensors have been degraded by adverse environmental conditions such as rain, mist and dust

“It would be desirable to observe and assess the sensors’ performance over an extended time period in a production environment,” Dr Widzyk-Capehart said.

“Furthermore, it is suggested that any such testing should aim to incorporate as varied operating conditions as possible, including operation in significantly different ore types, for example, coal and iron.”

The team’s ACARP report is called *Performance of Laser and Radar Ranging Devices in Adverse Environmental Conditions* and is the combined work of CSIRO scientists Nicholas Hillier, Julian Ryde, Eleonora Widzyk-Capehart and Mike Bosse, ACFR scientists Graham Brooker and Javier Martinez, and Andrew Denman from CRCMining.

**The gear**

The three scanning range sensors tested as part of this study were:

- A Riegl LMSQ120 scanning laser range finder
- A SICK LMS291S05 scanning laser range finder
- ACFR’s prototype 95GHz millimetre-wave radar (2D HSS)

The two sensing technologies investigated within this study are considered complimentary because:

- Radar generates point-cloud type information that is robust to adverse environmental conditions including heavy mist, rain and dense dust clouds. The measurements are of (relatively) low accuracy but sufficient for the provision of structure and large object segmentation
- Laser provides a more easily interpreted measurement that is ideally suited to the creation of digital models of the surrounding terrain with high precision and accuracy.
Innovate to succeed

Rio Tinto’s Head of Innovation, John McGagh, tells Matthew Brace how automation is taking centre stage in the development of the mine of the future.

How is innovation different from invention?
Invention relates primarily to coming up with the new ideas that populate the early stage of the innovation pipeline. The innovation process has a much broader connotation, however, and covers the entire pipeline from idea generation, proof of concept and prototyping, right through to the commercial implementation of that idea into an industry operation. Step-change innovation is born from our packaging of inventions into new, value-adding combinations that achieve a step-change in performance.

What are the chief benefits for the exploration and mining industry of advances in automation?
Rio Tinto has developed a strong vision for the ‘Mine of the Future’, and automation takes centre stage. Automation increases the level of control in what is inherently a chaotic process. It gains control by applying more stringent rules to decision-making processes, and removing the randomness inherent in isolated decision making.

It is about applying a controlled process to variable mine geology and ever-changing topography. With improved control comes higher productivity and lower cost.

Automation allows for the management of disparate information flows in new ways to deliver unified end-to-end interlinked processes. Mining processes have traditionally been viewed as being stand-alone but much theoretical work has been done on how the processes should interact. Also, removing human intervention and running end-to-end with machine control allows for unparalleled levels of efficiency and repeatability: true process quality.

How far advanced is Australia in terms of technology, automation in particular?
Our vision of a fully-automated remotely-controlled mine is deliverable but will take years, substantial R&D investment and a broad collaborative network involving original equipment manufacturers and leaders in automation. The creation of a fully-automated mine could not be achieved by any mining company working in isolation. Rio Tinto’s approach is to seek out the most capable groups in the world to work with. We are partnering with the University of Sydney to create the Rio Tinto Centre for Mine Automation. Others will contribute to the development of advanced sensors. In our view, the capability of groups in Australia is absolutely world class. CSIRO is an important contributor to this vision.

Can you give me two examples of Rio’s groundbreaking automation innovation?
As part of our ‘Mine of the Future’ programme, we are commissioning a test mine in the Pilbara called ‘A Pit’ that will be highly automated in a number of new and fundamental ways. It is a substantial undertaking, the capacity of the A Pit system being around 25 mtpa. This is a commitment to true commercial level evaluation. We will combine the Komatsu autonomous truck system with our own autonomous drills and progress highly-advanced Rio Tinto drill-blast autonomous ‘expert systems’. A Pit will run for just over a year to develop a ‘Pilbara’ template which will be deployed across the next generation of iron ore mines in the Rio Tinto network.

A second example is the Remote Operations Centre which Rio Tinto Iron Ore is establishing in Perth to manage operations in the Pilbara.
Do you think federal and state governments take automation innovation (for exploration and mining) seriously enough?

We believe governments can and do play a key role in establishing the necessary core capability, skills sets and latest technology to support the development of automation innovation. Industry must then be accountable for galvanising the activity, identifying the challenges and exploiting opportunities.

Notwithstanding that, government bodies cannot carry this load alone; simply adding capacity and capability will go nowhere unless it is driven by and valued by an end customer. Industry has to step up to the plate and help guide and drive the work to deliver maximum value for all parties.

Enlightened self-interest actually works as a motivator; a virtual feedback loop is created when the researchers are working on topics that are truly valued and recognised as value-adding to industry. That’s a win-win. This is hard work but I am convinced it is a critical success factor for Australia to consider.

We are a mining-centric country and have a proven track record in mining technologies. Our country has much to benefit from a closer value-driven interaction between business and research.

