

Issue 20 APRIL 2020



# Resourceful

BRINGING CSIRO RESEARCH TO THE MINERALS INDUSTRY

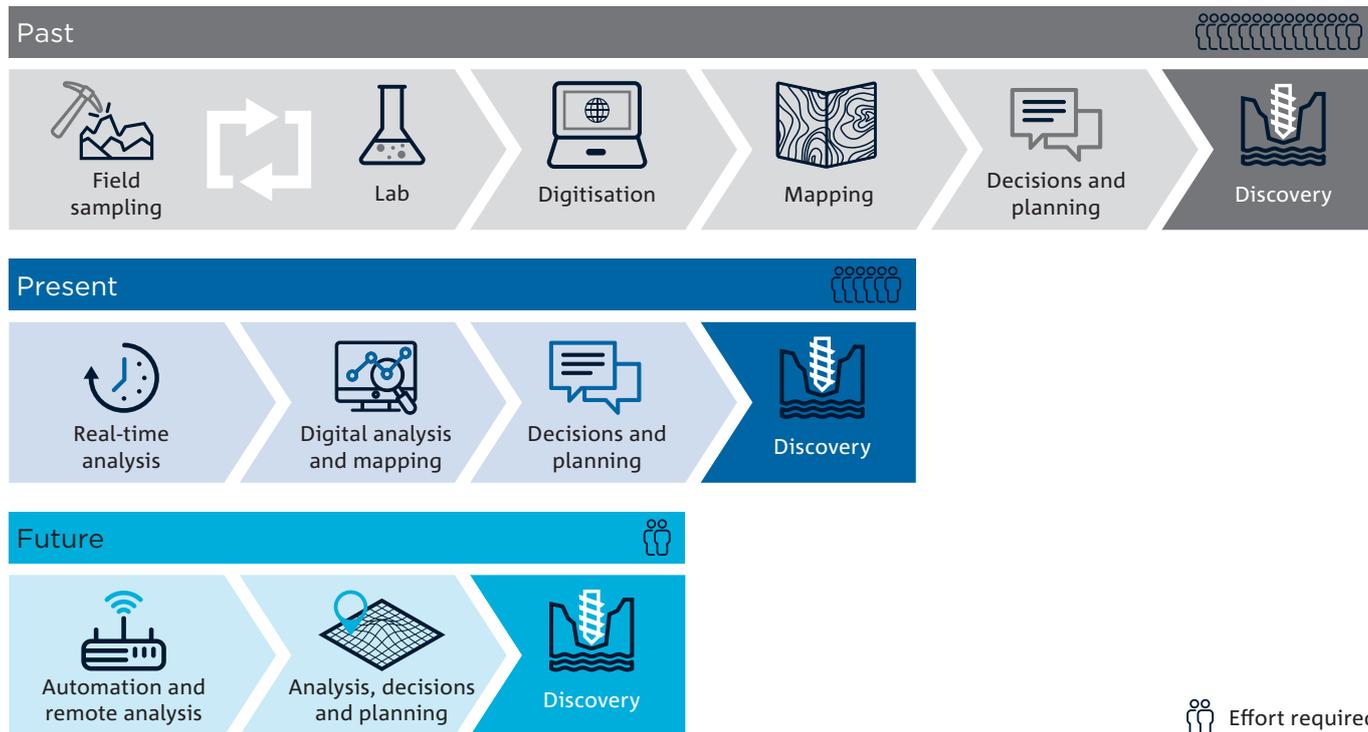
## DECODING DIGITAL IN MINING

**Digital innovations to make  
exploration and mining  
safer, more sustainable,  
resilient and productive**

CSIRO Australia's Innovation Catalyst

# DIGITAL TRANSFORMATION IN MINERAL DISCOVERY

Technological advances are reducing risk and time to new mineral discovery



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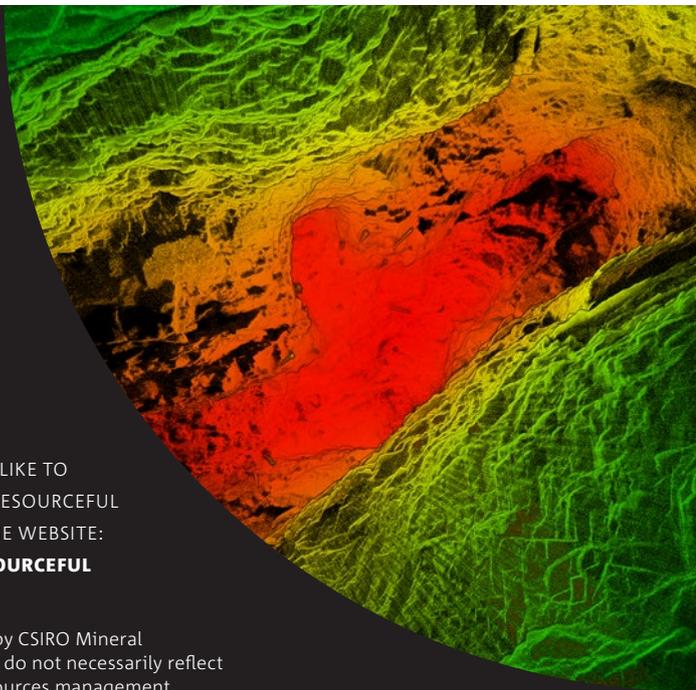
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IMAGE CREDITS  
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**COVER IMAGE**  
A cross-section scan generated by Hovermap of an underground stope. Read more about drones and digital tools in mining on page 2.

Image credit: Emesent.



## LEADER'S COMMENT

# DECODING A DIGITAL MINING FUTURE



The potential for digital disruption to and in, the exploration and mining industry has been widely recognised and discussed, but as yet, the opportunities are not being realised. **ROB HOUGH** writes

With the speed that technological advancements are accelerating today, it is easy to imagine that tomorrow's world could be unrecognisable. This is even more apparent when we consider how we have all rapidly adapted to working differently during this COVID-19 pandemic, technology is at the forefront of enabling us to stay connected, to help us keep working, to access and process data remotely. This of course also applies to our world of exploration and mining where new and innovative technologies are being developed to ensure safer, sustainable and consistent operations and production.

Dr Sue Keay, Research Director Cyber Physical Systems eloquently shares in her article, "the barrier to adoption remains developing a business case and system-level approach to technology implementation that would see application on a large scale rather than in a piecemeal fashion". In this issue of Resourceful, we explore what a digitally enabled mine looks like now and what will a future digital mine mean for mining workforces? Could the current crisis encourage a wave of new digital implementation to operations?

