LATEST ISSUE

resourceful

BRINGING CSIRO RESEARCH TO THE MINERALS INDUSTRY

MEET MINING3

THE NEW RESEARCH COLLECTIVE THAT'S TRANSFORMING MINING

MINING3'S ROADMAP FOR SUCCESS

ROADMAP TO DELIVER OUTCOMES FOR EXISTING AND FUTURE MINES

GRAND CHALLENGE

1	**Surface mass mining**	Step-change and next generation technologies for hard rock and surface mining, including equipment, methods and processes to reduce infrastructure and capital that lower costs and increase productivity, safety and sustainability.
2	**Underground mass mining**	Step-change and next generation technologies for underground coal mining, including equipment, methods and processes to lower costs, lessen dilution, improve recovery, and increase productivity, safety and sustainability.
3	**Selective mining**	Low-cost, highly productive and safe methods and technologies to selectively mine large deposits.
4	**Rapid mine development**	High-speed, safer access to mine deposits for rapid profitability.
5	**Mining in challenging environments**	Productive, safe and highly profitable techniques to work in problematic locations and to meet government regulations.

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LEADER'S COMMENT

JOINING FORCES FOR THE FUTURE

The mining boom hid many of the challenges that have since been re-exposed by falling commodity prices. With productivity at the fore, no single company is afforded the capacity to address the major long-term challenges on their own, writes Director of CSIRO Mineral Resources, JONATHAN LAW.

Jonathan Law

Profits are down and so the mining industry, particularly in Australia, is focused on how to lift productivity in the short term.

This focus on productivity has meant many of the major long-term challenges for future mining – such as declining ore quality and mining to greater depths – have become too difficult for any individual company to solve.

This is especially true in the large capital business of mining technology and equipment. The technologies that the industry needs in order to evolve are increasingly complex and expensive to develop.

There's no question that innovation will play a pivotal role in transforming the industry, but our success in getting there depends on the industry, original equipment manufacturers (OEMs), mining equipment and technology services (METS) and the research sector coming together to work on these common challenges.

At CSIRO, we also believe that effective collaboration – based on strong benefits for all – is the best way to accelerate innovation aimed at transforming the mining industry.

It's for these reasons that we've established a pre-eminent partnership with CRCMining to create Mining3.

Mining3 brings together miners, OEMs and the innovation sector to tackle big problems at scale and deliver them to the global mining industry.

This edition of *resourceful* highlights some recent research and development contributions from Mining3 partners, as well as several perspectives from industry leaders on how the partnership is positioned to change the way we tackle mining innovation.

Digital disruption is happening everywhere and the mining industry is no exception. Mining3 will also draw on CSIRO's digital arm Data61 to provide the glue to integrating data into the next generation of mining technologies.

Some of the new tools that will underpin this revolution are covered in this edition, including downhole real-time sensing; pre-conditioning for block caving; new explosives; and inherently safe spark testing.

Right now, there is a great opportunity for new innovators to compete with global giants as we have seen in other sectors – there are opportunities to transform existing companies and build innovative start-ups that position Australia on the global stage.

Mining3 will focus on identifying opportunities to disrupt the traditional mining cycle to enable productivity gains and potentially revolutionary new approaches to mining that embrace ore variability using real-time information. This is a vision that's shared by highly regarded industry leader Peter McCarthy from AMC Consultants in his interview on page 10.

KEY ADVANTAGES FOR MINING3 ARE ITS SCALE, PARTNERSHIPS AND FOCUS, BUILT ON AN EXTENSIVE GLOBAL NETWORK OF EXPERIENCED RESEARCH COLLABORATORS AND INDUSTRY PARTNERS.

We hope to bring together integrated solutions from the many elements required to transform mining globally – a great ambition for Australian innovation.

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FEATURE

MINING3 – TRANSFORMING MINING

Meet the highly anticipated new entity – Mining3 – the world's largest, most advanced mining research powerhouse that's set to deliver on the next generation of technologies for the industry.
ADAM COURTENAY reports

A new world of mining research and innovation has arrived. Two global leaders in mining research with track records in delivering breakthrough technologies – CRCMining and CSIRO – have joined forces to create Mining3.

Headquartered in Brisbane, Australia, Mining3 will combine the experience and expertise of CRCMining and CSIRO into a single entity, fully engaged with industry.

CSIRO has strong capabilities in the areas of mechanical rock-cutting and drilling, automation and control, as well as in geological sensing and geophysics for mining. Whereas, CRCMining's strengths relate more to mining automation, energy optimisation, asset performance, blasting, material transport optimisation, as well as mechanical excavation, drilling technologies, rock mass characterisations and machine-rock interactions.

CSIRO will now conduct all its mineral (metalliferous) extraction research through Mining3 and bring to the party the capabilities of its formidable digital innovation arm, Data61.

Jonathan Law, Director of CSIRO Mineral Resources, says both organisations have had similar designs to develop technologies for commercial use, but until now, have operated largely independently of one another.

"Mining3 will have both the strategic direction of a national science agency with CSIRO and a very strong industry-focused group with CRCMining. We need both to give this venture the focus and scale it needs to be successful," he says.

Mr Law says that, in the past two years, momentum for the deal has grown by degrees. CRCMining transitioned to an industry-funded venture in mid-2014 and so a potential opportunity to integrate mining research was born.

Given the match with CSIRO's industry and government-backed research, the move for a unity ticket became progressively irresistible.

"You can't achieve impact without working with industry, and industry cannot prosper unless they sort out the technical issues facing traditional mining technologies as they battle to keep pace with commercial, social and environmental pressures," Mr Law says.

Mining3 will start with 13 industry members, including four multinational mining companies, four industry supply companies/manufacturers, four universities and CSIRO.

Its mining members are Anglo American, AngloGold Ashanti, Barrick Gold and Vale. The industry supply companies are Caterpillar, Joy Global, Sandvik and Komatsu. The research partners are CSIRO itself, Curtin University, the University of Queensland, The University of Newcastle and the Queensland University of Technology.

> **Mining3 will have both the strategic direction of a national science agency with CSIRO and a very strong industry-focused group with CRCMining.**
>
> **JONATHAN LAW, CSIRO**

As with CRCMining, Mining3 will be governed by a representative board, chosen from its members, and including independents. The board delegates responsibility for research to the research committee, which directs funding decisions and oversees research execution.