John McGagh

EDUCATION
1980  BEng (Honours) Bradford University, UK (Chemical Engineering and Management Economics)

CAREER
1980-1984 Chemical Engineer, Rio Tinto (Plastics, Acids, Waste Treatment)
1984-1987 Marketing Officer, Rio Tinto Iron Ore Europe (London)
1987-1989 Marketing Officer, Rio Tinto Iron Ore Asia (Perth)
1989-1993 Manager, Argyle Diamonds (Perth)
1993-1996 Manager Business Analysis, Argyle Diamonds (site operations, Kununurra)
1996-1998 General Manager Procurement, Rio Tinto (Melbourne)
1999-2007 Global Head of Procurement, Rio Tinto (California)
2007- Head of Innovation, Rio Tinto (Brisbane)

PROFESSIONAL AFFILIATIONS AND APPOINTMENTS
- Fellow, Institute of Chemical Engineers
- Fellow, IOM3 (Institute of Materials, Minerals and Mining)
- Member, Chartered Institute of Purchasing & Supply (UK-based)
- 2000-2007 Board Member, Quadrem (Strategy, HR and Governance Committees)
- 2008- Board Member, Brisbane CitySmart

John McGagh’s vision for automation in 2030

Imagine for a moment a mine site where:
- Automated blast-hole drill rigs perfectly position every hole, conduct analysis during drilling, and dictate to the explosives delivery vehicle the explosives load and blend to be charged for each hole
- An excavator can ‘see’ the difference between ore and waste in the muckpile and can separate the two and automatically load the driverless haul truck before dispatching it
- Haul trucks safely navigate around the mine landscape to move waste and ore in a precisely choreographed/optimised manner with no human intervention
- Haul trucks automatically report to the workshop when maintenance is due
- Driverless trains are fitted with an array of sensors that enable them to ‘see’ beyond the horizon
- People on-site are predominantly essential service and maintenance staff
- A remote operations centre oversees the running of the mine while experts working in a capital city fine-tune and drive the processes for maximum added value, 24x7
- A master supervisory system combines data flows and updates the orebody knowledge in real time
- Real time AI (artificial intelligence) coordination takes place across all mine working faces and coordinates all aspects of the mine orebody-to-port supply chain in a manner that ensures that quality-controlled correctly-blended product arrives at the port ready for shipment to customers

Put these and other systems together and it is easy to imagine the future of a mine operating more like a ‘rock factory’ where processes are interlinked and work in unison, very similar to a production line rather than the variable stand-alone processes that comprise the mines we see today.

Can you give me a taste of two more examples of Rio’s groundbreaking automation innovation that are still in the lab or undergoing testing?

We are currently working on a number of options under the Mine of the Future banner, including autonomous drills providing unparalleled precision, real-time orebody sampling straight from the drill, intelligent blasting and rapid underground development for the next generation of super block-cave mines.

Do you think we are going through a Golden Age in terms of advances in automation?

Yes, we are entering a Golden Age but our journey has really only just begun. Logic would suggest that the easy-to-find things have already been found. It follows that, if we are to keep pace with demand, exploration and discovery must become more efficient and the technology used to detect and characterise mineral deposits on and below the earth’s surface must become more capable.

The identification of the geologically rare Tier 1 deposits is the highest prize. Their discovery is a necessary part of the total solution to satisfying growing global demand for minerals and metals. History has repeatedly shown that the probability of converting exploration targets into economic deposits is very low, and the key challenge for exploration geology is to increase this probability of success.

Do we have the tools we need to take on this journey?

The tools at our fingertips today are truly amazing. Moore’s law continues to drive Central Processor Unit capacity, software to drive automation is increasingly available and we have some truly fantastic mathematical modelling capability that can be used to attack a problem before it ever reaches the field.

I am convinced that to exploit the opportunities in this new age will demand new management and organisational structures. We live in the time of the network extra-net; I see no reason why a group doing breakthrough innovative work on the other side of the planet cannot be as much a member of my team as the physical lab next door. Australia has capability in this area and can play on the world networked stage.

mines some 1,300km away. Construction and fit-out of the facility at Perth Airport is well advanced, and commissioning is expected to occur later this year. This is a key step on the path towards a fully automated mine-to-port iron ore operation.

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Research project shows that long-distance relationships can work if you get the technology right

Newcomers to the field of telerobotics could be excused for thinking this is little more than a new and ambitious adaptation of a science fiction novel.

The concept of a human being remotely operating a robotically-wired piece of equipment from several hundred metres – or several hundred kilometres – away sounds fraught with risk.

In fact, telerobotics has been practised for the past 50 years using conventional technology and based on the following fundamental sequence of events: video is recorded at a site and the images transmitted to a human operator who makes a decision based on the visual evidence and responds by commanding the robot to take action.

