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QCAT Industry and Research Report 2009-10

Queensland Centre for Advanced Technologies

Mission

The Queensland Centre for Advanced Technologies is a world class research and development precinct recognised for the excellence of its contribution to the mining, energy and manufacturing industries. Our mission is to generate products and processes of high value to Australia's mineral, energy resources, and manufacturing industries with particular focus on those resources and industries located in Queensland.

Goal

Our goal is to increase the international competitiveness and efficiency of Queensland's and Australia's resource based and related industries.

History

The Queensland Centre for Advanced Technologies is a collaboration between the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the State Government of Queensland. The establishment of the Centre flows from an agreement between the Australian and Queensland Governments in 1990 to expand and diversify the research and development activities undertaken by CSIRO in Queensland. The Centre commenced operation in 1992 and was officially opened in 1993. Following the construction of new facilities, Stage Two was opened in 2000. The precinct continues to grow and planning for Stage Three expansion is under way.

Government occupants

CSIRO

- Energy Technology
- Earth Science and Resource Engineering (formerly Exploration and Mining)
- ICT Centre
- Process Science and Engineering (formerly Minerals)
- Energy Transformed National Research Flagship
- Light Metals National Research Flagship
- Minerals Down Under National Research Flagship
- Wealth from Oceans National Research Flagship

Defence Science and Technology Organisation

Commercial occupants

Applied Mining Technologies Pty Ltd

BHP Billiton Carbon Steel Technical Marketing Group

CET Group

GeoTek Solutions

Rio Tinto Alcan Queensland Research and Development Centre

Teakle Composites

CSIRO

Queensland Government

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denotes QCAT Commercial tenants

Foreword

This year marks the 20th anniversary of a landmark agreement between the Queensland and Australian governments to expand and diversify the research and development activities by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in this State, which ultimately led to the establishment of the Queensland Centre for Advanced Technologies (QCAT) in Brisbane as a collaborative facility between CSIRO and the Queensland Government.

Since its establishment in 1992, QCAT has continued to grow to become one of the largest, collaborative, technology precincts for the resources and advanced technologies industries in the world. I am pleased to note that 2010 will see even further development of the precinct with the move by BHP Billiton of their coal research facilities and research coking ovens to the site.

The QCAT facility embodies the Queensland Government objectives for a Strong, Green and Smart State economy. It actively enables CSIRO, industry, government and other R&D providers to form partnerships in areas essential to Queensland's future development, in fields as diverse as low emissions coal technologies, smart mining, minerals processing, niche materials manufacture, information and communication technologies, and aeronautical engineering.

The research support provided by QCAT helps deliver a competitive edge to the Australian and Queensland mining, minerals processing and energy industries at a time of continuing global uncertainty. It is the continued health of our mining industry that has largely helped us avoid the economic turmoil that has engulfed other economies.

This is particularly so for Queensland. In 2008-09, the mining industry's contribution to the state economy stood at $49.4 billion or more than 20% of gross state product and directly or indirectly provided for over 200,000 full-time jobs – roughly one full time job in eight.

The importance of this industry is also why, despite tight financial circumstances, the Bligh Government is investing a further $18 million in a Greenfields 2020 program to target key under-explored geological terrains over the next four years.

The continuing success of the QCAT partnership between CSIRO, the Queensland Government and other research initiatives, is of critical importance for its tangible benefits to industry, and therefore the economy and employment in this State.

As example of these tangible benefits, I am pleased to note the recent significant developments regarding successful underground testing of the wireless ad hoc system for positioning ('WASP') localisation technology, development of prototypes for a lightweight corrosion-resistant piping system for underground coal mines by Teakle Composites and progress in field-testing CSIRO's 25 kW VAMCAT (ventilation air methane catalytic turbine) in collaboration with Huainan Coal Mining (Group) Co Ltd in China.

The VAMCAT device in particular has the potential to concentrate low levels of otherwise waste methane gas in coal mines for use in power generation, thus reducing greenhouse gas emissions and improving site safety and economics – a win for everyone.

I congratulate QCAT on its continuing ability to deliver world -leading technological and materials development from which we all benefit, and hope for the organisation's long and continued success in the future.

The Hon Stephen Robertson

Queensland Minister for Natural Resources, Mines and Energy and Minister for Trade

Executive Manager's report

The Queensland Centre for Advanced Technologies (QCAT) continues to develop in its role as a global research precinct for the mining, mineral processing and energy domains.

In July 2009 we welcomed BHP Billiton's Carbon Steel Technical Marketing Group to QCAT, forming an alliance that has led to collaborative projects between CSIRO and BHP Billiton including the relocation of research coking ovens from the company's Newcastle Technology Centre. This new research infrastructure will be housed in newly redesigned process bays and will be operational by early 2011. This is an exciting step, making it possible for QCAT scientists and engineers to work on most of the steelmaking chain from new iron ore and coal mining and processing technologies to the coke making process.

This year has also seen the implementation of CSIRO's Virtual Mining Centre. Simulation, visualisation and the processing of huge data sets are fundamental to innovation in our resource industries. This new Centre is well positioned to meet the demand for these new technologies, with an immersive display coupled to a supercomputer capable of processing and storing huge data sets. To date, the Centre has been used to visualise mine layouts, predict fluid dynamics in the real-time mine environment and provide an immersive display to test the control and supervision of semi-autonomous and autonomous machines. The Centre has already seen results with a pilot project to tele-operate a ship loader going live in June 2010.