The development of a digital mine requires the use of smart sensors for data capture and analysis throughout the mining value chain. Sensing for high quality data at different staging points can reduce uncertainty and risk, but to achieve a predictive approach that allows for management of variability, the focus needs to be on very high quality and targeted sensing points building on detailed characterisation to generate quality data up front.

This then supports a detailed model of the ore body that is the crux of all subsequent planning and decision making. Although hard to win, that investment up front, could provide Boards and Executives greater certainty on future performance including for productivity, safety and environmental outcomes.

Intelligent ore body knowledge allows for a detailed and predictive understanding of the properties that matter to the operation. Decisions that impact value creation and loss or have environmental impacts, such as supporting reduction of emissions or waste could be made earlier in planning, design and engineering, resulting in improved triple bottom line benefits. All with greater certainty for, decision makers, investors and Boards.

The ability to sense and map mineralogy is a good example, it could be more valuable to the triple bottom line of an operation than just sensing grade. This becomes apparent when considering clay mineralogy; clay content can control hardness (and thus energy budget for comminution), can impact waste materials and waste storage, moisture content of certain ore streams. Prediction and management of these factors via multi-scale sensing – downhole, on mine faces, benches, material on trucks, conveyors and stockpiles enable better decision making for mine plans, beneficiation variability and of course waste streams. If much of this data can be collected during exploration, the value addition is amplified.

Take modern cars as a good example, they encompass complex software to support the driver with information to make decisions, with apparently millions of lines of code involved. This compute capability is nothing without the series of sensors feeding the real time data, from GPS, cameras, light, rain, and radar sensors to name but a few.

As deployment of sensors across all industries and facets of daily life becomes widespread and provides new streams of information supporting end-users to make better and quicker decisions with reduced uncertainty, we can also expect a new generation of users who expect such data, want more, and embrace the opportunities it gives them.

As CSIRO's Integrated Mining Research Engineer Craig James reflects in the article 'Unleashing the potential of digital twins', although "automation is changing their roles, people are essential to operations as they're a lot more creative and can respond to exceptional circumstances more effectively". Perhaps the greatest gains from this disruptive transition to a digital future could come from the flexibility these advances in technology, real time data, and tools for decisions, could enable for a future workforce, ultimately attracting more talent and workforce diversity to our industry and future proofing our ability to manage and build resilience against such shocks, as the COVID19 pandemic, keeping us working remotely, and even more enabled and productive! ♦

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# DRONES AND APPS – DIGITAL TOOLS IN MINING

The minerals resources industry faces unique challenges to locating ore bodies in Australia. Not only do researchers have to cover vast land areas in limited time, they often do so in extreme temperatures and difficult terrain. However, digital technology may hold the key to overcoming these challenges and improving data collection. **Louise Pobjoy** reports

Minerals exploration across large, remote and inhospitable areas, like some regions of Australia, can be extremely challenging, labour intensive and expensive. CSIRO is embracing digital technology to make surveying even the most isolated areas more efficient, easier, cheaper and safer.

CSIRO has been working with industry and universities to explore how two digital tools – mobile apps and drones – could transform minerals exploration in Australia and around the world.

One of these tools is the FAIMS i.e. Field Acquired Information Management Systems mobile field app. This automated system was originally developed at Macquarie University to record archaeology data, including samples, GPS coordinates, photos and notes. Using CSIRO's paper-based data collection tools as a starting point, its developers created a geochemistry module.

“When you use this app in the field, you know where you are, what the time it is, what you're doing, who you are, what campaign you're on. Any additional information then boils

down to just a few drop-down menus, and maybe a note and taking a photo, and everything is documented,” CSIRO Geoscience Analytic Team Leader, Dr Jens Klump, says.

“We had immediate take up because it saves so much time. Geochemists love it.”

CSIRO Team Leader Minerals and Water, Dr Nathan Reid, has used the app in several major CSIRO projects, including a recent geochemical survey of the Nullarbor Plain.

“By using the app, we shaved time by about 40 or 50%, which, when you're using a helicopter, literally time is money with the amount of fuel you're burning,” he says.

FAIMS improves data quality, accuracy and consistency by reducing human error during recording and transcribing. It even produces barcodes to stick onto sample bags, so researchers don't need to write IDs and other details on them.

The app automatically uploads data onto a portable server, which increases data security and makes it easy for researchers to work in very remote

locations, because they don't need Wi-Fi or phone networks.

This means data can be processed more quickly and strategic decisions can be made in close to real time, leading to more efficient operations and cost savings.

“Introducing this new technology into fieldwork really gives us the opportunity to make the whole process more dynamic and to feed back what we have learned from analysing the data much more quickly. This makes the whole exploration process much more efficient,” Dr Klump says.

FAIMS is relatively inexpensive, so could benefit smaller companies by giving them more affordable options to produce better results. It could also make fieldwork safer, by reducing the time researchers spend in the field, and marking hazards and fencing-off areas.

Over the past few years, CSIRO has worked with several companies successfully using the app, including the Geological Survey of Queensland and Geological Survey of NSW. While the focus so far has been on minerals exploration, Dr Reid believes FAIMS



could be adapted for almost any industry that collects data outside, including agriculture and ecology.

“At the end of the day, this is just a data capturing mechanism. The idea is to make something that you can adapt to make a workflow,” he says.

In addition to FAIMS, CSIRO sees drones as promising exploration tools. It recently received its operator’s license – the first large, interstate organisation in Australia to do so – and has started collaborating with Monash University on drone data processing.

According to Dr Klump, there’s a gap in the information that can be gathered from air- and space-borne surveys and ground-based surveys – and drones are ideal for filling it.

“Drones allow us to cover relatively large areas compared to somebody walking in the field, and provide data at a much higher resolution than aircraft do, because they fly closer to the ground. It’s cheap, it’s high resolution and it’s fast,” he says.

Drones are already widely used for safety, for shark spotting and marking edges of bushfires, so, like FAIMS, could be used to improve safety in exploration by identifying dangers like geohazards, landslides and sinkholes.

For example, Hovermap technology developed by CSIRO’s Data61 is giving operators insights beyond what the eye can see into areas that have not been mapped before (see image from the front cover). Hovermap’s advanced autonomy capabilities allow you to unlock above and below ground data with confidence and safety. It also has the versatility to let users switch easily from drone to handheld use, backpack or vehicle-mounted scanning, enabling the collection of critical data both from the air and on the ground.