"We will continue to operate with committees, populated with our industry members and researchers who engage to make active decisions about the focus and allocation of funding for projects and how projects are being delivered and executed," Mining3's Chief Operating Officer Kevin Greenwood says.

"This will engage CSIRO projects into the same mechanism, with the same industry oversight. They get a depth of engagement from the industry in the research, with greater input from the end-users and potential commercialisation partners for the technologies."

Industry too, will be drawn into understanding the complexities and difficulties that go with research.

"They'll be involved along the entire journey. From the original thinking about the benefits through to the practicalities of testing on operations," he says.

Members will join and participate in Mining3 for a membership period (currently until 2022), which can be rolled over.

Mining3's Chief Executive Officer Professor Paul Lever says this will bring "a critical mass of commitment from the industry side".

"This strengthens their understanding of the innovation cycle – the positives and negatives and the process for innovation to occur."

Prof Lever says one of the mistakes of the past has been the ad hoc nature of research applications for industry. Often researchers come up with ideas for a new and exciting piece of technology and try to take them to the market.

"Sometime down the road a mining company buys it and uses it. The probability of success is often very small. That's not what this is about," he says.

Mining3 will use its long-term relationships with its members to ensure support for what receives funding from the pool of projects and ideas originating from Mining3. Without appropriate membership engagement, a project will not be pursued.

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Importantly, Mining3 will continue focusing on, and developing CRCMining's 'industry roadmap' within the new venture, a vision which CRCMining developed in consultation with its industry partners. The Mining3 roadmap articulates industry's mining research needs over three time horizons: within two years, three to six years and beyond six years.

"Our roadmap details the mining industry's view of innovation needs, in order to respond to their commercial, environmental and social drivers of the future," Prof Lever says.

"It's about the entire operating premise that we should be adopting – how we get there and what are the challenges."

Mining methods and processes need to be developed in conjunction with mining equipment and technologies to optimise value. This approach is based on four major components:

- **New or modified mining methods and processes** – given the business climate for profitable mining now and in the future, what are the mining methods and/or processes that will generate the best return on investment based on the available mineral deposits?
- **New mining equipment technology** – the development of new or modified mining equipment and technology to meet mining methods and process requirements for existing and greenfield mine sites.
- **High level operational control of the mining value chain** – it's critical that we develop models that describe the operation and performance of mining methods and processes in order to achieve operational control of the mining component of the value chain.
- **Highly skilled people to drive the adoption of new technology** – the skill requirements for the current and future mining workforce, and the change management requirements to allow new mining processes and technologies to be adopted successfully.

Using this logic, the Mining3 roadmap outlines five core grand challenges for minerals extraction.

The first and second grand challenges focus on redefining surface and underground mass mining techniques. The targets here are around significantly reduced mining costs and higher mining production rates, with smaller footprints, less infrastructure, much lower capital costs, lower energy usage, and new tools and processes to improve workforce productivity.

The third challenge drives the performance of high capacity selective mining approaches. For example, today we mine many deposits using massive mining approaches where ore is separated using expensive processes in the minerals processing plant. Precise selective mining extraction techniques, and separation or processing technologies applied directly after face extraction, have significant potential.

The fourth challenge looks at the significant time and cost associated with bringing a mine into production. In the future, the growing minerals production requirements for population growth and the declining availability of large deposits will drive the need for many more mine starts per annum. Large, high risk and lengthy returns for capital investments with permanent infrastructure will become even more difficult to achieve.

Finally, the fifth is about mining in challenging environments. These are places where many high grade deposits are known to exist, but their location presents challenges to mining. These include underwater mines (both shallow and deep) and areas of high rainfall or high altitude or where there is limited water supply.

Prof Lever says the overarching mission for Mining3 is to enable cheaper and greater volumes of production of mineral resources in the future – and all of it done smarter and more effectively, with less social and environmental impact.

"We can't just keep creating very large holes in the ground and moving tonnes of material to a process plant or waste site downstream."

"We need to define new methods and processes, and develop tools and sensors that allow us to measure and control the extraction process to deliver the resources we need. It's critical to extracting in a sustainable and commercial way," Prof Lever says.

PROF LEVER SAYS THE NEXT 12 MONTHS WILL BE CRITICAL. INITIALLY, IT WILL BE ABOUT ENSURING THAT THE TWO PARTS OF THE NEW VENTURE WORK TOGETHER AS A SINGLE ENTITY. ANOTHER ASPECT WILL FOCUS ON MARKETING MINING3 TO PROSPECTIVE MEMBERS BOTH IN AUSTRALIA AND INTERNATIONALLY.

We intend to make Mining3 an 'innovation hub' that has strong international connections and global clout.

"After one year, we hope to have significantly grown the membership group and to have researchers engaging effectively with industry members."

Mr Law believes this is the start of bringing the digital revolution to bear on this area of mining.

"This is about integrating the data and sensor revolution with new mining technologies, all the while being respectful of the environment and the social impact of what we do. It won't just be about the betterment of the industry but the betterment of what we do for the broader community."

Mr Greenwood believes Mining3 will be at the forefront of mining research.

"Research activities have often been fragmented in Australia and Mining3 is focused on consolidating some of these as the global leader in the mining research space."

The fall in the value of many commodities over the past few years has been obvious, but there is still huge global demand. If the demand is there but the values are less, then resourcefulness and productivity improvements will become far more critical.

"We know that the value derived from commodities has reduced significantly and that has driven the industry to rethink its approach," says Prof Lever.

"We have to mine with less energy, with smaller footprints and make the extraction process not just about extracting rock from a mine but about optimising the extraction of the commodity out of the resource. This is what we're aiming to do."

"This is our chance to make a difference, both creating value for now and a common vision for the future. After all, what are commodities for? They're for people. Our lifestyles and way we live is dependent on them."