What CSIRO scientists have realised is that this type of interface does not offer the human decision-maker enough situational awareness to effectively maintain manual production levels. In other words, there is limited economic benefit in using telerobotics over good old-fashioned hands-on operation.

What was needed, they defined, was a “higher level of immersion”: a significantly wider range of more detailed information being delivered in real-time to the human operator.

According to CSIRO’s ICT Centre, there was much interest during the late 1990s in mixed-reality (MR) telerobotics applications using either augmented reality (AR) where data and virtual objects are displayed to the operator, often on top of the video stream, or augmented virtuality (AV) where real data is placed in a virtual environment.

This technology has never been realised in the mining industry but now, with recent advances in network interfaces, control and software standards, the industry is taking a pro-active interest in telerobotics. This is evident in two large on-going projects in Western Australia (also see pages 14 and 15).

Breaking rocks

The first is the telerobotic operation of a rock breaker, responsible for smashing oversized rocks dumped into the ore receptacle or ‘Run-of-Mine bin’ which are prevented from entering the crusher because of their size.

The CSIRO researchers were commissioned by Rio Tinto Iron Ore Automation Group to install a telerobotic control system to the primary rock breaker at the West Angelas iron ore mine, 110km west of Newman. Scientists and technicians from the CSIRO Exploration & Mining Division and ICT Centre are working through the Minerals Down Under National Research Flagship to develop the technology.

Rio’s West Angelas mine is no stranger to robotics; Rio Tinto is planning to fully automate a trial iron ore project there including robotic haul trucks fitted with computers, lasers and GPS systems.

At present, an on-site operator monitors an oversize rock by identifying it with the naked eye and relays a command to the remote operator. The CSIRO researchers are looking to achieve full automation by 2011.
eye and then uses a wireless remote-control pack to examine it in more detail – size, shape, colour, texture and its position in the bin. This information helps the operator to determine the most efficient and effective way to break the rock.

The CSIRO project is calculating whether it is feasible to give the operator the same or better perception of the rocks for a remote-control system (RCS) that would enable the operator to be removed from the site and based at Rio Tinto’s Remote Operations Centre in Perth, more than 1,000kms south of the mine.

The manual operation is not particularly hazardous but it takes place in a hot, dusty and remote environment. The main objective is to increase operator utilisation, availability and sustainability. By moving operations to a capital city it is possible to offer a better working environment and an improved work/life balance.

**Tyranny of distance**

According to CSIRO scientists, the distance “introduces a number of technical (communications bandwidth and latency) and cognitive challenges (lack of spatial and situational awareness)”.

“These challenges can be addressed by developing technologies at both the local and remote ends of the system. Improving the intelligence of the control system (ie, Cartesian motion, collision avoidance, move to pose) can mitigate the effects of latency, whilst the development of mixed-reality user interfaces can improve the situational awareness of the operator,” they said.

“In this project, the [rock breaker] arm was fitted with a number of sensors to detect its pose in space and actuated by signals that bypass the existing remote-control system.

“PTZ (pan, tilt, zoom) cameras were fitted to poles on either side of the Run-of-Mine bin and a pair of high-resolution digital video cameras (approx 80cm apart) were mounted below. All wiring was fed back to the local control room.

“The control room was fitted with a computer to monitor and control the arm, another computer to process the stereo cameras, three high-quality video compression units, an industrial Programmable Logic Controller to monitor the site safety, and an Ethernet IO system to monitor and control the state of the hydraulic control system.”

**Virtual reality**

After the installation of the hardware and the development of custom software, the research team was able to remotely simulate the workflow of the local human operator. When the operator is alerted to the presence of a large rock (an event which the team says could be automated in future versions), the operator is presented with an overview of the rock breaker from a wide-angle video stream and augmented virtuality. This is a real-time extension to CSIRO’s successful Sirovision technology that was commercialised several years ago.

From the two pairs of stereo cameras it is possible to reconstruct the 3D profile and texture of the rocks in the Run-of-Mine bin. After detailed calibration, it is then possible to ‘place’ the 3D rocks into the virtual Run-of-Mine bin that the operator sees.

The interaction between the RCS and the operator is managed by a telerobotic user interface which would enable the operator to drive the rock breaker hammer to desired locations using various input devices.

According to the CSIRO scientists, “from the user interface in Perth, the operator is able to ‘walk around’ the rock breaker (via mouse commands) to inspect the oversized rocks from different angles”.

“Once [the operator] has established the appropriate breaking strategy, the operator is able to deploy the arm with a joystick. As the arm is commanded to move, the motion of the arm is replicated in the AV.

“Both PTZ cameras can be programmed to follow the tip of the hammer simultaneously. When ready to break the rock, the operator can focus on live video stream, which monitors the breaking of the rock. Once the operation is complete, the arm can be automatically sent to the rest position.”

One of the advantages of combining VR and AR is the ability to switch back and forth between the two interfaces as and when required. The choice of interface is determined by conducting a number of human factor studies to find the most acceptable and productive.