Currently, CSIRO is collaborating with industry and universities here and overseas to develop and integrate FAIMS and drone technology.

When it comes to FAIMS, Dr Reid tells us his team is looking to create a workflow generator and modules that can be tailored to individual company needs.

“We’re also looking at how to upgrade the hardware and server box, and make that into a simple, off-the-shelf product,” he says.

And when it comes to drones, Dr Klump explains the plan is to put more processing power on the aircraft to allow for data pre-processing and cleaning, without having to download raw data that needs to be processed later.

“A package of app, machine learning and drone could make exploration more accessible, because it would be easier and cheaper to produce high-quality data on relatively large scales compared to today,” he says. ♦

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**IMAGE:** Using drones equipped with Hovermap technology automates the collection of valuable data in areas too dangerous or difficult for people to survey or navigate.

CONFERENCES

# OPEN FOR BUSINESS AT THE RESOURCES INNOVATION SHOWCASE

CSIRO's Mineral Resources expertise and technology was on display at the Resources Innovation Showcase, held on 18 February 2020 in Fremantle.



1. Rob Hough (acting) Director Mineral Resources, Sandra Occhipinti, Research Director Discovery with Chris Wijns, Group Geophysicist First Quantum Minerals. 2. Rob Hough (acting) Director Mineral Resources giving the opening address to the well-attended inaugural Resources Innovation Showcase. 3. Keynote Asmita Mahant, BHP manager Technical Services and Data Integration sharing her thoughts on the future of mining. 4. Rob Hough (acting) Director Mineral Resources, Andrew Bailey, Chief Executive Officer MinEx CRC, Simon Bolster, Managing Director Portable PPB and Anil Subramanya, Research Portfolio Manager Minerals Research Institute of WA. 5. Ewan Sellers, CSIRO Research Director, Hard Rock Mining and Mining3 Collaborative Research Partnership speaking on realising the invisible mine.



6. Mark Dunn, CSIRO Mineral Resources Senior Principal Research Engineer, Sustainable Mining Technologies discussing CSIRO capabilities in visualisation of real time underground mining operations. 7. Dave Cole, CSIRO Data61, Senior Research Engineer presenting on predictive exploration. 8. Jeff McCulloch, Managing Director, Clean Mining Limited discussing cyanide-free gold processing. 9. Exhibitor booths at the 2020 RIU Explorers Conference. 10. Laura Kuhar, CSIRO Mineral Resources Research Team Leader, Processing presenting on in-situ recovery.

Presented in conjunction with the RIU Explorers Conference, the showcase focused on the latest techniques and technologies emerging from CSIRO in the area of resource characterisation and precision mining.

Opening the event, keynote speaker Asmita Mahanta from BHP offered an industry perspective of the challenges across the minerals value chain. Mahanta highlighted the significance of data at all stages of the process, using the example of the impact machine learning at one point in the chain can have to determine parameters at different points in the stream.

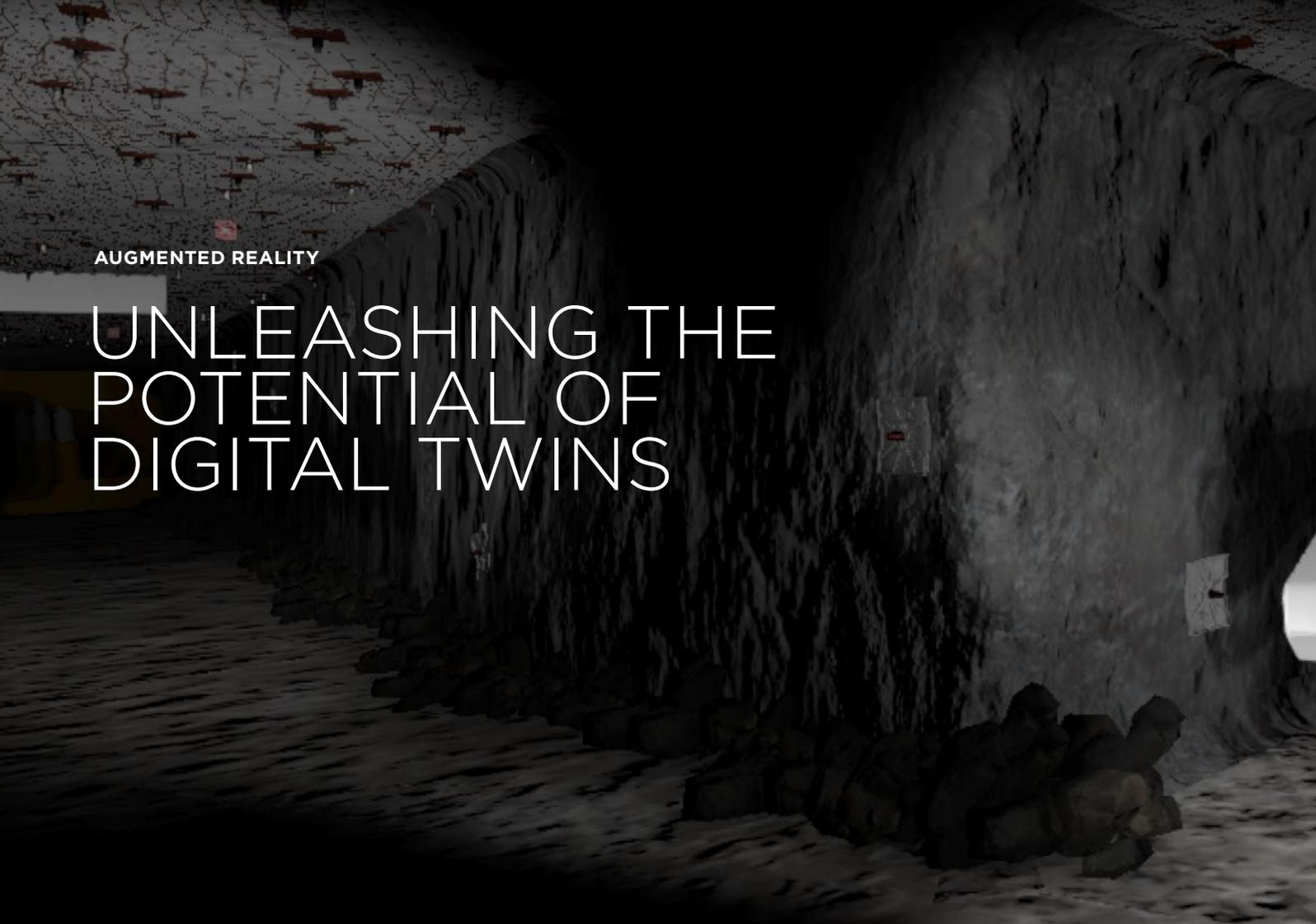
Leveraging off these insights were presentations on resource characterisation and tools for exploration and processing. A major session topic was low impact, precision mining, discussing a vision of invisible mining in the future, brought about through digital innovations in data acquisition, interpretation and application.