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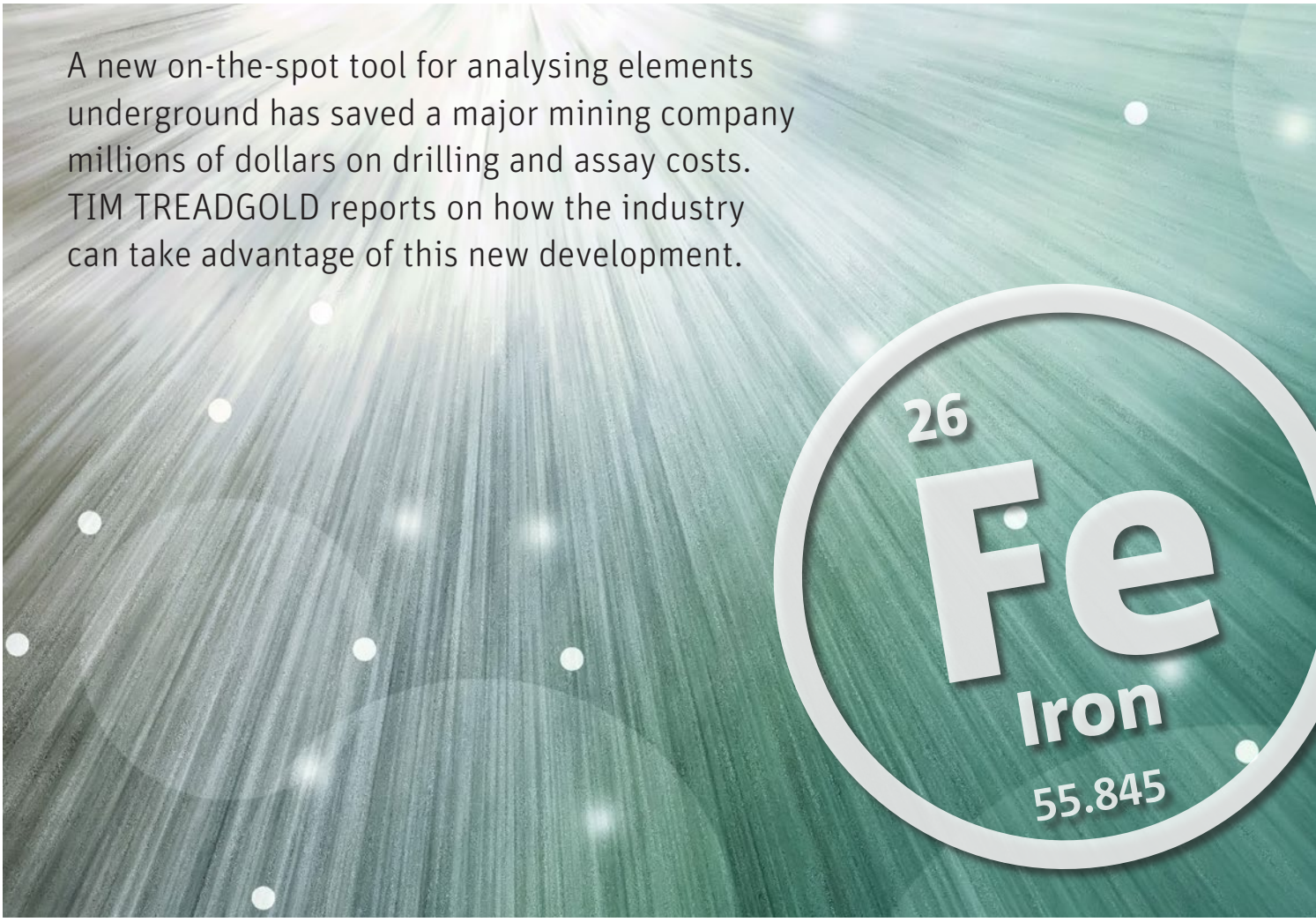
mining3
TRANSFORMINGMINING

DOWNHOLE DATA WITHOUT DELAY

A new on-the-spot tool for analysing elements underground has saved a major mining company millions of dollars on drilling and assay costs. TIM TREADGOLD reports on how the industry can take advantage of this new development.



Time is money in any business and one reason why the mining industry has embraced a technology that eliminates the weeks, and sometimes months, it can take to receive assay results from exploration and mine development drilling.

Another reason is that fast assay results means that drilling can quickly sterilise areas that do not contain economic mineralisation, or accelerate the focus on potentially ore-rich targets.

Speed and accuracy are the keys to a technology developed by CSIRO with its French partner, Sodern, a nuclear-science arm of the aircraft manufacturer Airbus.

THE APTLY NAMED 'FASTGRADE' SYSTEM IS ESTIMATED TO HAVE SAVED ONE USER, BHP BILLITON, MORE THAN US$10 MILLION ON DRILLING AND ASSAY COSTS AT SITES NEAR ITS WESTERN AUSTRALIAN IRON ORE MINING CENTRE OF NEWMAN.

"FastGrade is a technology that hits all the right points for a mining company," says Mining3 research program director from CSIRO, Stephen Fraser.

"After a hole is drilled, it saves time waiting for assays to be returned from a laboratory because the results with FastGrade are available immediately."

The key to the technology is the way it pulses neutrons deeply into the rock surrounding a borehole. The data generated can be quickly analysed to provide a detailed picture of the elements in rock up to 50 centimetres from the hole.

French nuclear technology is amongst the most advanced in the world with a history that dates back to the mother of research on radioactivity, Marie Curie. The French have pioneered the use of neutrons in a process called pulsed fast and thermal neutron

activation (PFTNA), which avoids the use of radioactive isotopes.

Earlier underground element analysis tools did use radioactive material, which made it difficult to handle in a field environment and required strict quality and safety control.

Sodern's system is based on the use of an electrical source that poses no radiological risk for the environment if the tool is lost in a borehole – which has been known to happen.

CSIRO's contribution to the groundbreaking technology behind FastGrade has been in designing and building the tool. It's inserted into a borehole as a piece of equipment measuring some three-and-a-half metres and consisting of three distinct parts.

"The probe lowered into a borehole contains an emissions module comprising Sodern's Sodilog tube, which is a miniaturised particle accelerator in a ceramic body," Mr Fraser says.

"Behind that sits a detection module that accommodates a scintillation crystal. This is synchronised with the Sodilog unit to measure the gamma rays emitted from different elements after they're hit with neutrons.

"At the top end of the tool, is the service module that's designed as the communication and power interface for the logging tool and is connected to the surface via a 240-volt power link."

As the nucleus of most elements gives off a unique gamma-ray signal, when activated by neutrons, the FastGrade tool can quickly measure the distribution of iron and other elements in rock surrounding the borehole.

In BHP Billiton's case, they're looking for iron ore around their Newman mining centre, which means the tool is calibrated to identify and measure the levels of iron ore and other elements important to mining iron ore, including deleterious elements.

"Because neutrons and gamma rays used in PFTNA are energetic particles, they are able to penetrate the material surrounding the borehole by up to 50 centimetres. This is a far better sample area than simply assaying what comes out of the hole during drilling," Mr Fraser says.