Congratulations are due to our property services team for winning CSIRO's Environmental Award for reducing water usage at our Queensland sites (including QCAT) by 70% over the past five years.

In the coming year, QCAT's innovative scientists and engineers will continue to have a substantial impact on our industry and community as we continue to provide solutions to the challenging problems being set by the Australian energy, mining and mineral processing industries.

Mike McWilliams
Executive Manager, QCAT

Mining

The last financial year has seen major upheavals, domestically and internationally, in mining and the mining services sector. In this challenging environment Australia is investing in technology to help maintain the industry's market position; in short, Australia's mining industry has to become more sophisticated. A fundamental goal of QCAT is to research and deliver technologies to address these industrial challenges.

The smart mining cluster at QCAT incorporates CSIRO and a number of small to medium enterprises from the mining services sector. Collaborative R&D at the precinct covers a broad range of mining activities from coal to hard rock and sand, mined by underground and open cut systems. Research aims to improve safety, increase productivity and reduce environmental impact by providing applied technological and robust solutions.

Mining geoscience

Geology and geophysics

Geological knowledge underpins all mining decisions. Our research spans the energy domain – coal, coal seam gas, CO_2 sequestration and geothermal energy – and the metalliferous industry. Mining and exploration companies access and generate vast amounts of geoscience data, from which they extract critical information and knowledge. Research into the collection, manipulation, modelling and visualisation of data allows for a diverse range of activities, from understanding basinal controls on coal deposit formation to the development of new computational tools for analysing and interpreting complex spatial data.

The ability to analyse and determine relationships between complex and disparate, spatial and non-spatial geoscience data sets is crucial to extract the maximum information from the enormous data sets available. New computational tools are being developed based on data mining technology that will provide geoscientists with an improved capacity to understand subtle clues and discover new relationships in diverse data sets.

Advanced microseismic monitoring systems and data interpretation software packages have been developed for coal mining. These systems have been used for longwall geomechanics assessment and hazard control. This technology is developing towards a real-time microseismic monitoring system for longwall coal mining. Passive seismic techniques using machinery sources (mining machine and drill bit) that can used for rock mass characterisation and geomechanic imaging have also been demonstrated.

Geophysical imaging is undergoing a revolution with new 2D and 3D seismic reflection surveying techniques and borehole tomography surveying and analysis using seismic, radio imaging and radar techniques. Developing new techniques for data processing, analysis and interpretation will result in greater understanding of ground behaviour and response to mining.

An important research goal is to integrate three-dimensional distributions of geophysical, geochemical, geological, geotechnical, petrophysical, physical, mining and metallurgical information into a 'common mine model'. These data sets are then analysed in an integrated fashion using various techniques including traditional statistical modelling and advanced data mining approaches, to reduce industry risks and uncertainty associated with mine evaluation, design and production.

Coal characterisation

Optical microscopy is being used to provide textural, density and chemical information of individual grains of coal and rock from cores, stockpiles and on-line sampling.

The coal grain information is matched to markets that maximise their economic worth and to develop processing strategies that optimise recovery. CSIRO has developed a unique ability to identify coals that are amenable to liberation and hence to produce low ash, higher value traditional products. This is coupled with identification of coals most suited for use in high value, high efficiency processes such as direct conversion of coal to liquid fuels or as coal water feedstock for large scale diesel engines. Coal grain information is also used to track the flotation response and flotation kinetics of individual grain types. Coal companies routinely use this information to quantify inefficiencies in the flotation process that result in loss of recoverable coal to tailings and entrainment of minerals in the coal.

Nuclear science: Borehole logging

CSIRO prompt gamma neutron activation logging technology has been used by ANSTO to develop a method of measuring hydraulic conductivity. This technique will help in the development of groundwater flow models that assist in understanding the effects of removal of water from underground aquifers. The technology is also being used in mine development and grade control applications in developing countries such as Bangladesh and Pakistan.

Research on borehole logging technologies is investigating methods for analysis and interpretation of disparate borehole logging data. Sophisticated data analysis methods are being employed to process disparate borehole geological, geophysical and geochemical data sets to deliver improved interpretations of all available data in an integrated approach.

3D Imaging and 3D data processing

The efficiency, ease of use and support features of Sirovision® have made it the leading technology to generate and analyse high-precision 3D images of rock mass surfaces in mines around the world.

The product enables the generation and analysis of high-precision 3D images of the exposed rock mass surfaces for open pit and underground environments. The spatial and visual data in the 3D images supports precise and previously unachievable capability for mine mapping of rock mass structure, slope stability analyses, blast optimisation, fragmentation and other mining activities. This capability is also being used for providing machine vision for remotely controlling equipment, such as SAG mills and on-line monitoring of mining processes. A prototype rock breaker has been developed for Rio Tinto and tested with excellent results.

The increased use of large scale 3D imaging requires improved visualisation of the data produced. These systems now produce very large and detailed data sets that were previously impossible to generate on desk top computers. To support the increasing use of 3D imaging new tools capable of displaying gigabyte data sets at pixel resolution have been developed.