Also presenting on the day were representatives of NextOre, Chrysos and Clean Mining; companies demonstrating commercial success in bringing CSIRO-developed technologies to the sector.

Good feedback was received from attendees. Overall, the event was a great networking opportunity and cross-fertilisation of science, R&D and industry knowledge. ♦

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In hosting the inaugural Resources Innovation Showcase, CSIRO aimed to continue to break down silos across the mining value chain and to workshop some of mining's biggest challenges with colleagues from a diverse range of technical backgrounds.



AUGMENTED REALITY

# UNLEASHING THE POTENTIAL OF DIGITAL TWINS

The latest digital-twin technology uses virtual models of physical processes and objects to make mining safer, more sustainable and more productive. **Jane Nicholls** reports

People in remote-operations centres in large cities have been controlling locomotives and haulage trucks at major Australian mining operations for some years, with automation and robotics moving humans from dirty and dull tasks in dangerous environments to safer and more desirable locations where they can do their jobs more effectively.

CSIRO's Integrated Mining team is working on solutions for yet another 'D' problem, distance, using mixed-reality and digital-twin technology to enhance non-line-of-sight control by making remote operations more immersive, giving operators a stronger sense of 'being there'.

"We call remote operations 'human in the loop automation', because even though automation is changing their roles, people are essential to operations as they're a lot more creative and can respond to exceptional circumstances more effectively," explains Craig James, Senior Research Projects Officer for the Integrated Mining team in Mine Processing Technologies (part of the Sustainable Mining Technologies program of CSIRO Minerals Resources).

"Situational awareness – knowing what's happening around you when you are controlling something – is crucial to remote operations – that's what we're working to create," says James, who operates CSIRO's Remote Management Centre [RMC]. Typical remote-operations centres – which most big mining companies now have – see people working with multiple screens, keyboard, mouse and perhaps a joystick or steering wheel.

However, that set-up, where people are somewhat disconnected from the process is limited in its ability to put people into a 'flow' state, which helps them to use a wide range of incoming information more instinctively and effectively. "Immersing people deeper in virtual environments, modelled with actual data that replicate mining processes in real time, gives a much more powerful perspective, letting them step in rapidly as required," says James. "This is the essence of the digital twin, and it helps you to focus on what is important in the environment around you."



“Mixed reality is a term that covers a range of technologies from augmented reality [AR] to virtual reality [VR]. In between AR and VR is augmented virtuality [AV], also known as the digital twin,” explains James. “It involves bringing real-world data into virtual environments, and it’s where we do most of our work at the RMC.”

The RMC, in Pullenvale, Queensland, is equipped with cutting-edge hardware – including a 6-metre cylindrical display system, a multi-display wall, and wearable computing gear, including a wide range of VR and AR headsets. It’s an impressive display for the industry, government and academic visitors who tour the RMC each year, but it’s the work developing the systems to bring it all to life which is critical, as more mining companies and more areas of the mining process move to being remotely controlled.

“People want to work in the cities,” says James of the move to reduce FIFO and DIDO roles in the sector in favour of remote operations. Early on in the remote-ops era, many workers previously operated heavy machinery on a mine site, so even when they switched to remote control, they had “experienced it first-hand and could translate those skills to the new [remote] interface” explains James. But as those people retire or move on, “you lose a lot of that first-hand skills and knowledge.”

Recently, the computer gaming industry has been reducing the cost and increasing the quality of technologies to create immersive, mixed-reality environments. These gaming technologies can be applied to real-world problems in a field called ‘serious gaming’. “Not so long ago, a flight simulator would cost a couple of million dollars,” explains James. “That kind of technology is still critical in some cases, but now we see very good outcomes, across a wider range of roles, from people using serious gaming systems that cost more like \$6,000.”

“ Situational awareness – knowing what’s happening around you when you are controlling something – is crucial to remote operations – that’s what we’re working to create  
**Craig James, CSIRO**

IMAGE: Digital model of a continuous miner used in developing roadways underground.

AR and VR headsets showing holograms of equipment or of a process – which can increasingly be controlled by natural gestures – are already being used to provide immersive training for mining employees who did not come into the industry via a traditional on-site job.

Remote-ops training for people who will never be on a mine site using “this immersive, mixed-reality technology can train new generations and give them ready access to high-quality, spatially accurate information,” says James. “For example, there are virtual-reality systems that can train people on hydraulic excavators and build up the muscle memory that you can’t get by watching videos or using simulators driven by keyboard and mouse. There’s also growing research on how digital twins can be used to improve ‘human in the loop’ automation.”

CSIRO teams are working in this area of serious gaming to advance from training systems to operational ones, enabling workers to interact in real-time with the digital twin, and thereby observe and control the physical world. “We aim to help people do more with less and continually improve the whole process,” says James.

“We have a lot of experience in applying digital twin technologies in the mining industry, particularly in challenging underground environments where it has been difficult to acquire the data to power the digital twin – for example our laser-based ExScan sensor, part of our LASC [Longwall