The feasibility project has been completed demonstrating that it is possible to operate the rock breaker remotely without affecting production and proving that the collaboration of an original equipment manufacturer (Transmin), an R&D organisation (CSIRO) and industry (RTIO Automation Group) provides three essential blocks required for a successful technology transfer from research to field.

**Next step**

The project’s next phase is to commercialise the telerobotics technology and discussions are underway between Transmin, Rio Tinto and CSIRO. CSIRO scientists are also focussing their research on reducing the cognitive load of the operator (attending to and switching between multiple tasks) to improve the transition from AV to AR, so that the operator might not even be aware of the change.

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**Rio’s grand rock breaker**

Rio Tinto Iron Ore Automation Group Manager, Victor Schweikart, summarised the telerobotic rock breaker project for earthmatters.

“It is an integral part of the Remote Operations Centre (ROC), designed to operate the Rio Tinto Iron Ore Pilbara rock breakers remotely from Perth.

“By removing the operators from the field and relocating them to the ROC, they perform their work in a safer and cleaner environment. Among other benefits, the plant operator can be responsible for operating one or more rock breakers, negating the need for a dedicated rock breaker.

“This technology reduces the number of people on site, in turn reducing the number of fly-in-fly-outs and the pressure on site accommodation,” he said.

RTIO’s Project Manager, Craig Green, added: “There is also more chance of a reduction in crusher downtime resulting from delays of deploying plant operators to the rock breaker when rocks require breaking – such delays are caused mainly by difficulty in accessing the rock breaker area.”
Remote and semi-automated control of loading iron ore bulk carriers could mean safer and more efficient operation

The chief objective of introducing teleoperation is to remove human operators from hazardous environments while increasing the efficiency and reducing the risks of an operation.

Central to this automation is the development of a new, advanced teleoperated control system that would enable the operator to be removed from the shiploader boom and wharf to a safe distance – possibly several hundred metres away.

CSIRO Exploration & Mining Division and the ICT Centre researchers through the Minerals Down Under National Research Flagship are collaborating with Pilbara Iron and Rio Tinto Expansion Projects Iron Ore Automation Group to apply automation at the Parker Point iron ore loading facility at Dampier.

Safer and more economical

According to the project proposal prepared by CSIRO’s Research Projects Engineer, Chad Hargrave, the goal is to “develop, install and commission a pilot teleoperation system for remote controlled operation of the SL3P loader at Parker Point”.

In his proposal, Mr Hargrave stated the shiploader “will soon be the only significant unit operation in the port ore transport system that is manually operated” since sensing and control technologies have already been applied to remote and/or automated control of other mining operations such as underground loaders, excavators, draglines, haul trucks, truck and shovel operations and longwall coal mining systems.

“The primary driver for the move to teleoperation is the safety and comfort of the shiploader operator. A secondary consideration is the reliability and sustainability of operations if all control and coordination of the port takes place from a single control facility.

“There are also efficiency gains that could be realised with even the core teleoperation scenario, while introducing higher levels of automation could provide further productivity benefits,” he said.

Nuts and bolts

According to the research team, two core levels of teleremote control are required. ‘Basic Teleoperation’ allows the operator to control the shiploader in a similar way to the
current operation but from a place beyond line-of-sight and with the addition of video images of the operating area.

‘Extended Teleoperation’ provides additional sensors to compensate for the operator’s absence from the physical, machine environment. These sensors deliver a suitable level of situational awareness including: a graphical display model of the loader that moves synchronously with the machines, a display of information on proximity to the ship and other critical infrastructure, and profiles of the load in the hold where visible.

Once the core technology for teleoperation has been developed, it will be possible to consider additional staged improvements to the systems to provide enhanced levels of control to further improve system usability, productivity and traceability. They would include:

- Handling Improvement Semi-Automation
- Load Distribution Characterisation and Mapping
- Automated Hold Loading

Among the hi-tech hardware and software involved in this project are specialised video cameras, laser scanners and radar systems which will be installed on the boom and provide real-time data from each hold during loading. Simultaneously, a new operator interface will include a panoramic dome on which the operator will see a wrap-around display of the view from the shiploader boom, together with a 3D display of the shiploader to provide highly accurate boom position and proximity information.

The first phase of the project will be a trial of the new sensors together with the sensor feedback component of a Human Machine Interface (HMI) system. This will include sensor and software development, installation, commissioning and monitoring.

The second phase will be the full teleoperation system trial. This phase consists of system design, development (including HMI modification to incorporate controls), installation, commissioning, and full production trial.

Industry input

According to Rio Tinto’s Automation Group Manager, Victor Schweikart, the teleoperated shiploader project is safety-driven.

Challenges of loading

Loading a bulk carrier ship with iron ore is anything but simple and requires a highly-skilled and experienced operator.