A process of improvement is ensuring that new facilities in Sirovision® will continue to support operations in open pit and underground environments.

Coal mining

Thick seam mining

Longwall Top Coal Caving (LTCC) techniques allow for the recovery of more than 80% of a thick (4.8–12m) seam, significantly exceeding the current longwall extraction heights in Australia of 4.8 m.

LTCC was developed by the Chinese coal industry. The technology has the potential to double the recoverable amount of coal as well as offering safety benefits through lower cutting heights and a reduced risk of spontaneous combustion by reducing the amount of coal left in goaf areas. CSIRO has been working with several major mining companies to assess the potential of LTCC implementation at mine sites in Australia.

CSIRO is undertaking a feasibility study of using LTCC for thick seam (up to 10m) in Singareni Collieries in India. This project is supported by the Asia Pacific Partnership on Clean Development and Climate.

Mine fire control

Heatings and fires in underground longwall mines are a major industry issue resulting in safety risks and production losses. CSIRO, with funding from ACARP and strong support from Australian coal mines, has carried out several projects in the recent years to address this issue.

The initial projects were aimed at developing a fundamental understanding of airflow patterns and heating gas flow behaviour in longwall goaf areas. Involving extensive field and numerical modelling studies, these projects investigated oxygen ingress into the longwall goaf areas and the behaviour of heating-related gases such as carbon monoxide and hydrogen. Studies took into account a variety of mining and operating conditions and the impact of different goaf inertisation techniques on effective dilution of heating gases.

Recent projects have been aimed at developing optimum technologies and strategies for control and prevention of spontaneous combustion, heatings and fires in longwall goaf areas. Field studies conducted at a number of underground coalmines in Australia have shown that the proactive strategies were successful in reducing oxygen ingress into the longwall goaf areas and in reducing the risk of fires and explosions in the longwall mines.

Research in this area has been further extended to develop appropriate proactive strategies and technologies for prevention and control of heatings and fires in difficult mining conditions such as bord and pillar thick seam extraction panels at Singareni mines in India. This project is supported by the Asia Pacific Partnership on Clean Development and Climate.

Longwall dust control

Dust control on longwall faces remains a challenging issue for mine operators. With the support of ACARP and industry, several dust research projects have been carried out over the last few years. The projects involved 3D computational fluid dynamics modelling of respirable dust dispersion patterns on longwall faces, and investigation and development of a range of dust control options, technologies and strategies.

A major outcome from these studies is the development of a new shearer scrubber system to reduce the longwall operator's exposure to dust. Recently, the system was successfully demonstrated on a longwall shearer at BHP Billiton's Broadmeadow mine, with tests showing significant reduction in operators' dust exposure levels. CSIRO is also working on the application of water mist technologies for dust suppression.

Three dimensional mine scale simulations of coalmine geotechnical and environmental issues

The Australian coal mining industry's license to operate is under increasingly intense public and political scrutiny due to unprecedented social and environmental accountability. The absence of robust and accurate predictive tools for impact assessment and management may significantly affect industry ability to gain mining approval where significant aquifers, surface water or flooded workings are involved.

Current research will improve the ability to characterise ground conditions, produce a better understanding of rock deformation and make more accurate predictions of hydrogeological response, groundwater inflow including aquifer interference and mine gas emission. This work will reduce risk and environmental impact, positively influencing mining safety, productivity and coal resource recovery by providing industry with a generic site hydrogeological assessment methodology.

COSFLOW remains the centrepiece of this research. COSFLOW is an integrated simulation software package developed by CSIRO, in conjunction with JCOAL and NEDO in Japan, which couples fluid (gas and water) flow through a porous medium with rock deformation and stress.

CSIRO has recently started a two year ACARP-funded research project aimed at advancing understanding of the fundamental mechanics of strata and groundwater interaction processes to facilitate prediction of water inflows into longwalls and mining-induced aquifer interference.

Comprehensive field work is ongoing at Springvale colliery to understand the *in situ* hydrogeological environment and to determine the extent and magnitude of induced hydrogeological changes in the surrounding strata during longwall mining. Similar work is about to start at the BHP Billiton Dendrobium Mine and Peabody Metropolitan Colliery in NSW.

Another project at Singareni Colliery in India involves selection of reliable site characterising tools and methods. Currently geological and geotechnical characterisation work and assessment of strata caving characteristics are under way. This work will assist in assessing the viability of introducing highly mechanised longwall mining, and the recommendation of a suitable longwall mining design and equipment.

Mine subsidence control and remediation

The possibility of ground subsidence from longwall mining or old bord and pillar mining under river systems, gorges, cliffs, power lines, pipelines, communication cables, major roads and bridges, and other significant surface facilities is increasingly becoming a major community concern. Some old bord and pillar mines in densely populated areas (e.g. Collingwood Park in Ipswich) have encountered sudden ground failure and subsidence many years after the completion of mining. New cost-effective technologies are required to prevent, control and remediate the subsidence.

Grout injection is used to control coal mine subsidence by injecting waste material (e.g. fly-ash) into the mining voids and/or the overburden bed separations. This technology has great potential for wide implementation in the Australian mining industry and the communities affected by old

mines because it is cost effective and environmentally friendly.