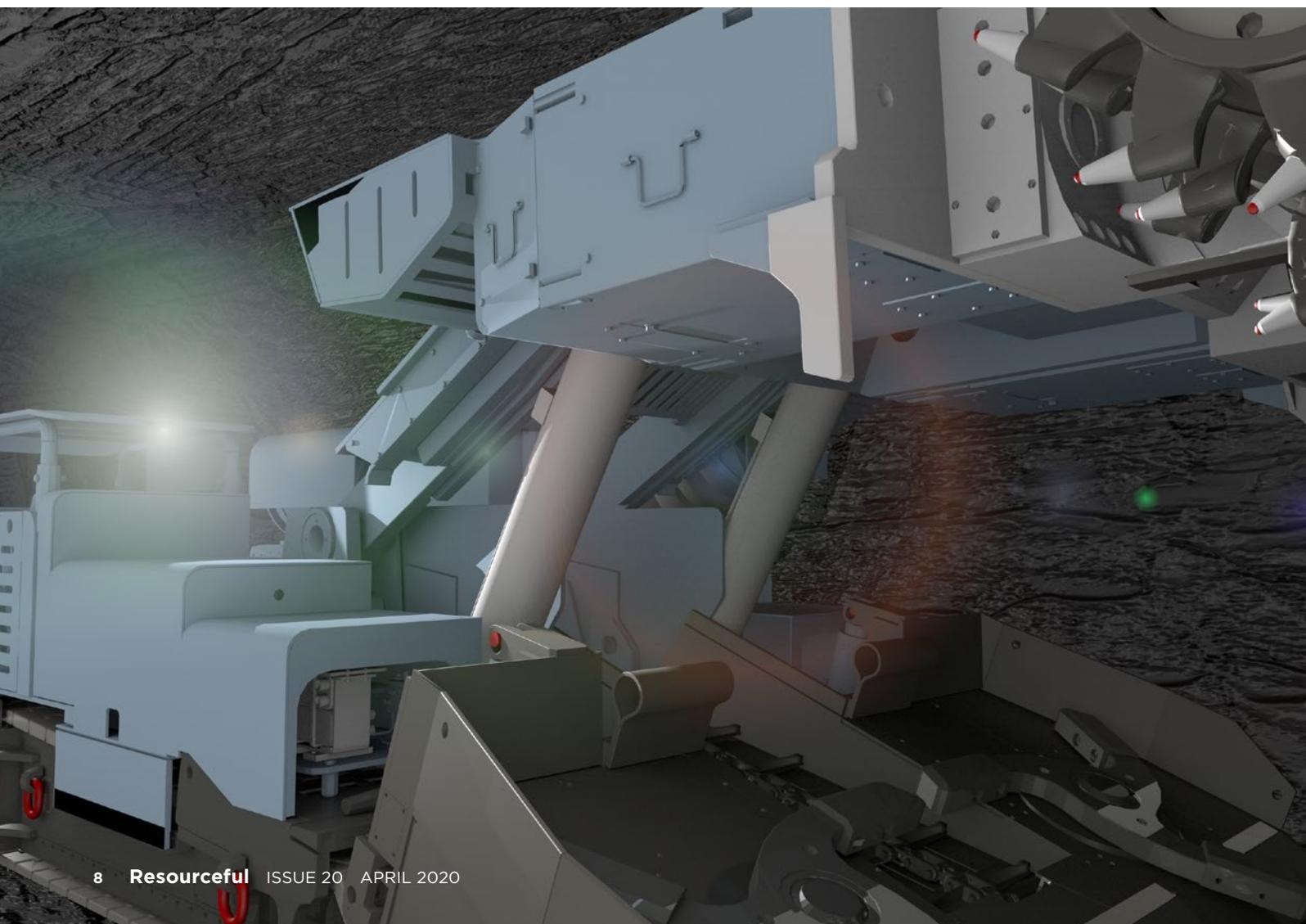
Automation Steering Committee] suite of technologies, now enables us to faithfully recreate the snapshots of the dynamic underground mining environment,” says James.

The future of this technology isn’t only earthbound. As well as “the terrestrial side of things” adds James, the team he works in is also connected to the CSIRO Space Technology Future Science Platform. The vision is to build digital twins that will advance mining processes for future space exploration, where the distances are even more extreme. Mining remote resources will be crucial for space operations to be sustainable.

“When you go to the Moon or to Mars, you need to generate oxygen, water, fuel and building materials,” he says. “There is a whole process of ultra-remote mining being investigated called In Situ Resource Utilisation [ISRU], and digital twins can help with the operational side. So far, we’ve only scratched the surface – CSIRO is working hand in hand with the Australian and international space agencies to take our terrestrial technologies and apply them to our burgeoning space industry.” ♦

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## HUMANS AND HOLOGRAMS IN ACTION

At CSIRO's Data61 Immersive Environments Lab in Canberra, Dr Matt Adcock and his colleagues are recognised for their advanced capabilities in augmented reality and work with the latest technology – such as Microsoft's HoloLens 2 mixed-reality headset – to create more natural ways for humans to interact with holograms.

“The trend with headset technology is a wider field of view, so you can see more holographic information at once,” says Adcock. “One of the holy grails is to bring as much relevant information together in a coherent way. In the case of remote operation, you can have a 3D model of a robot in front of you and you can control your view of it by moving your head around, instead of having to think about how to use a joystick to control a camera. You can reach out our hand, grab the hologram with a pinch gesture in space, and move the end of the robot where you need it to be next. You're doing it very directly with your own hand – it's like using a miniature version of the robot and the types of gestures we use to interact with the physical world normally.”

This will be critical for training future remote workers. “Although we may have people who have never physically been on site, the technology could make it possible to interact more closely with these assets than ever before, even if they were on site – because on site they may have been using a joystick to move a machine. Instead, we'll have a human-robot control loop that taps into a lot of our natural, physical ways of interacting. We've prototyped some of those things in the remote-ops area, including the use of haptics, which allows you to feel resistance from the robot.”

As headset technology advances, HoloLens 2 and others now have hand-tracking to allow such direct manipulation and interaction. Service-technology company Trimble has made HoloLens 2 part of a hardhat with its XR10 unit, which puts data into holographic form and overlays it within the physical job site, enabling construction workers to check digital models against reality, for example. “It is in these kinds of industries where AR is likely to see broad early adoption. It enables you to see things that aren't easy to see and it can also be used to overlay real-time data from sensors”.

**IMAGE LEFT:** Digital simulation of an underground coal mine showing typical lighting conditions in the working environment. **ABOVE:** Simulation of an unconventional gas well from the surface before going underground demonstrating CSIRO's emissions monitoring and microbial enhancement technologies.

PERSPECTIVE

# THE FUTURE OF DIGITAL



Digital transformation in the mining industry is not simply about collecting and analysing data, it is about the application of artificial intelligence to provide feedback loops to the sensors, and machines operating on mine sites. **Sue Keay** writes

**Sue Keay is the Research Director for Cyber-Physical Systems at CSIRO's Data61. With more than 20 years experience in the research sector, Sue has worked with physical scientists, engineers, social science researchers and economists and loves the challenge of managing research across distributed sites.**

**Sue set-up the world's first robotic vision research centre and led the development of Australia's first robotics roadmap, outlining how robotics and automation will impact on every sector of the Australian economy.**

**She has a PhD in Earth Sciences from the Australian National University, an MBA with UQ Business School, is a graduate of the Australian Institute of Company Directors and serves on the Board of the CRC for Optimising Resource Extraction and Women in Robotics International.**

Working in Cyber-physical systems gives me a box seat to witness the transformation possible by combining the digital with the physical, sometimes referred to as the fourth industrial revolution. In this new era, it is not sufficient for machines to be automatised, they must operate with true autonomy, relying on feedback from sensor data to modify their actions.