Sodern describes FastGrade as a major breakthrough in conventional core sampling, doing away with the costly extraction of cores as well as the transport and preparation of samples for assays – not to mention the time lost in waiting for assay results.

"Moreover, the analysis will be much more accurate and will be available in real time," Sodern has stated.

FastGrade is a technology that hits all the right points for a mining company.

STEPHEN FRASER, MINING3

Use of the FastGrade tool is expected to spread across the mining industry following a well-received technical paper presented by Sodern at a mining conference in Canada last March.

Sodern prefaced its paper by saying that: "in-situ borehole elemental analysis is a new driver of productivity for exploration".

The tool itself has been designed to be lowered into 14 centimetre holes drilled by a low-cost reverse circulation rig as used in most mining areas around the world.

Because the data from FastGrade flows immediately to the surface, it can be quickly analysed in the field. Not only is an accurate assay recorded, but so too is the depth of what's being analysed, enabling a quick assessment of an exploration or mine development target.

Mr Fraser says FastGrade is being recognised by industry as a tool that saves time, while also providing an accurate picture of underground elemental composition.

"It's opening up opportunities to accelerate the flow of information and that means it will enhance the productivity of mining and exploration," he says.

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MINING EVOLUTION

Peter McCarthy

AMC Consultants Principal PETER MCCARTHY shares his view on the evolution of the mining industry – from 20th century large-scale mining toward a low-impact, data driven future in selective underground mining.

What's your take on the evolution of mining around the globe – where has the industry come from and where is it going?

Last century, we discovered economies of scale. Mines got increasingly bigger and bigger with unprecedented rates of production. Bougainville Copper, one of the world's largest copper mines in the 70s, began with 95 tonne trucks and soon was moving as much as 72 million tonnes per annum using 155 tonne trucks. Today, we can buy a 500 tonne truck.

In the 21st century, however, machines aren't going to get any bigger. Large open pit mines will still exist but those with significant waste-stripping requirements will become less economically or environmentally viable. The economies of scale have reached their limit. Selective mining underground is the future.

Secondly, there aren't enough tier one deposits around, and the risk of developing them is becoming unacceptable, even for the largest companies. That's why I think that, in the future, huge companies are going to be replaced by medium-sized companies, with different niche assets to reduce their exposure to catastrophic risks.

Finally, one hundred years ago in an underground mine, everyone worked autonomously and wouldn't be seen by managers until the end of their shift. This meant they made their own decisions every day down in the mine.

As operations got larger, we saw a lot of top down communication – more supervision and direction.

In coming years, we'll likely see a return to autonomous decision-making as a result of big data. Decisions will be back in the hands of operators.

So, what does the mine of the 21st century look like?

The industry's future is moving towards high-tech underground mines that have a low impact on the environment, less waste and are more energy efficient.

Future mines will look less like the mines we see today and more like an industrial site.

Mining companies will be dealing with their tailings and with their waste in a neat way. And, these smaller-scale operations will have a single, central conveyor to carry the ore out of the mine.

THE MINE'S OPERATIONS WILL DEPEND ON BIG DATA, WHICH THROUGH NEW ADVANCED TECHNOLOGIES, WILL BE USED TO INFORM WORKERS AND AUTONOMOUS SYSTEMS IN MAKING DECISIONS ON SITE, IN REAL TIME.

> **The industry's future is moving towards high-tech underground mines that have a low impact on the environment, less waste and are more energy efficient.**

What technology developments do you think will be the biggest game-changer?

Technology for the continuous cutting of hard rock will be a big game-changer and is something the mining industry is eagerly waiting for.

Flexible autonomous haulage systems, unlike the conveyor systems currently used in coal mines, is another. These will be robotic trucks that carry just a few tonnes of material from the face and deliver it directly to where needed.

Thirdly, sensing devices that quickly know what's waste and what's not, at the face, will offer a step change in efficiency. These will also apply to large tonnage bulk sorting of ore on a conveyor.

The mining industry is considered to be conservative when it comes to adopting new technologies – are they ready for this transition?

It takes 20 years for anything new to be adopted by the mining industry. According to one of my studies, anything that's going to be a good idea underground takes about 20 years from when the first commercial prototype is developed to being commonplace in the industry.

Take for instance, autonomous trucks, which were first developed in Sweden in 1973. We're still yet to see them widely adopted even 40 years later.

It's because there's a large capital risk in mining and adopting a new technology is another added risk. All the shareholders investing and the bankers lending don't want to take a risk on technology and so the directors don't take the plunge.

Small companies operating a marginal mine, and struggling to make it work, are the most likely to adopt a new technology. They either try it or risk going out of business.

How can mining companies better tap into research and development expertise?

Company directors need to appreciate the importance of R&D, because I think that very often they don't.

They are more concerned with immediate financial performance – the three-year cycle – and too often technology isn't valued.

Companies need to be employing experienced technical people who can rise up the chain and present a technology case to directors in a meaningful way.

Mining3 brings together two major, world-class research organisations for the minerals and mining industry in Australia. What opportunities does this new partnership open for the global industry?

Mining3 puts a better structure in place and will give companies more confidence in investing in R&D. The industry believes that Mining3 can do R&D well and deliver it.

Importantly, members will be able to direct the research the way they want - in a way that's most profitable to them.

Mining3 will also provide the expertise to tackle new challenges.

Mining companies can't achieve a competitive advantage with new mining equipment and technologies, because everyone will buy it as soon as it becomes available on the market. Rather, technology gives all companies an advantage over nature to increase safety and reduce their costs.

Thanks to new developments, companies will be able to mine deposits that they can't at the moment. And, those companies with mines in production, will be able to do more with them.

Is Australia's resources boom really over or is the next commodity boom waiting around the corner?

The last resources boom is over and probably ended about five years ago. It's the worst experience for geologists in about 30 or 40 years. I do think there will be another boom, but realistically they only come every ten to 20 years.

My prediction is that the next commodity boom will be uranium, because if extreme events linked to climate change continue at the rate we're seeing them at the moment, there's going to be a greater push to source clean base-load energy.

Is Australia best placed to lead the way in mining innovation?

Right now, Australia is best placed. We are leading the world in mining innovation.

A few years ago I would have said Canada, particularly Ontario, where they were putting a lot of money into research but that's since dropped off.

South Africa isn't involved much anymore and Africa as a continent doesn't have the capacity.

There are pockets of good R&D in the USA, but their industry is way behind and very much in catch up mode. The industry is very conservative in the USA and finds it comparatively harder to change the way they mine.