Over the past seven years, through two ACARP projects and two BHP Billiton sponsored projects, an integrated method of feasibility assessment in grout optimisation and site specific injection design have been developed. A pilot injection trial was carried out at Baal Bone Colliery using flyash grout. The trial provided data on grout flow in underground fractures which is essential for operational injection design. Detailed geotechnical monitoring and feasibility studies have been conducted in West Cliff Colliery, Mandalong Colliery and Moranbah North Colliery for using this technology.

CSIRO is currently working with the Department of Infrastructure and Planning (Queensland) on remediation treatment of the mined-out areas in Collingwood Park, Ipswich. Two subsidence events have previously occurred under the residential areas, damaging houses and roads. This study is aimed at providing a feasible and effective remediation method that will reduce or eliminate the risk of further subsidence events in this area.

In this project CSIRO has developed a cost-effective remediation method using non-cohesive backfill material which is estimated to save $17 million compared with conventional cohesive backfill for Collingwood Park remediation. CSIRO has also developed methods and procedures to evaluate the subsidence risk in areas undermined in the past.

This research is leading to the development and implementation of new technologies that not only prevent or reduce mine subsidence but also utilise mine waste, coal wash and flyash, reducing the environmental impact of coal mining.

Deep coal mining

The depth of underground coal mines is increasing in Australia and overseas, resulting in a range of challenges including high stress, high gas pressure, low permeability and high rock temperature. To assist the future development of mining deep coal safely and effectively, new technologies are needed.

CSIRO has established a research program, in collaboration with the Chinese Huainan Coal Mine Group, to develop integrated mining and gas extraction technology for deep mines. A systematic research program is being carried out on two Chinese mines that are up to 800 m deep. This project includes comprehensive geotechnical field monitoring, tracer tests for gas flow patterns, and 3D coupled numerical modelling of the site.

The project has been successful in systematically measuring the strata movement, stress change and fluid pressure change in the overburden of an 800 m deep longwall panel. Based on the results from field measurements and 3D numerical modelling using the unique CSIRO COSFLOW, a coupled mechanical/fluid/gas strata response model to longwall mining has been developed.

The interim results have significantly improved understanding of the caving characteristics and fluid flow patterns in the overburden strata in the deep mine environment. These results provide critical information for the design of gas extraction during mining. This research will lead to maximum extraction and utilisation of mine gas and a significant reduction in greenhouse gas emissions from deep coal mines.

Outbursts of coal and gas

Due to the dynamic, sudden and violent nature of coal and gas outbursts, these events are poorly understood. This complex interplay is one of the major safety issues in underground coal mining. The key to effective management and control of outburst is accurate prediction attained by studying the mechanisms and characteristics of their occurrence.

CSIRO has established a research program, in collaboration with China Huainan Coal Mining Group, to develop practical technologies to predict outbursts. Over the last four years, through two projects, key components of gas content based outburst prediction technologies have been developed. These include a detailed understanding of the mechanism of the outburst initiation and propagation, development of an innovative coal sampling technology in soft coal seams, and development of a 3D numerical simulator of outbursts of coal and gas. These breakthroughs are critical for development of a comprehensive system of outburst prediction.

In the long term, this research will lead to development of site-based operational procedures for outburst prediction, hence minimising the risk of gas and coal outbursts in underground coal mining.

Coupled fracture mechanics

With increasing concerns about environmental issues related to the mining, petroleum and energy sector worldwide, the field of rock mechanics is being advanced and widened to address the complex behaviour of mechanical, thermal, hydraulic and chemical responses of rocks. Understanding and predicting the effects of the interactive processes between explicit rock fracturing, temperature change and fluid flow remains a key challenge for industries such as geothermal and CO_2 geosequestration.

To address these issues, CSIRO has established an international collaboration project with SKEC (S Korea), KIGAM (S Korea), LIAG (Germany), GeoFrames GmbH (Germany) and FRACOM (Finland). The aim of this project is to develop knowledge and numerical tools that help us to understand coupled facture mechanics on engineering scales.

In this project a thermal-mechanical coupling using fracture mechanics software called FRACOD has been developed. Laboratory investigations on rock strength and fracture toughness in a temperature range of -90°C to 250°C have been carried out. The coupled code has been applied to a pilot liquefied natural gas (LNG) underground cavern operated by SKEC at Daejeon, South Korea. The code simulates the cases where excavation, concrete lining and thermal insulation layer are all present. A good agreement has been obtained between the FRACOD simulation and the actual field measurement data in the pilot LNG cavern.

The hydro-mechanical coupling in FRACOD has recently been completed. It focused on fluid flow in explicit rock fractures using the cubic law. Future developments of FRACOD are planned for solving 3D problems and complex coupling issues.

This study will provide a unique analysis tool for many existing and emerging industries including mining, coal mine gas extraction, geothermal and LNG underground storage.

Metalliferous mining

The Minerals Down Under National Research Flagship has provided a renewed focused investment into metalliferous mining that will transform the way that mining is undertaken across a number of key mining domains:

- enhanced knowledge from drilling
- geologically intelligent surface mining
- non-entry underground mining.

Enhancing knowledge from drilling

Drilling is essential to locate mineralisation, and to measure and quantify critical rock mass characteristics and parameters at depth. In particular, it provides essential information for resource definition, extraction and processing purposes. Research in this area is targeted at significantly reducing the cost of exploration through improved drilling technologies, and by enhancing the quality and quantity of information obtained from boreholes.