Digital transformation in the mining industry is not simply about collecting and analysing data, it is about the application of artificial intelligence to provide feedback loops to the sensors, and machines operating on mine sites. It is an important step in the ambition to achieve a zero entry, fully automated, integrated mine that can be applied to any orebody type and at any scale.

The most fun part of my job is getting to see many of the new developments in embedded artificial intelligence, that is, AI applied to physical devices. Embedded AI is manifested in the fields of robotics, computer vision, sensing systems and cybernetics. While there is no shortage of new technologies being developed in these fields that can be applied to the mining industry, the barrier to adoption remains developing in a business case and system-level approach to technology implementation that would see them applied on a large scale rather than in a piecemeal fashion.

This is difficult to achieve unless incorporated in new mine designs, and why it is important to consider the opportunities that new embedded AI technologies may deliver in the future and plan accordingly.

“ But technology is just a tool. The key to embracing a digital future is people. Sue Keay, CSIRO

Some of the trends that I see in the future based on the work being conducted within my research program at CSIRO include:

### **The robotisation of commodity products**

While nothing is more exciting than seeing a new robot being designed and built from scratch, there are a lot of advantages to turning something that already works well into a robot. The robot product cycle can last decades before you achieve a robust and reliable mass commodity product (think robotic vacuum cleaners). What if you could just convert your existing vacuum cleaner into a robot?

There is a reason that self-driving cars are based on existing car designs – because they have been extensively safety tested before being allowed on our roads. Using modular robotic components, in the future we will be able to convert commodity products into robots – think self-driving car kits.

### **Robust and ubiquitous sensing systems**

In developing sensing systems at continental-scale for monitoring the environment, increasingly, our sensors are becoming smaller, cheaper, more robust, reliable and able to operate with no or minimal energy requirements in communication-denied environments.

We are developing algorithms that require low computation power allowing edge computing and teaming this with direct-to-orbit satellite communication from our devices to enable remote IoT (Internet of Things).

Applied to mine sites, integrated sensing systems will enhance safety and real-time decision-making, allowing tracking of all mine assets (including people) in real-time, information which could be used, for example, to ensure that blast zones are clear.

### **Computer vision systems increasingly trained on synthetic data**

Computer vision is fast becoming an indispensable tool for obtaining situational awareness, predicting future events and enabling perception for autonomous machines. Despite rapid advances in machine learning, computer

vision systems remain limited by access to large datasets of labelled images, that are hard to obtain for all but tech giants and unreliable at identifying rare events due to the scarcity of training data.

Many high-risk activities are rare but may have catastrophic impact, so it is important that computer vision systems are able to correctly identify any signs of such an event. It is now possible to create data simulators to generate contextually relevant data with quality labels in order to train computer vision algorithms and which can in turn be used to train robots for different activities.

The accuracy of synthetic data can be tested against real data, for example using motion capture systems such as Australia's largest MOCAP system at CSIRO's Data61 facility at the Queensland Centre for Advanced Technologies that is open for use by industry. Synthetic data has the potential to disrupt the tech giants whose power lies in access to proprietary datasets (data moats) and will allow start-ups to scale into many new areas.

### **Collective Intelligence**

Australia's Team CSIRO Data61 recently competed in the DARPA Subterranean Challenge in the US. The SubT Challenge requires teams to deploy robots underground with no access to communications (save what the robots can carry) where they are given one hour to explore and find artefacts, replicating a disaster response scenario. This brings together several strands of our research over many years.

One of our most exciting outcomes has been the successful application of multiple robots working together as a team with a common navigation platform to share and correct one another's maps and understanding of the world in real-time under challenging circumstances.

The IoT era means we will be increasingly dependent on multiple sensors (some carried by robots) and we will rely on these sensors to validate each other's data. This helps to ensure the accuracy of the sensor data itself, where we are increasingly using blockchain to record

verified data and monitor the integrity of supply chains to spot substitutions or product loss. As well as applications to supply chain management, the same collective intelligence can be applied to many other areas on a mine site such as predictive maintenance.

### **Self-repair and self-fabrication**

The advent of 3D printing has enabled us to rapidly prototype-test-redesign-repeat robot components to optimise their performance. Pairing this with new developments in materials science and the increasing ease of multi-material 3D printing opens up the possibility, long dreamed, of self-maintaining and even self-creating robots.

This is an important consideration for projects such as the “moon village”, a European Space Agency backed lunar construction project where the aim is for building to be completed before a human ever sets foot in the village.

There are similar potential applications in many parts of Australia that rely on remote operations, and in the future, we will need a range of skilled people and insights from AI to continue to explore new and creative ways of solving problems using intelligent machines.

### **The Future**

The range of new technologies being developed opens up the possibility of us solving more and more problems that were once considered unsolvable. But technology is just a tool. The key to embracing a digital future is people.

While it's important to understand what tools are now available that work better than tools of the past, we require people with the vision and drive who will seek to make whole-of-system changes and put the hard work in to demonstrate the business case that makes the adoption and integration of many of these technologies, a wise choice for the mining sector.

Without that vision and drive, mining will not see the same level of productivity improvements from the application of digital technologies that we are starting to see in other sectors. ♦

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## DARPA SUBT CHALLENGE

# ROBOTS BOLDLY GO UNDERGROUND TO FLY THE FLAG

CSIRO robots can detect and locate objects and navigate their way through previously unknown underground areas. **Tony Heselev** reports

The CSIRO robots – two drones and five tracked vehicles – competed in an international event that simulated potentially unsafe scenarios faced in mining, search and rescue, defence and even space exploration.

The competition challenges autonomous robots to find objects, such as mannequins, backpacks, fire extinguishers and mobile phones, and accurately report their locations – without GPS.

CSIRO is the only non-US lead organisation selected to compete in the event, known as the DARPA Subterranean (SubT) Challenge. DARPA, the Defense Advanced Research Projects Agency, is the main US government-funded defence research agency.

The competition, in Elma, Washington State, took place in an underground industrial environment at an unfinished nuclear power plant, which was fitted with corridors and barricades, with stairs and shafts connecting different levels. No human competitor was allowed inside.