Australian mining companies are pretty good at innovation compared to the rest of the world. They are still conservative and slow to adopt, but a lot of technologies have been developed, advanced and taken up in Australia.

RESEARCH NEWS

EXPLOSIVE IDEAS

A 25-year research partnership could provide a significant breakthrough in the safety of explosives. Now, Mining3 is working to bring this new, nitrogen oxide-free formulation to market.
LOUIS WHITE reports

Since dynamite was discovered in the 1850s, explosives have become accepted industry practice in the extraction of minerals, where they are used to shatter and break rock.

One hundred years or so later, the power of ammonium nitrate (AN) explosives were discovered. AN explosives combined with fuel oil (known as ANFO) have since revolutionised mine blasting.

Explosives were further developed in the 1960s and 1980s with the introduction of AN-based water resistant gel and emulsion products. But AN-based explosives have some drawbacks and don't always react efficiently due to a number of uncontrollable and complex factors.

This can sometimes result in the generation of harmful nitrogen oxide fumes (NOx).

"The dominant explosive in the mining arena is based on AN," Mining3 project leader in explosives engineering, Miguel Araos says.

"It is an effective explosive, however, sometimes it produces NOx, which is a harmful fume that comes from the nitrogen present in the AN molecule (NH4NO3)."

Control strategies are used to minimise the risk of NOx hazards, but these rely on personnel.

In a strategic partnership that spans 25 years, Mining3 (formerly CRCMining) and the University of Queensland School of Mechanical and Mining Engineering, are working together on the next generation of explosives to remove the hazard altogether.

The result has been a substitute explosive formulation that does not generate harmful NOx fumes. The team's new breakthrough formulation eliminates NOx fume emissions by removing the nitrogen and using hydrogen peroxide, as the main oxidiser.

"The initial project was to find the detonation properties of the hydrogen peroxide fuel-based explosives," Mr Araos says.

"Generally speaking, explosives used in mining detonate with a velocity between 2,000 to 7,000 metres per second. To put this in context, if you were to travel from Sydney to Newcastle – which is approximately 120 kilometres – it would take an explosive anywhere between 18 to 60 seconds to cover that distance."

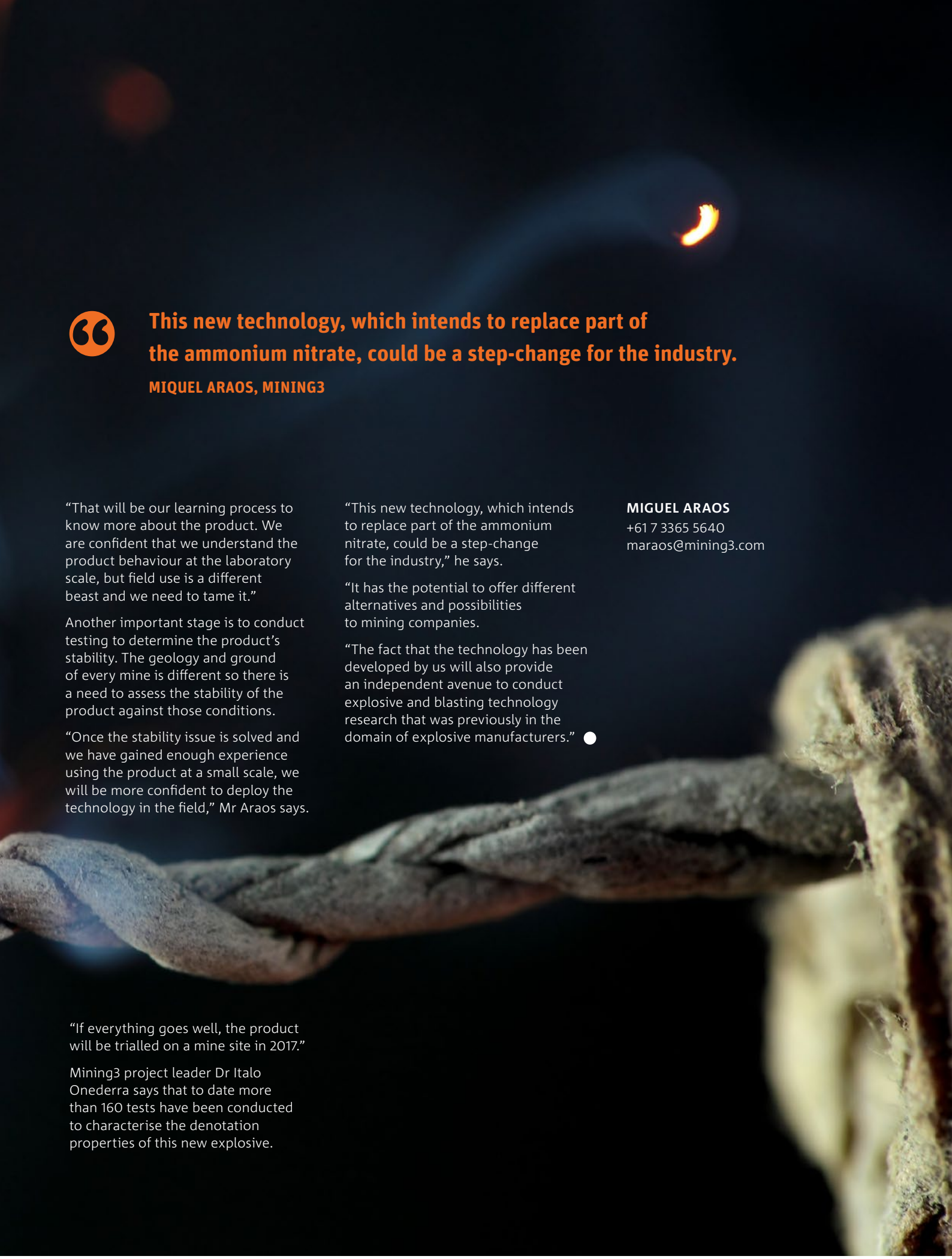
A key aspect of the project is to understand the velocity, or explosion reach, of the new hydrogen peroxide fuel-based explosives.

"After two years, we have conducted extensive research thanks to funding from the Australian Coal Association Research Program (ACARP)," Mr Araos says.

Another active partner in the development of this new mining explosive has been Solvay, who are an international chemical and advanced materials company. They assist customers in innovating, developing and delivering high-value, sustainable products and solutions, which consume less energy and reduce CO_2 emissions.