CSIRO is a founding research provider in the newly established Co-operative Research Centre for Deep Exploration (DET CRC). CSIRO sponsored and worked with other industry members to help plan the research programme and establish the CRC. The CRC brings together international mining companies, equipment suppliers and researchers to deliver step-changes in drilling, logging and exploration technologies. While CSIRO is undertaking collaborative research across all DET CRC programs, at QCAT researchers are contributing to the application of seismic technology, down-hole geochemical and geophysical logging and drill rig automation and guidance. Teakle Composites, one of QCAT commercial tenants is also involved in the research to develop composite down-hole components.

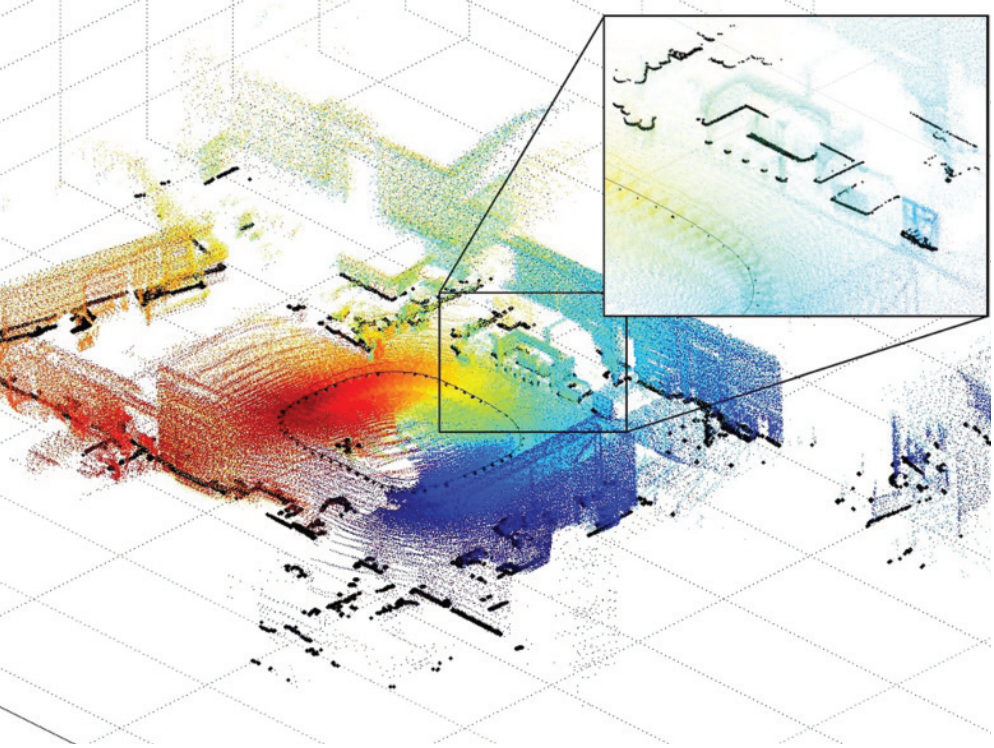
Through the DET CRC, researchers have undertaken a collaborative project with the Australian Resource Research Centre in Perth to explore the fundamental characteristics of rock and drill bit interaction during drilling. This research is developing new methods of 'exciting' the drill bit to improve performance.

Geologically intelligent surface mining

A new concept for surface mining will transform the industry into an intelligent and remotely controlled operation using smart machines capable of responding automatically to the mineralogy and lithology of geological formations.

Technologies for machine localisation and control continue to be developed with recent demonstration of automated digging (using an autonomous Bobcat). A method of using scanning lasers to automatically localise and map the environment from a moving vehicle has been demonstrated. The solution was achieved by developing a novel variation of a method known as simultaneous localisation and mapping. It requires no other instruments or input data apart from a scanning laser to build maps in real time from a moving platform such as a mine vehicle. One license has been issued for the technology and further licenses are expected.

To facilitate appropriate adoption and effectiveness of tele-remote and automated technologies by the mining industry, scientific investigation into the interaction between people and machines is under way. This involves exploring the human factors involved while operating advanced control



interfaces such as immersive, mixed reality, and virtual environments in a collaborative way with other, perhaps remote, operators. This will enable real-time remote operational control through advanced knowledge of human-machine-environment interactions.

Inertia-based navigation and localisation systems are now being augmented with satellite based navigation for surface application and wireless ad hoc system for positioning for underground and surface applications. To assist in this work, a virtual mining centre developed at QCAT is being used to interface with a number of remote and automated machines. A similar facility will be installed at another CSIRO site to demonstrate collaborative control environments.

In the area of human factors of automation, two important international collaborations have begun with Carnegie Mellon University (USA) and Scuola Superiore Sant'Anna, (Pisa, Italy). Work is also progressing on the development of relevant industry communication standards in cooperation with AMIRA, which includes key mining companies and OEMs.

Research into sensing techniques for mapping geological features of deposits has entered a new phase of development: multi-sensor assimilation, data fusion and information extractions for equipment control are now being tested at QCAT before field deployment.