The fundamental goal is to load the vessel to the exact total amount and in the exact sequence detailed in the loading plan, matching the tonnage and distribution specified for each hold of the vessel.

A wide range of physical factors must be taken into account including the even and balanced pour of the cargo and the effect it has on the ship’s seaworthiness, the weight of the cargo and the effect it has on the ship’s trim (to ensure an even keel stern-to-bow), and the speed of the pour relative to the speed of the pumping out of seawater ballast.

The benefits of teleoperation for the shiploader

Safety

Reduces risk to human operators from:
- exaggerated boom movement
- accidents traversing the boom
- unsecured movement on moving platform
- working at heights suspended over ship or water
- collision between boom and other infrastructure on port or ship
- wind gusts, heavy rain and dust exposure

Productivity

Reduces the following challenges:
- Operator having difficulty seeing into a hold’s interior
- Manual decision-making regarding loading of hatches (start/stop loading at times to get the distribution right)
- Independent manual control corrections that are required to move the boom end to a desired location over the hatch
- Lack of a single remote facility to control loading for multiple berths, or even ports
- Lack of ability for operator to measure vessel’s trim directly (teleoperation could do this and significantly reduce the time required for trimming at the end of the loading process)

Reliability / Sustainability

Offers the following benefits:
- Operators able to relieve one another easily during a shift
- Centralised work location allowing for more efficient training of new operators
- Machinery lifespan extended due to smoother movements, reducing wear-and-tear associated with manual compensation
- Boom ‘auto-positioning’ during a pour to compensate for any tidal drift in the ship, maintaining the correct over-hatch location

“There is a big difference between having an operator at the end of a 50-metre boom and having him in the comfort of a control room.

“There is also a productivity factor, given that we would be able to operate under severe weather conditions such as high wind. We have involved the operators early in the design process to get their input on the layout of their work space, the location of displays, and the size, shape, and placement of the individual console relative to those displays.

“This project, under the guidance of Rio Tinto Iron Ore (RTIO) project manager Julian Gonzales, has been a very good experience for the RTIO Automation Group in managing the challenge of the change, and the support of the CSIRO team has been essential in the process,” said Mr Schweikart.

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CSIRO is planning to create a teleoperation system but first it must design a unique virtual mining environment in which it can develop. Matthew Brace reports

CSIRO’s Exploration & Mining Division (CEM) and ICT Centre are planning to develop an advanced immersive interface to facilitate the next generation of teleoperation of robotic mining equipment. This will offer significant improvements in productivity and safety and is in step with the Australian mining industry, which is increasingly looking at virtual reality technology to facilitate the teleoperation of mining equipment using a virtual environment.

Some companies are examining how the mine control room of the future may operate with this technology.

To develop this system successfully, the CEM and ICT teams must first create a fully immersive virtual environment that will provide real-time sensory feedback for sight, sound, touch and motion. They will be drawing upon CEM skills in automation, sensing and visualisation, and ICT’s skills in robotics and medical teleoperation.

An initiative called the Virtual Mining Centre (or VMC) will bring together skills and technologies from across CSIRO. While having similarities with military command and control systems and space exploration, the system will provide a unique facility focussed on the task of remote mining.

**Technology blend**

This facility will benefit from traditional technologies such as 3D visualisation, sensing and automation. 3D visualisation especially has been used globally for many years for the interpretation of complex and diverse geospatial data sets.
Why automate?

Teleoperation is a mature technology. CSIRO developed the navigation system for an autonomous LHD (Load Haul Dump machine) which is now mainstream in underground metal mining. However, researchers are going to take this technology to other, more challenging applications in hazardous areas that require more advanced sensing and visualisation techniques.

The mining industry and its associated research bodies are investing in the development and deployment of remote controlled and autonomous (semi-autonomous) mining equipment.

According to Con Caris, “designing machines to do work in hazardous places where humans fear to tread and arming machines to behave appropriately (protect themselves or other machines) during exceptional conditions is not so far fetched. In fact we’re doing it now (for example collision avoidance in mining equipment)”.

In fact we’re doing it now (for example collision avoidance in mining equipment)”.

Not all machines can be fully automated (ie, handle all exceptions that are presented to the machine). Teleoperation will allow humans to assist semi-autonomous machines when exceptions occur. In other words, humans will fill the technology gap.

“Teleoperated mining has great potential for saving costs and increasing productivity as humans could operate machines remotely and enable mining equipment to move faster and longer distances,” said Mr Caris. “For example, a continuous miner in an underground coal mine could plunge deeper, exposing more unsupported roof and dust, during roadway development.”

However, as CEM’s Mining Automation 3D Visualisation Coordinator, Con Caris, explained, “when used in isolation, 3D visualisation can be very limiting in terms of providing a convincing virtual environment for monitoring and equipment control applications”.