"The reason we contacted Solvay is that they have a manufacturing plant in Botany, Sydney and are the largest producer of hydrogen peroxide in the world," Mr Araos says.

"While the technology has not been applied yet, we are working with a small company that will put the product in the ground.



> **This new technology, which intends to replace part of the ammonium nitrate, could be a step-change for the industry.**
>
> **MIQUEL ARAOS, MINING3**

"That will be our learning process to know more about the product. We are confident that we understand the product behaviour at the laboratory scale, but field use is a different beast and we need to tame it."

Another important stage is to conduct testing to determine the product's stability. The geology and ground of every mine is different so there is a need to assess the stability of the product against those conditions.

"Once the stability issue is solved and we have gained enough experience using the product at a small scale, we will be more confident to deploy the technology in the field," Mr Araos says.

"If everything goes well, the product will be trialled on a mine site in 2017."

Mining3 project leader Dr Italo Onederra says that to date more than 160 tests have been conducted to characterise the denotation properties of this new explosive.

"This new technology, which intends to replace part of the ammonium nitrate, could be a step-change for the industry," he says.

"It has the potential to offer different alternatives and possibilities to mining companies.

"The fact that the technology has been developed by us will also provide an independent avenue to conduct explosive and blasting technology research that was previously in the domain of explosive manufacturers."

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THE NEW STANDARD FOR BLOCK CAVING

A CSIRO breakthrough in block caving is helping companies cost-effectively mine large, low-grade deposits with greater control.
TIM TREADGOLD reports

If you're working in an underground mine, there is no power harder to harness than gravity, for the simple reason that the ore being mined has to be hauled to the surface. But, there is a way of using gravity deep beneath the Earth's surface: it's called block caving.

Technically difficult and painstaking in its preparation, block caving is pretty much what it sounds like – dig underneath a block of ore and let in cave in. Once 'caved' the broken ore is collected and hauled to the surface for processing.

If the preparation is not done well or the ore does not fracture into pieces small enough to be easily handled by underground equipment, then an expensive problem can be created.

One of the best ways to avoid a 'blocked' cave, and to reduce ore to a manageable size, is to apply the rock-fracturing techniques a team from CSIRO has helped develop and which has become a worldwide standard in block cave mining.

"Hydraulic fracturing of the ore to be caved has proved to be extremely successful in a number of mines in Australia and overseas," says CSIRO senior research technician, Kevin Quinlan.

The process involves drilling a series of holes into the orebody, inserting inflatable packers that are filled with water, sometimes with a gel added to prevent leakage, and then apply pressure which expands natural cracks in the rock to 'pre-condition' the ore.

In cold climates, nature has a similar way of cracking rocks because water that has entered a natural fracture expands as it freezes, exerting pressure which extends the fracture.

In a man-made situation, once the hydraulic fracturing has done its work, the ore is blasted in a conventional way and gravity takes over, with the ore dropping to be collected and lifted to the surface in manageable pieces.

Principal users of the technique are companies working with large, low-grade orebodies such as copper miners in Chile and gold miners in Australia. The Cadia and Ridgeway goldmines of Newcrest Mining in western New South Wales are examples of successful block caving.

Done well, block caving is a cost-effective way of extracting large volumes of ore in an underground setting.

But, like many advances in science and technology a better understanding of block caving started in a trial and error fashion. Problems with a cave at an Australian copper mine in the 1990s provided an example of what can go wrong if the ore is not fully fractured when blasted.

The formation of an 'air-gap' meant that a large portion of the ore high up in the area being caved became stuck, presenting a complex problem which required considerable time and money to be fixed.

"Pre-conditioning with hydraulic fracturing can play an important role in ensuring that events such as that do not occur," Mr Quinlan says.

There are a number of aims of pre-conditioning, which generally starts with drilling a number of holes spaced about 50 metres apart into the orebody, ensuring the best alignment with natural fractures in the rock before inserting the inflatable packing units.

"Hydraulic pre-conditioning can help induce caving and provides greater control of the cave," Mr Quinlan says.

"It also helps reduce the size of rock fragments and helps produce closely spaced fractures to prevent blockages making the ore easier to handle as it drops into the collection zone."

"Pre-conditioning is also useful in de-stressing the ore, especially as you get deeper underground, reducing the risk of rock outbursts, which can be both a safety and cost factor," he says.

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> **Hydraulic fracturing of the ore to be caved has proved to be extremely successful in a number of mines in Australia and overseas.**
>
> **KEVIN QUINLAN, CSIRO**

RESEARCH NEWS

BRIGHT SPARKS REDUCE UNDERGROUND RISKS

Breakthrough electronics research by Mining3, has been acknowledged for its potential to improve safety and reliability in underground coal mining. TONY HESELEV reports

Researchers are developing a prototype spark testing device that may set a new standard of risk management in the potentially explosive environments of underground coal mines.

The new electronic spark tester is designed to replace the electro-mechanical spark testing device, which has challenged the industry for 50 years.

The test is performed to ensure power supplies are inherently safe, which means they can't cause an explosion if there's a short circuit on the output terminals of the power supply.

The existing device is used in intrinsic testing and certification of power supplies. It provides only a pass or fail result, with a high degree of variability. Tests are expensive and time consuming, and can be undertaken only at a few specialised laboratories.

Power supplies can pass one day and fail the next, even though the test setups are identical. The device also provides no data or analysis of the response of the power supply during the test, so there is no way of telling why it passed or failed. This can be frustrating for manufacturers trying to get their power supplies certified.

Fortunately, a new electronic spark tester is being developed by Mining3 to provide a more reliable, informative and versatile test method, and deliver better protection against explosions.

Mining3's electronic systems engineer and project leader, Enver Bajram, says the new method simulates sparks – rather than creating real sparks or explosions – and then uses computer analysis.

"It makes a series of measurements using a specially designed electronic loading device and interprets these measurements based on knowledge of spark physics developed from experiments undertaken specifically for this project," Mr Bajram says.

"It measures the transient and steady state performance of a device and then provides an indication of spark energy that could be developed and compares this to an explosive limit.

"This information provides much greater value in terms of design validation and margins of safety."

The new technology will enable intrinsic safety testing to be conducted in factories and onsite to ensure continuing performance and safety of devices.

For end users, in-situ testing of power supplies could ensure continued compliance and a more informed approach to managing risks associated with electrical power supplies in potentially explosive environments.