Non-entry underground mining

The availability of easily recoverable ore is diminishing and underground mining conditions are becoming more challenging, particularly due to high stress, lower grades, elevated temperatures and deeper locations. Research is under way to develop new automated mining methods and equipment to remove people from hazardous locations in the mining environment. Working with Orica, one project will trial a new mining method called ROES®, a non-entry system to drill and blast ore by remote and automated control. Sponsorship from the mining industry to demonstrate key components of the technology in a quarry is being sought through AMIRA International.

New technology using Wi-Fi to accurately determine and track the position of people and equipment in an underground mine has been successfully demonstrated at an Australian mine site. The technology is entering a new phase as we work toward commercialisation.

Underground research is taking a new focus on rapid and safe mine development (tunnelling). Underground tunnels are required to gain access to ore and are almost always excavated using a sequential process of drilling and blasting in hard metalliferous mine rock. The objective is to improve existing processes but also to explore a new continuous excavation methods using CSIRO's SMART*CUT (see below) technology which is able to cut hard rock beyond the strength of traditional tungsten carbide cutting technology. This will allow for continuous operation without the secondary damage and subsequent weakening of the surround rock cause by blasting. This method is also more amenable to automation.

SMART*CUT – cutting tools for hard rock

SMART*CUT technology provides effective cutting tools for mining and civil industries to improve productivity and reduce operating costs. SMART*CUT uses a CSIRO worldwide patented bonding technology that joins thermally stable diamond composite cutting elements to the tool body. The technology can be applied to mechanical excavation, rock cutting, drilling and sawing.

SMART*CUT provides an economical and effective solution for cutting hard rock with reduced wear rates resulting in increased tool life compared with conventional tools. The ability to economically cut hard rock will enable new mining methods.

CSIRO Minerals Down Under Flagship is conducting further research and development to extend the applications of SMART*CUT technology from hard rock cutting to hard rock drilling, and has also successfully developed a prototype drill bit.

Large open pit mine rock slope stability project

CSIRO is internationally recognised for its expertise in the field of slope stability and open pit mining geomechanics. In 2005 the group initiated a major research project involving the stability of rock slopes in large open pit mines.

The project aims to address critical gaps in the knowledge and understanding of the relationship between the strength and deformability of rock masses and the likely mechanisms of failure in large open pit mines.

The research resulted in the development of an authoritative new generation pit slope text. The Guidelines For Open Pit Slope Design was officially released at the Slope Stability conference in Santiago, Chile, on November 9, 2009. The text links innovative geomechanics research with best practice in open pit data collection and management, slope design, mining, slope management and monitoring, and risk management.

Research is also being undertaken to provide new knowledge and design criteria in our current understanding of rock mass failure in large open pit mine slopes. This includes research directed at enabling the effective use of 3D modelling, rock mass strength simulation and uncertainty analysis in pit slope design, and the influence of pore pressures and the effect of blast damage on the stability of slopes in closely jointed rock.

The year five extension of the project is sponsored by eleven mining companies representing the majority of the world's production of diamonds and base metals. These companies are:

- Anglo American plc, London, England
- Anglo Gold Ashanti Ltd, Johannesburg, South Africa
- Barrick Gold Corporation, Toronto, Canada
- BHP Billiton Innovation Pty Limited, Melbourne, Australia
- Compania Minera Dona Ines de Collahuasi SCM, Iquique, Chile
- DeBeers Group Services, Johannesburg, South Africa
- Newcrest Mining Limited, Melbourne, Australia
- Newmont Australia Limited, Perth, Australia
- Xstrata Copper, Antofagasta Chile
- The RioTinto Group, Brisbane, Australia
- Vale (CVRD), Rio de Janeiro, Brazil.

Mining automation

CSIRO Earth Science and Resource Engineering and the CSIRO ICT Centre provide the capabilities to research and develop novel and robust industrial solutions in the mining technology and automation sector.

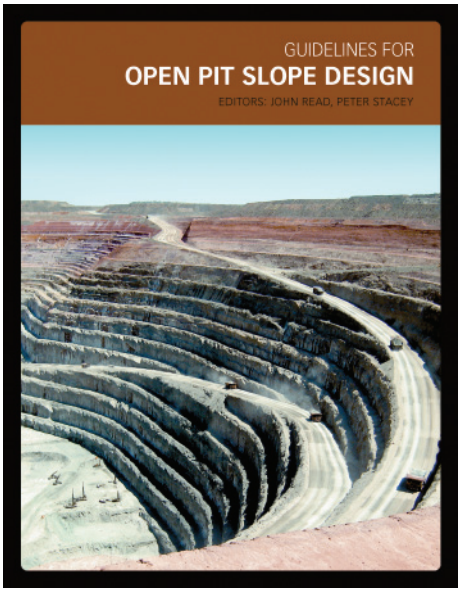
2009/10 has seen the development of field-proven robotics systems that provide the building blocks for future automation of mining equipment in surface and metalliferous underground operations.

The impact of this research is evident in applications across the full value chain: logistics, machine extraction, resource transport and resource dispatching. These efforts focus on activities that advance transformational change in mining.