“The trend, especially over the past decade, is to leverage 3D visualisation and augment it with other technologies such as stereoscopy, streaming video haptics [the science of applying touch to interactions with computer applications] and motion to deliver more effective and convincing (or more immersive) virtual environments.”

Aircraft flight and vehicle simulators have been used extensively for many years to train pilots and drivers. However, this type of virtual environment (delivering sight, sound, touch and motion) has not been developed commercially by mainstream mining equipment vendors. Research at the VMC will demonstrate how teleoperation and simulator technology can be integrated to produce next-generation control systems for the mining industry.

Immerse yourself

An immersive environment is a specialised facility that can provide one or more users with detailed real-time sensory information such as sight, sound, touch and motion that enables the user to feel they are in the real world, albeit a virtual world. The level of immersion required is dependent on a range of variables, including:

- What is the level of machine autonomy (autonomous or semi-autonomous)?
- Can the level of autonomy be changed (manual to auto)?
- What is the role of the human (supervisory or operator)?
- What level of perception do the sensors provide (machine status, location, orientation, environment)?
- What is the quality of the sensor data (accuracy, veracity)?
- What is the timeliness of the feedback (real-time, significant time lag)?

The VMC will be based at CEM and ICT’s Queensland home, the Queensland Centre for Advanced Technologies (QCAT), on Brisbane’s western fringe. It will be a shop window in which CSIRO can demonstrate its science to industry, government and the community. It will also provide a collaborative research platform and hub for the development of advanced real-time visualisation, simulation, data fusion systems - and the occasional mine-smart robot.

The research activities of the VMC will focus primarily on software application and hardware development for the following:

- Interactive real-time monitoring of mining operations
- Immersive environment for teleoperation of mining equipment
- User-interface design and human-computer interaction
- Collaborative computing, via the Access Grid facility, with iVEC (Interactive Virtual Environments Centre at the Australia Resources Research Centre) and WASP (Western Australian Supercomputer Program at the University of Western Australia)

The VMC will provide an experimental research platform that will bring additional benefits to mining and telerobotic science. Firstly, it will enable researchers and industry to understand mining operations more accurately and efficiently. This will in the short term minimise operational and project development risk, but in the future it will also enable scientists to investigate new mining techniques that are currently not possible or economic.

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What is your academic background?
I received a Bachelor of Engineering (Electrical) from the University of Queensland (UQ) in 1993, a Bachelor of Arts (English Literature) Honours from UQ in 1998, and I am now enrolled in UQ’s PhD programme in the IT & Electrical Engineering faculty. My thesis topic is concerned with the use of radar for tracking positional changes in underground mining equipment.

How did your career path lead to CSIRO?
After graduating from my BE degree I started work with Stork Electrical, an electrical contracting and engineering company, in the area of electrical switchboard design, draughting and testing. I moved into the area of industrial automation, doing a lot of work with Programmable Logic Controller (PLC) and Supervisory Control And Data Acquisition (SCADA) programming, and building a larger role in project management. In 2001 I heard that the CSIRO’s Mining Automation group was recruiting some people with practical industry experience to help with their new Landmark Longwall Automation project. I jumped at the chance to work where there was a genuine opportunity to get involved with innovative research. I haven’t looked back.

What is your title and your main responsibilities and areas of research?
My official title is Research Projects Engineer, my main responsibilities are project management, and my main area of research is associated with the use of radar systems in mining. Currently I’m in charge of an Minerals Down Under National Research Flagship project with the goal of achieving teleoperation for an iron ore shiploader for Rio Tinto Iron Ore. I also have some projects in the coal mining and transport areas.

What interesting and important projects have you worked on?
Probably the most significant project that I’ve had a role in is the award-winning Landmark Longwall Automation project that the CSIRO Exploration & Mining’s Mining Automation group completed a couple of years ago, and which has now been successfully commercialised. This was a breakthrough project for the industry and it has spawned a lot of opportunities both commercially and for on-going research and development.

I was also involved with a roadway development automation project for underground coal, a coal carryback reduction project (detecting and cleaning remnant coal from coal train wagons after dumping), and several radar research projects including both ground-penetrating radar and through-air radar aimed at improving productivity in underground mining.

What are you working on right now?
The teleoperated shiploader project with Rio Tinto Iron Ore (see pages 14 and 15). Also I’m involved in a new ACARP project, CM2010, developing automation systems for continuous miners, as well as developing a new project associated with coal carryback detection based on the success of an ACARP project completed last year.

Why is it such an exciting time to be in your field of work?
The mining industry in Australia is currently facing a very challenging time. Even in the context of a serious slowdown, our industry clients have remained very positive about the research that we are doing and the value of the service we provide. We also have the opportunity to reaffirm our commitment to longer-term research goals that sometimes can be squeezed by the immediate demands of project work.