The electronic testing method also helps manufacturers receive far more informative and reliable test feedback and the possibility of 'factory acceptance' intrinsic safety testing.

For testing agencies and laboratories, the new method is safer for staff and provides greater certainty in results.

The research has been funded by the Australian Coal Association Research Program (ACARP) and undertaken in collaboration with Germany's National Metrology Institute (PTB).

The researchers are planning to carry out a large batch sample test on multiple power supplies of various ages, which has been proposed to ACARP for 2016 funding.

A prototype of the electronic spark tester is scheduled to be available for industry use by the first quarter of 2017.

Mr Bajram says the new technology could also eventually be used in the oil and gas industry.

In December last year, Mr Bajram and his research partner Rajiv Shekhar received an ACARP research and industry excellence award for their work on the new tester.

ACARP Executive Director Mark Bennetts says their progress towards creating the new tester as an alternative technique to the flawed existing methodology was a remarkable achievement.

"The fact that their research has been delivered in collaboration with PTB indicates the potential for international change of both testing and eventually International Electrotechnical Commission standards," he says.

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RESEARCH PERSPECTIVE

STRENGTH IN NUMBERS

Dr Steve Harvey

While we have the choice in the research sector to work independently, now more than ever, it's in Australia's best interest to share the scarce resources that we have and collaborate, writes Deputy Director for CSIRO Mineral Resources, Dr Steve Harvey.

Greater collaboration is key to building both the capability and capacity that the Australian research community needs to tackle industry's biggest research and development (R&D) challenges. No single research institution has the available resources or the financial capacity to maintain the breadth or depth of capability required.

One of the key priorities in CSIRO's Strategy 2020 is to create a collaboration hub. This is focusing our efforts on working closely with our research, industry and government partners to enhance Australia's innovation performance.

We've committed to deepening our partner relationships with universities and other research organisations in the Australian innovation system to access a broader pool of external capability and to increasing its contribution to building a STEM (science, technology, engineering and mathematics) and innovation capable workforce for the nation.

What differentiates CSIRO in Australia's innovation ecosystem, is our ability to assemble multidisciplinary teams to tackle the big applied R&D challenges. However, we rarely have all of the capabilities required, which is why collaboration with other research providers is so important.

Of course, we have a long history of collaboration on minerals R&D. Over a 20-year period, CSIRO has played a leading role in no fewer than seven Cooperative Research Centres in areas as diverse as geodynamics, geophysics, regolith and computational geoscience, mining technologies, and hydrometallurgy. Through these collaborative ventures, we have been able to deliver profound impact to the global minerals industry.

That's why, when CSIRO decided to re-establish a significant market presence in hard rock mining to complement its world-class exploration, ore sorting and processing capabilities, an obvious approach was to partner with Australia's pre-eminent mining R&D entity – CRCMining.

The partnership between CSIRO and CRCMining has created the world's largest mining research venture, Mining3.

Not only does Mining3 bring together each organisation's world-class capabilities in hard rock mining, it connects CSIRO's new digital innovation arm, Data61. This strengthens our ability to advance developments in sensor technologies and automation to shape mining for the future.

Mining3 will have the scale and breadth of capability to tackle challenges beyond the reach of any one institution. The benefit for the mining industry is that we can provide a much better offering.

We could have sought to build this capability at CSIRO on our own, but we chose not to, because we believe collaboration through Mining3 is the best way to deliver results that benefit the industry and community as a whole.

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CHAIR'S PERSPECTIVE

A BIG IDEA FOR BIG OPPORTUNITIES

Mining3 Chairman DR LAURIE HAMMOND shares his insight into why industry-led research drives success and the opportunities it opens for mining and METS companies.

Our new strategic partnership, Mining3, will help to transform mining at a critical time for the industry.

The mining industry is deeply aware of the existential challenges it faces – financial, environmental and social – over the next few decades, and recognises that many of these challenges will be met only through sustained innovation. It also recognises that the nature and scale of these challenges are beyond the scope of individual companies and must be addressed through a collaborative working model.

Partnership – between companies, and between companies and research providers – is at the heart of CRCMining's success, and will characterise the way Mining3 will work with industry. It ensures that a diversity of views and experience across the industry is brought to bear on important research and innovation questions.

Mining companies, and the major equipment manufacturers working alongside them, will continue to provide direction to Mining3 on their research needs, through a process established with CRCMining in recent years. The industry identifies its 'grand challenges' on 20-year timeframes and then works with our researchers to build eight-year roadmaps for the required technologies – defining a rolling program of research and development.

Such a strategic approach is exemplary, and belies views that the industry has a low commitment to, and propensity for, innovation.

This process results in prioritisation of research opportunities and, through regularly revisiting the roadmaps, a periodic reassessment of those priorities. The result will be that Mining3 stays focused on higher value research questions and on the problems that really matter to the industry.

And, contrary to oft-expressed concerns, this close engagement with researchers does not lead to a focus on short-term, tactical research questions. Rather, the industry has demonstrated its willingness to participate in longer term, more fundamental research that is required to address the grand challenges successfully.

Mining3 is committed to accelerating industry adoption of new technologies. This is critical because the industry has identified the need to shorten the long innovation adoption cycle – 15 to 20 years for important technologies.

Mining3 represents a new world-class resource for the industry.

Working closely with companies, some of Australia's best researchers will contribute to solving the sector's truly wicked problems. It will create a critical mass of scientific and engineering capability that will cement Australia's global leadership in mining research, technology and innovation, and bring benefits to the industry, in Australia and globally.

Especially, we anticipate that new opportunities will be generated for Australia's world-leading METS (mining equipment, technology and services) companies.

The formation of Mining3 is a big idea that opens up big opportunities for the industry, CSIRO and CRCMining.

Dr Laurie Hammond

RESEARCH PERSPECTIVE

BREAKING NEW GROUND

Developments in continuous hard rock cutting are being accelerated by Mining3 in partnership with industry, promising greater productivity, lower costs and energy efficiency. DAVID SIMPSON reports

Like many other areas of the Australian economy, the hard rock mining industry is faced with the challenges of change. Short-term factors such as global commodity prices and exchange rates are combining with longer term issues including productivity decreases, owing to lower grade ores, longer haul distances and decreasing ore accessibility.

The result is that the industry is under pressure to improve the efficiency of mining processes to maintain and maximise Australia's competitive advantage as a leading producer of both energy and minerals.