Remote mining operations

Mining companies are particularly interested in the control of mining equipment over vast distances. This presents technical challenges including: high latency (the delay in sending data) and low bandwidth (the amount of data that can be sent), which in combination, make conventional remote control very difficult. With funding from the Minerals Down Under Flagship new technologies are being developed to improve the safety and productivity of remotely controlled mining along three lines of development:

- higher levels of machine autonomy to prevent the machine from damaging itself, anyone or anything at the remote mine
- communications standards and architecture that can provide quality of service over shared infrastructure
- immersive and interactive user interfaces that are capable of integrating complex geological and environmental data with real-time data streams from multiple and remote machine sensors.



The success of remotely controlled mining systems relies on the effective collaboration of spatially and temporary distributed teams of experts and operators using advanced visualisation techniques (tele-collaboration), remote guidance and just-in-time training (tele-assistance) and provision of sensing capabilities for effective remote operation of machines (tele-operation). This technology will provide significantly higher levels of situational and spatial awareness than conventional technology. These new technologies are now being applied and tested at mining operations across Australia.

Shovel load assist

An ACARP-funded project conducted jointly by CSIRO and CRC Mining aims to develop and demonstrate a system for automatically loading haul trucks using electric mining shovels. The technology is conceived as a 'cruise control' system for shovel operators. The system will be capable of automatically swinging the dipper over a haul truck, determining an optimal dump point in the tray, releasing the load without spillage and returning the dipper to the digging face. On completion of the automated cycle, the operator will seamlessly retake control in preparation for the next dig.

CSIRO's main contribution to this project is the development of the situational awareness module for machine control, which enables representation of the shovel work space and extraction of relevant features

and objects from the environment. While the operator will still be present, automation of the swing, dump, and return phases of the machine cycle will improve efficiency by allowing faster swings, minimising spillage due to poor dipper placement at dump, and significantly reducing the likelihood of dipper truck collisions.

The technologies developed by CSIRO have been successfully tested and demonstrated to key stakeholders in the project. Upon project completion, a number of systems will be deployed at mines across Australia. Funding for this second stage has already been secured through ACARP.

Mining Technologies

CSIRO continues to conduct research on enhancing mining technologies for improved productivity, safety and sustainability in mining. Major areas of research and application include:

Navigation: After initial application to longwall systems, new outcomes in inertial-based localisation have been applied to other mining contexts. Work is continuing on fusion of multiple data sources within the underlying inertial platform to improve accuracy and robustness. The inertia-based systems are now being augmented with satellite based navigation for surface application and wireless ad hoc system for positioning (WASP) for underground and surface applications.

Automation: Work is continuing on development of sensors for use in mining equipment localisation and sensing for improved geological-based machine guidance in coal and metalliferous mining.

Profiling: Real-time, high accuracy 3D profiling systems for transport applications are being enhanced through the development of visualisation systems for tele-operation and autonomous control.

Mapping: Research and development of new radar-based imaging continues. This technology includes environmental mapping and subsurface imaging. Key application areas include navigation, tracking, resource utilisation, and situational awareness capabilities.

These key technologies are now being applied across a range of major projects closely aligned to industry demands.

Longwall automation

Commercialisation of the major outcomes of a 10-year longwall automation research and development program is now complete. The five major global longwall equipment suppliers licensed to exploit CSIRO longwall automation technology are now offering commercial LASC longwall automation equipment to the Australian coal mining industry. Currently eight longwall faces utilising LASC automation systems are either operational or in manufacture. International markets are also being explored.

A project to develop LASC verification software is now complete. By using this freely available software, longwall equipment manufacturers and customers alike are now able to verify that particular equipment complies with the open-system LASC automation requirements. The licensing model and the verification software project thus satisfy the ACARP requirement that LASC technology is to be available through all equipment suppliers and that the benefits of LASC automation can be realised through interoperability on longwalls comprising equipment sourced from various manufacturers.

Demonstration and commercialisation of the next phase of automation will concentrate on improved horizon control through real-time horizon sensing. It is expected that these technologies will be available commercially in the next 18 months.

Continuous Miner Automation

Several key research outcomes of the longwall automation research project have been successfully transferred to continuous miner navigation and guidance. Promising navigation results have been demonstrated at the halfway mark of a $2.6 m ACARP project targeted at continuous miner automation for underground roadway development.

Tele-operated Shiploader

CSIRO is working with Rio Tinto to develop a tele-remote controlled interface so that ship loader operators in Dampier can be relocated from the ship loader to a remote control room on the shore. Several technologies have been applied to provide the remote operator with an enhanced level of perceptual awareness. The ship loader project is continuing.

NEXSYS™: an information system for real-time risk management

Nexsys™ introduces a step-change in the areas of real-time safety and operational management through information capture, data integration, and rule-based and predictive analysis. Intrinsically safe communications hardware, developed as part of the Nexsys™ project, is set to provide the world's underground coal mining industry with full utilisation of the ethernet-based communications systems enjoyed for so long by surface and non-hazardous area industries.

The system is capable of monitoring and capturing data from proprietary safety and productivity systems (including proprietary supervisory control and data acquisition systems) over a fibre optic network, integrating and analysing the data as a whole and converting the results into information for decision support and rapid information transfer to relevant personnel in emergency

situations. The data captured may encompass:

- ventilation monitoring and gas detectors
- coal seam gas drainage holes
- fires and spontaneous combustion
- roof-fall monitoring
- man and equipment locations
- operational and productivity data
- environmental monitoring.