What is the next phase of your work?
For my existing project work, the focus is on a smooth transition from the working prototype to a commercially viable reality. This handover phase is always difficult but critical if our research solutions are going to make a real difference to industry. For my research work, the goal is to take some currently promising theoretical concepts to the demonstration phase, including testing in a mine environment.

Where do you see your career going from here?
I am currently enjoying the challenge of managing research projects within CSIRO and I would like to continue to work in consultation with our industry clients to deliver innovative solutions that only a dedicated research team can generate. At the same time I hope to develop my own radar work into a larger scale research project that will, in turn, transfer some results to industry.

Name a particular dream project or research study that you want to be involved in.
As strange as it may sound, our group has an ongoing research focus on the possibilities of crossover work in the area of space exploration. A key requirement for successful space exploration is to use resources that exist out there – “mining on Mars” in other words. Our group has been contributing ideas via the Global Exploration Strategy (a NASA initiative). I hope some of the ideas for automating remote, hard-to-access machinery in space can be transferred to mining tasks down here, and vice-versa.

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Remote mine site rehabilitation monitoring using airborne hyperspectral imaging and Landscape Function Analysis (LFA)

I.C.Lau, R.D.Hewson, C.C.H.Ong, & D.I.Tongway

Landscape Function Analysis (LFA) is an environmental monitoring technique which is internationally recognised as a method of measuring and monitoring ecosystem function and rehabilitation progress. Airborne hyperspectral data were used to generate maps of the three Landscape Function Analysis (LFA) Indices over a 5 x 20 km area of a rehabilitated bauxite mine in southwestern Australia. The technique involved measuring field spectra of 35 LFA sites and generating Final Regression Coefficients using partial least squares analysis for the three LFA Indices, Stability, Infiltration and Nutrient Cycling. Both field and airborne spectral data were used in the calibration dataset, as the ground based sampling technique was not able to capture the information on the crowns of the tall eucalypts in rehabilitation older than eight years of age. The Final Regression Coefficients were applied to the airborne hyperspectral imagery to produce LFA Maps with good correlations to the field LFA measurements (Stability r2=0.76, Infiltration r2=0.67 and Nutrient Cycling r2=0.71 for n=15). The results demonstrated that airborne hyperspectral data could be reliably used to derive spatially continuous LFA maps over forest rehabilitated after bauxite mining in the Darling Range of Western Australia.

ISPRS XXDI Congress, Beijing, China; Beijing, China 2008

Predictive targeting in Australian orogenic-gold systems at the deposit to district scale using numerical modelling

W.Potma, P.A.Roberts, P.M.Schaubs, H.A.Sheldon, Y.Zhang, B.E.Hobbs, A.Ord

3D numerical models of coupled deformation and fluid flow provide a useful tool for exploration in orogenic-gold systems. Numerical modelling of ore-forming processes can lead to a reduction in targeting and detection risk, thus improving the value proposition of mineral exploration. Hydrothermal mineralisation arises from a complex interplay of deformation, fluid flow, conductive and advective heat transport, solute transport and chemical reactions. Coupled simulation of all of these processes represents a significant computational challenge that cannot be solved within the time-scale of a mineral exploration programme. However, the problem can be simplified by identifying a subset of processes representing the first-order controls on mineralisation at the scale of interest. For most orogenic-gold systems, it is argued that the first-order controls on mineralisation at the camp to deposit scale are deformation-induced dilation, fluid flow and fluid focusing. Hence, numerical models of coupled deformation and fluid flow can provide a quantitative insight into the localisation of ore-forming fluids in this type of system. In two case studies, known deposits were modelled in order to determine the critical deformation and fluid-flow-related factors controlling the localisation of mineralisation in these systems. The quantitative results from the forward models were then used as a basis for constructing predictive models that were applied to regional targeting, prospect ranking and selecting the choice of detection methods. Both case studies show that numerical modelling is capable of reproducing the distribution of known anomalism, and that it can predict anomalies that were not expected or accounted for by purely empirical analysis


Looking beyond the horizon: key messages from the Mineral Futures Initiative social research workshop

K.Moffatt, A.Littleboy

Sustainability is a complex topic in any sector. In the minerals sector, the opportunity and the challenge for Australia is to maintain our high market share of the global commodities market in the face of declining ore grades, a critical shortage of labour in the sector, accumulating waste materials and emissions, high safety expectations, and escalating development costs. While facing these challenges, we also need to ensure that national benefits flow to regional Australia in the form of environmental stewardship, financial dividends, and social capital. In June 2008, a workshop was convened in Brisbane by the Minerals Down Under National Research Flagship to develop a programme of work to examine and plan for this uncertain future. Specifically, social and socio-economic researchers from The University of Queensland, Curtin University of Technology, University of Technology Sydney, and Central Queensland University, and from within the CSIRO, met to develop a collaborative research agenda for the Mineral Futures Initiative within the Minerals Down Under Flagship. Three areas of focus were identified by participants:

- Issues characterising the present (eg, Australia’s connection to the global context, impacts of mining on communities)
- Requirements for change (eg, the need to develop a broader understanding of the total cost and benefit of a mining operation)
- Understanding the future (eg, using scenarios and other methods to bound uncertainty about the future on issues such as peak minerals, impact of new technologies, requirements for an industry social licence to operate)

Core elements of this collaborative research agenda later formed the basis of a successful cluster proposal by the attending university representatives. Importantly, a major aim of the workshop was to develop a strong collaborative research identity among the university partners and with CSIRO to ensure the cluster produces integrated research outputs aligned with the technology development aims of the Minerals Down Under Flagship.