The CSIRO robots have intelligent payloads, including a ‘perception pack’ featuring four cameras and a spinning laser that are the robot’s eyes.

The robots use software developed by CSIRO, called Wildcat SLAM (simultaneous localisation and mapping), to generate a map of structures around them. Another software program uses these maps to plot a safe pathway for the robot. This stops the robot from (for example) bumping into obstacles, trying to scale walls or falling off cliffs.

Only one human supervisor is allowed to communicate with the robots, so each robot needs to be capable of navigating itself.

Navinda Kottege, Research Team Leader and Senior Research Scientist with CSIRO’s Robotics and Autonomous Systems Group at the Queensland Centre for Advanced Technologies in Brisbane, said: “The robot has to go in there and figure out the location of doorways, passages, obstacles and open space.”

Another part of the SubT Challenge is for teams to be able to add sensors to the robots – for example, to detect gas leaks.

Robotics has significant implications for the mining industry. Robots could enter a collapsed mine after an explosion to tell if it is structurally sound and safe for people, and develop accurate maps of the structure to enable continuous mining. Robots could also be useful in mine rehabilitation, enabling estimates of how much fill is required to be brought in, saving money and time and keeping people safe.

The DARPA SubT Challenge comprises tunnel (held in August 2019), urban (February 2020) and cave (August 2020) circuits. The final, for which DARPA will select six competing teams, will be held in August 2021.

The CSIRO team, which is funded by DARPA and CSIRO, came fourth of 10 competitors in a tight urban competition. It received a special mention for reporting the location of a backpack within 22 cm of its actual location. The CSIRO robots detected backpacks, mobile phones, survivors (thermal mannequins), heated vents as well as gas leaks (CO<sub>2</sub>) in the four scored runs of the event.



We are hoping to put Australian robotics capability under a global spotlight in this challenge, and also to use the technology that we develop to apply to problems faced by Australian industries.

**Navinda Kottege, CSIRO**



Since finishing fifth of 11 in the tunnel challenge last year, the CSIRO team has been further developing the robots' hardware, software and communications.

"We have upgraded the chassis, motor and gearbox of the larger tracked robots, to make them lighter and improve weight distribution for easier handling and stair climbing," Dr Kottege said. "And we have introduced communication nodes that give us much more robust and reliable bandwidth at a longer range, and enable multiple robots to share each other's map frames."

He said tracked robots cannot access areas such as mezzanine floors, and drones cannot access narrow entries and passageways. The type of robots CSIRO used in the event depended on the type of environment encountered (DARPA provides no advance information on this).

Atlas (pictured) is a fully autonomous robot consisting of a Superdroid LTE2 platform as the base and CSIRO's Perception and autonomy pack on top. This robot is capable of localising itself in an unknown environment while creating a map of the surrounding area using CSIRO's Wildcat SLAM technology. It can then communicate this information back to a remote base station using wireless mesh networking.

The drones, which are carried on top of the larger tracked robots going into the course, have a shorter run time (about 15 minutes) compared to more than one hour for the tracked robots. The total time allowed for the course is one hour.

Points are earned if the robots correctly identify the type of object and the reported location is within five metres of the actual location. Each course has a maximum of 20 objects.

The 20-member CSIRO team combines the expertise of CSIRO's Data61, spinoff Emesent, US research partner, the Georgia Institute of Technology, and other Australian partner universities and robotic companies.

"We are hoping to put Australian robotics capability under a global spotlight in this challenge, and also to use the technology that we develop to apply to problems faced by Australian industries where they require exploration in dangerous environments," Dr Kottege said.

The technology behind the robots – the perception pack, comprising the SLAM software, cameras and sensors – is in demand from companies who want to use it on their own vehicles. CSIRO is in negotiation with potential industrial partners including oil and gas companies, the mining equipment, technology and services sector and the defence industry. ♦

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WORKING IN INDUSTRY

# MARGAUX LE VAILLANT AND BHP

CSIRO's SWITCH program has given a research scientist from halfway across the globe the opportunity to get her hands – figuratively – dirty while immersing herself in prospectivity analysis at mining company BHP for three months.

**Rob Hobson** reports

It was an opportunity Paris-born CSIRO geologist and research scientist Margaux Le Vaillant found out through, of all things, a brainstorming session, about ways to improve collaboration between industry and research institutes.

“During one of the brainstorming sessions I said, ‘We should have more placements, secondments and close direction’, and through that I found out there was already a program in place,” she said.

“At the end of that session I asked for more details about the SWITCH program, and I started to think about who I would do the secondment with because I’ve always wanted a bit more industry exposure.”

The program is open to everyone at CSIRO which aims to give its researchers direct exposure to the ‘business side’ of scientific research by embedding them in partner organisations for a period of time.

It is hoped these placements will broaden their horizons by being exposed to the host organisation’s business models, markets and commercial operations, and using that information to better align their research to the needs of industry.

Margaux said research scientists can often fall into the trap of designing projects or research proposals first and seeking industry approval and funding second. If the approach was the other way around, it could give researchers more clarity as to the challenges faced by industry and thus forming their research solutions and projects to overcome those challenges.

This would also increase the possibility of funding being granted for their projects.

“I came straight from academia, so I haven’t spent that much time within the mining industry,” she said.

“I think if you want to align your research to what they really need, you have to understand how their funding model works, the cycles that they have, when is a good time to ask for funds and when it’s definitely not, how they pick the project they’re going to fund, and how they identify the areas they need research done in.”

The off-the-cuff comment certainly paid off for Margaux who decided on a placement in BHP’s Technical Centre of Excellence and Legacy Assets, which she describes as the company’s ‘internal experts’ because of their work in identifying system bottle-necks and issues, training and upgrading staff capabilities, and providing guidance as to which research projects to fund.

She also gained experience with the Metals Exploration and Nickel West teams, where she applied her research into magmatic nickel sulphide systems into developing best-practice procedures, workflows for prospectivity analysis and potential applications of geochemical exploration tools.



“Before I started the secondment, I knew I wanted to work on bringing my expertise, which was around nickel, and combine it with mineral systems thinking,” she said.

“So by using mineral systems thinking and applying it to magmatic nickel sulphide systems I helped build some of the frameworks for exploration targeting, which basically applied a lot of what I was doing in the past eight years of research.”

“Working with the BHP teams was a highlight for me because I got to work on real projects and did some actual prospectivity analysis on actual exploration grounds.”

The SWITCH program also has great benefits for the host organisation, enabling them access to the skills and insights of their secondees for their business.