The efficiency goal in hard rock mining is to change from batch to continuous production. The batch process is the familiar drill and blast fragmentation system in which rock is fractured by explosive blasts and mechanically removed before the process is repeated.

Continuous production on the other hand, is typified by the shearers and conveyors used in coal mining. This leads to a continuous flow of material for processing and increases efficiency and safety, while lowering the overall costs of production.

Another important factor is that as easy-to- reach, high-value surface deposits are depleted, hard rock mining operations are migrating underground, which is capital intensive and requires developing complex infrastructure.

This changing production model, together with the need to maximise the safety of the work environment, are adding to the impetus towards continuous and autonomous production.

Hard rock cutting is generally energy-intensive, and the existing technologies, such as tunnel boring machines extensively used in civil industry, are inflexible and cumbersome, making them unsuitable for mining operations.

Mining3 is developing solutions for continuous production in hard rock mining. The main objective is to achieve competitive excavation and cutting rates. This requires long-life cutters with low-energy requirements, minimal machine footprints and suitable material handling – especially in confined underground areas.

Building on a successful track record in developing cutter/rock interaction models, sensing for characterisation, and smart control systems for

automation, the Mining3 team is currently working to bridge the knowledge gap on the mechanics of hard rock failure under the action of static and actuated undercutting discs.

According to Mining3 researcher, Dr Sevda Dehkhoda, the process of undercutting could revolutionise hard rock mining operations. Breaking the rock under tension while rolling around its axis, these cutters are theoretically more effective and efficient than their conventional equivalents: drag picks and roller discs.

"The energy requirement of the cutting method determines the excavation rate," Dr Dehkhoda says.

"While the cost of energy usually is not a problem, the amount of energy transfer through the tool to the rock – which is in turn controlled by the strength of the cutter material – is the real constraint.

"This means we can't improve the rates just by increasing machine power – we have to look for methods like undercutting disc that require less energy for breaking the rock."

Dr Dehkhoda has expertise in rock mechanics and rock fracture mechanics and says she is looking for processes that take advantage of rock weaknesses to break the rock with minimal energy requirements.

"I look into a rock's failure mechanisms taking into account the kinematics of the cutter, cutter/rock interaction and properties of the rock, answering questions like: What happens at the boundary of the cutter and the rock? What factors influence how rock breaks? How does the strength/toughness of the rock affect the whole rock failure mechanism?"

By using fully-instrumented, kinematic controlled and highly stabilised test rigs, Mining3 researchers are able to isolate their objectives and measure the stresses and forces at the cutter/rock interface, which are solely the result of the cutting process.

Of particular interest are two types of rock failure, known as ductile and brittle. Ductile failure involves breaking rock grain by grain, creating a powdery material. Whereas, brittle failure produces larger chips – shards of material that literally chip off the rock.

Since it fails the rock in finer particles, for a unit volume of rock, ductile failure generally requires more energy than brittle failure and will consequently be less efficient for excavation.

"Our primary objective is to contribute to the development of a successful hard rock mining machine – a machine that is robust and strong enough to re-disband the high reaction forces from cutting in hard and abrasive material, but at the same time, be small enough to manoeuvre in a confined underground environment," Dr Dehkhoda says.

Mining3 is also working on applications of novel rock cutting technology. Mining3 (initially when operating as CRCMining) has licensed their oscillating disc cutter technology (ODC) to a leading mining equipment and services provider Joy Global since 2006.

The company has rebranded the technology as DynaCut, and since then, equipment development has been carried out by Joy Global, who has made substantial improvements to the operating performance and mechanical reliability of DynaCut technology.

Brad Neilson, President of Hard Rock Mining at Joy Global, said that DynaCut will revolutionise hard rock cutting for mining.

"The gains for mining are significant. A continuous mining process in hard rock tunneling can yield a 20 percent improvement in advance rates, and up to 20 percent reduction in costs," Mr Neilson says.

"Another benefit is less disturbance of the surrounding rock mass when compared with drill and blast methods."

According to Mining3 Principal Research Engineer, Dihon Tadic, continuing collaboration with Joy Global will further develop the DynaCut system to improve cutter performance and service life, while developing predictive performance models for the cutting tools.

"The future is very promising – I believe we'll develop highly flexible and mobile hard rock cutting machines that can cut varying excavation geometries, negotiate tight bends and ultimately become fully-autonomous systems for mine development and orebody extraction." Mr Tadic says.

Reaching this goal will be a significant contribution to achieving, maintaining and maximising Australia's competitive advantage as a leading producer of both energy and minerals.

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CSIRO blog

THE CONVERSATION

WHAT'S LIFE LIKE ON AN RV INVESTIGATOR VOYAGE?

At 11am (local time) on Thursday, Investigator was declared all fast at berth in Wellington, New Zealand, ending Leg 1 of a busy research voyage. Here's a snapshot of what we got up to while at sea.

Early on in the voyage, we explored the realm of icebergs. Unfortunately this coincided with a lot of fog so all we saw for the first few days were yellow 'blips' on the radar. At night (a considerable part of a 24 hour period at high latitudes), the ship often made slower progress as Captain Mike wanted to be alert for 'growlers', icebergs too small to detect on radar but still big enough to puncture the hull.

The icebergs made steaming south a bit fraught but boy are they impressive! After the fog cleared we saw a couple close up in the light of day. It can be hard to get a sense of scale in the ocean but the second one seemed pretty big from where we sat!

We went up to the bridge to look at it and take photographs, and were stoked to have a little flock of (pure white!) snow petrels fly past while we were up there.

Our game plan then changed a little. We were on course to arrive at our southernmost station in the dead of night but the Captain wanted to SEE the sea ice before we put any instruments in the water. The new plan saw us complete a more northern station first, making use of the time we would otherwise have spent waiting for the light. We then skipped the station on our line heading back north to make up lost time.

For the full story, visit: blog.csiro.au

THE FUTURE OF CHATBOTS IS MORE THAN JUST SMALL-TALK

Human communication goes beyond words. It is complex, rich in nuances and frequently includes non-verbal signs. Yet despite our technological limitations it is not impossible for some aspects of communication to be emulated by a machine with surprising effect.

This has been part of the challenge in developing Harlie (Human and Robot Language Interaction Experiment), a smartphone chatbot app developed by researchers at the CSIRO and University of Queensland.

It's primarily aimed at people who may have trouble conversing including those with neurological conditions such as Parkinson's disease and dementia, or even autism.

For the full story, visit: theconversation.com

RESOURCEFUL

UP NEXT

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