Mineral Futures Initiative Social Research Workshop, 11 & 12 June 2008
Mercury or Quicksilver as it is also known, is the 80th element of the Periodic Table. It is a heavy, silvery metal and is rare in being liquid at room temperature, with a melting point of -38.83°C and a boiling point of 356.73°C.

It has a high molecular weight, low ionization energy, low dual-ionization energy, high liquid density and liquid storability at room temperature. It becomes poisonous when transformed into soluble forms such as mercuric chloride or in the gas phase.

The metal is a rare element in the Earth’s crust. It is also found in some ores, cinnabar (HgS) being the most common and from which mercury is procured by reduction. Cinnabar occurs mainly in Spain and Italy; the Almadén mine in central Spain dates back more than 2,000 years.

Mercury ores usually occur in young orogenic belts where high density rock is forced up to the crust often in volcanic regions.

Mercury became important in the mining industry in the mid-16th century when a process known as the ‘patio process’ was devised to extract silver from ore using the metal. This process and the subsequent abundance of valuable silver played a key economic role for Spain and its colonisation of the New World (Americas). Tens of thousands of tonnes of mercury were mined from the region of Huancavelica in Peru in the 300 years following the discovery of the metal there in 1563.

China was the world’s leading producer of mercury in 2005, with more than half the global share.

Mercury’s most famous use has been for glass thermometers because it is a convenient liquid over the desired common range of temperatures, it is opaque, unreactive with glass and generally chemically stable. This is, however being phased out because of toxicity concerns.

The metal is primarily used for making industrial chemicals and in electrical and electronic applications.

Among its chief uses are thermometers, barometers, diffusion pumps, batteries electrolysis, insecticides, ‘tilt’ switches in home thermostats, and as the basis for dental amalgams. Gaseous mercury is used for advertising signs.

Mercury was once used in the amalgamation process of refining gold and silver ores. The metal was used to help the gold to sink through a flowing water-gravel mixture by forming mercury-gold amalgam and increasing the gold recovery rates but large-scale use of mercury stopped in the 1960s. However, this polluting practice is is believed to be still used by local small-scale gold miners in Brazil and illegal miners in Africa.

Mercury

- was named after the Roman god Mercury, famed for his speed, and it shares an alchemical symbol with the astrological sign for the planet Mercury.
- goes by the symbol Hg, which is short for the Latin word hydrargyrum meaning ‘liquid silver’
- was lauded as a health-giver by the ancient Chinese, Greeks and Romans who believed it had life-preserving powers. They used it as a medicine, ointment and a beauty treatment, with disastrous results
- was used by American artist and sculptor Alexander Calder to create a mercury fountain for the Spanish Pavilion at the World Exhibition in Paris on 1937. It is now on display at the Fundació Joan Miro gallery in Barcelona
- in non-prescription thermometers was banned by the US in 2002 and a phase-out programme instigated.

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The metal is primarily used for making industrial chemicals and in electrical and electronic applications.

Among its chief uses are thermometers, barometers, diffusion pumps, batteries electrolysis, insecticides, ‘tilt’ switches in home thermostats, and as the basis for dental amalgams. Gaseous mercury is used for advertising signs.

Mercury was once used in the amalgamation process of refining gold and silver ores. The metal was used to help the gold to sink through a flowing water-gravel mixture by forming mercury-gold amalgam and increasing the gold recovery rates but large-scale use of mercury stopped in the 1960s. However, this polluting practice is is believed to be still used by local small-scale gold miners in Brazil and illegal miners in Africa.

Mercury

- was named after the Roman god Mercury, famed for his speed, and it shares an alchemical symbol with the astrological sign for the planet Mercury.
- goes by the symbol Hg, which is short for the Latin word hydrargyrum meaning ‘liquid silver’
- was lauded as a health-giver by the ancient Chinese, Greeks and Romans who believed it had life-preserving powers. They used it as a medicine, ointment and a beauty treatment, with disastrous results
- was used by American artist and sculptor Alexander Calder to create a mercury fountain for the Spanish Pavilion at the World Exhibition in Paris on 1937. It is now on display at the Fundació Joan Miro gallery in Barcelona
- in non-prescription thermometers was banned by the US in 2002 and a phase-out programme instigated.