BHP’s Head of Geoscience Excellence Cam McCuaig said Margaux’s knowledge of nickel, the ability to hit the ground running and applying mineral systems thinking into real geoscience datasets made her a valuable addition to the company.

“Margaux was our first secondment from CSIRO in the centre and she integrated very well with the teams,” he said.

“Commodity experience was an essential part of her input and specifically her very high calibre knowledge of the processes which form a nickel sulphide system,”

“Her prior experience in applied academic research in a variety of nickel deposits allowed her to frame and articulate a solution to the work she was asked to complete for us,”

“Her work definitely impacted our thinking and we would certainly consider taking advantage of the SWITCH program again for the right individual.”

Margaux thoroughly recommends the SWITCH program, however, advises candidates to ‘do their homework’ in the areas and industries they wish to be seconded to.

“I think because CSIRO is an applied research centre it just makes sense to understand who we do research for. And choosing the right partner for that is important,” she said.

If you are interested in being a secondment partner or would like to discuss potential secondment opportunities to host CSIRO team members at your organisation, please contact Keryn Mendes, CSIRO Human Resources Advisor by emailing [keryn.mendes@csiro.au](mailto:keryn.mendes@csiro.au). ♦

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IMAGE: Margaux on the job in the Pilbara with Mark Pearce, Samuel Spinks and David Fox from CSIRO.

CONFERENCES

# SCRATCHING THE SURFACE AT SUBSURFACE 20

CSIRO Deep Earth Imaging Future Science Platform recently hosted its inaugural subsurface imaging conference on 12-13 February at Optus Stadium in Perth.

Over two days, attendees heard from keynotes Lucy Macgregor, Edinburgh Geoscience and Cognitive Geology and Malcolm Sambridge, Australian National University and experts with extensive experience in energy, minerals and inference and discussed challenges on imaging, conceptualisation and prediction of mineral, water and energy resources.

Subsurface 20 also gave attendees the opportunity to identify synergies and gain awareness of methodologies and workflows that are routinely used in one domain but largely unknown or receive limited application in another.

The consensus view in industry, government and academia, highlights the need for advanced geophysical, mathematical and computational tools, along with new geochemical and geological approaches and understanding to more precisely image the subsurface, to direct our exploration efforts and predict processes that form these resources.

An additional challenge and opportunity for those working in the sector is a recognition that social and environmental performance must also be met. All stakeholders should work together to develop and secure our resource base in a sustainable way. ♦

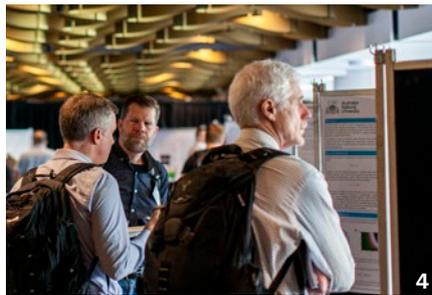
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1. Keynote presenter Lucy MacGregor, Edinburgh Geoscience Advisors, Cognitive Geology discussed the current status of techniques and technology to understand the subsurface, and future directions of research and industry needs.  
2. Jayden Boundary, Tim Munday and Shaun Nannup.

Australia's future endowment of mineral, energy and water resources will come from far greater depths in the Earth. Onshore, this will be in settings where regolith and sedimentary cover characterise the landscape, not least because these materials cover ~80% of Australia's land mass. Our ability to find and develop these resources is limited by their complexity and thickness.



3. Sandra Occhipinti, Research Director Discovery and Cathy Foley, CSIRO Chief Scientist. 4. Professor Richard Smith from Laurentian University and CSIRO's Thomas Poulet and Peter Schaub checking out the Sub20 poster exhibition. 5. Andrew Fitzpatrick, Chief Geophysicist Independence Group and Michelle Salmon, Australian National University. 6. Audience and attendees at Sub20 Conference holding hands during Welcome to Country. 7. Peter Schaub, Research Team Leader 3D Structural Geological and Numerical Modelling presented on numerical simulation of critical mineral system geological processes. 8. Professor Boris Gurevich from Curtin University discussing the importance of rock physics for CO<sub>2</sub> geosequestration. 9. Troy Thompson, DownUnder GeoSolutions presenting on full waveform inversion advancements for subsurface interpretation.

# SCIENCE COLLABORATION TO SUPPORT REGIONAL AUSTRALIA AND THE MINING INDUSTRY

The federal government's announcement of a new Co-operative Research Centre (CRC) provides a unique collaborative research opportunity to support regional communities facing mine closures.

As Australia's national science agency, CSIRO will bring expertise across environment, indigenous and regional engagement, mining technology, systems integration, and data processing and management into the new CRC on Transformations in Mining Economies (CRC-TiME).

The \$29.5 million funding announcement for the CRC by federal Science Minister Karen Andrews MP today is part of a total 10-year investment of \$135.4 million to support the successful transition of mining communities to form sustainable community and development opportunities.

The CRC is jointly led by the University of Western Australia and the University of Queensland. The centre brings together a unique partnership that includes 75 mining industry, government, METS companies, research organisation, including CSIRO, and community/regional groups with a vision for sustainable mine closures and community and regional development opportunities in Australia.

CEO Dr Guy Boggs said, "CRC TiME has the potential to create hundreds of new opportunities and regional jobs through the implementation of restoration activities and increased supply of closure and post closure products and services."

Senior scientist Dr Jason Kirby, who leads CSIRO's involvement in the CRC, said "the scale of investment across community, government and industry will have major benefits for regional Australia with several large mines reaching their end and closing in the near future."

"This effort will support regions to transition to a more prosperous and sustainable post-mining future, acknowledging the need for whole-of-community benefit, including indigenous futures, environmental restoration, and economic outcomes."

CSIRO's role is to support the collaborative research programmes and assist the CRC to establish nationally recognised demonstration sites where technology and solutions can be shown to bring positive benefits to the community and to mine closures.

"The demonstration sites will provide an avenue to assess, test and showcase technologies and solutions through a unique collaborative platform." Dr Kirby said.

The CRC is in initial stages of establishment and planning to deliver value to its partners, government and regional communities. Research planning is underway develop a research framework, identify capability, and refine research questions. Consultation with CRC partners will start in late April 2020 to discuss the research framework and to identify and scope a range of short-term foundational projects that can be commissioned early in FY20/21.

Visit the CRC website ([smi.uq.edu.au/crc-time](http://smi.uq.edu.au/crc-time)) for more information and a full list of current CRC-TiME partners.

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As Australia's national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.

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