Once integrated into a central database, the Nexsys™ Real-Time Risk Management System relies on a series of pre-set rules to determine the real-time risk profile of the mine. Analysis of historical data combined with current conditions and anomaly detection algorithms allows for pre-emptive, corrective and preventative action. All data and risk analysis information together with the location of workers and equipment is displayed in real-time using a 3D graphic user interface. This system provides essential information to mine personnel enabling rapid and efficient decision making, especially, in an emergency situation.

The real-time analysis software system has undergone an extensive pre-commercial field trialling and validation at an Australian coal mine.

In 2009, commercial agreements were signed with an Australian manufacturer, Ampcontrol Pty Ltd, for technology transfer of the hardware devices, and with Mining Logic Solutions, an Australian company based in Mackay, for commercialisation of the integrated software system.

Collision avoidance

Collision avoidance technologies for mine haul trucks will lead to significant safety benefits at mine sites. ACARP-funded research in this area has progressed over a number of years using prototype Doppler radar proximity detection. The technology is now licensed and going into pre-production with Industrea Ltd.

Diesel particulate agglomeration

Recent identification of suspended diesel engine particulates posing a risk to underground miners has led to a project to agglomerate and filter the particles from diesel engines without loss of engine efficiency. Carbon soot particles attract metals and toxic substances, produced by diesel engines, to adhere to the particle surfaces. Aldehydes, such as formaldehyde, and polycyclic aromatic hydrocarbons, have been identified on the diesel particles. These are all carcinogens specifically linked with lung cancer.

The project aims to remove 95% of particulate material from the exhaust stream using ultrasonic agglomeration followed by cyclonic filtration. Ultrasonic agglomeration increases the mass of diesel particulates using a probe-generated sound wave tuned to increase the energy in a small particle such that it is attracted to other diesel particles. Using cyclonic filtration methods, which do not create a back pressure on the diesel engine, allows for the increased mass particulates to be easily removed.

The first trial project, supported by ACARP, reduced particulates by 92% with very little reduction in engine efficiency. A second project using a triple chamber acoustic agglomerator has been approved and is aiming for 99% remove of the potentially harmful materials.

Applied Mining Technologies

Applied Mining Technologies Pty Ltd (AMT) plays a leading role in the successful transfer of mining guidance technologies from research to commercial, industry-accepted solutions for highwall mining applications.

Machine guidance is considered essential for safe and productive highwall mining and for more than a decade international equipment manufacturers have incorporating AMT technology into new and existing production systems. This has resulted in significant improvements in production rates and resource recovery, and provided the enabling technology for ongoing advances in automation.

In collaboration with major equipment manufacturers and suppliers, AMT has developed a complete and integrated highwall monitoring and control package incorporating inertial and horizon control technologies. A next-generation system is now being developed for release in late 2010.

CET Group

Cutting Edge Technology Pty. Ltd.

Cutting Edge Technology Pty Ltd (CET) was established at QCAT in 1995 as a mining consultancy that specialises in the research and development of mining systems, integrating geomechanical and mining equipment engineering.

CET aims to promote auger mining technology and to identify and develop opportunities in the Australian surface and underground mining industries through Coal Augering Services Pty Ltd (CAS). In the 2009/10 year CET's primary focus has been the development of CET Resources Pty. Ltd. (CETR). CET, CAS and CETR have common ownership but trade as independent companies from their head office at the QCAT precinct.

Coal Augering Services Pty Ltd

To maximise the commercial return from its mining technology CET expanded into contract mining in 2003 as Coal Augering Services Pty. Ltd. Auger mining is employed to increase reserves by accessing coal lying beyond the economic reach of conventional surface mining operations.

Since its formation CAS has undertaken a range of contract mining projects on behalf of Anglo Coal, Centennial Coal, Foxleigh Mining, Vale, Coalpac and Peabody, in Queensland and New South Wales.

CET Resources Pty Ltd

CET Resources Pty Ltd was formed to participate in mine ownership building on our mining technology and contract mining background. The aim is to develop CETR as a niche resource based company, leveraging off in-house mining technology and expertise to realise the full potential of brownfield and greenfield opportunities.

In November 2006 CET Resources Pty. Ltd. purchased a controlling interest in Coalpac Pty Ltd. This marked CET Resources' entry into coal mine ownership. The company's aim is to generate a balanced portfolio of operations which encompass long term local power station supply, domestic thermal supply and export thermal coal supply. CETR is focused on acquiring additional projects and is looking towards future growth.

GeoTek Solutions

GeoTek Solutions (GTS) is a geotechnical consultancy specialising in slope stability for open cut mines. The company has operated from the QCAT Technology Transfer Centre since its formation over a decade ago in 1999. Almost all of GTS's business comes from Queensland domiciled companies or Queensland based projects.

Underground coal gasification, potentially can provide much more environmentally friendly carbon-based energy than any other source, while at the same time utilising resources currently considered to be uneconomic. CSIRO successfully spun off its research outcomes into the company Carbon Energy. GTS worked with Carbon Energy during the establishment of its successful demonstration site and during the past year has provided advice to another major mine that is exploring its potential for underground coal gasification.

As part of its longstanding support of CSIRO's Sirovision technology, GTS was the first to demonstrate the effectiveness of CSIRO's new algorithms that allow for one-person, 3D digital photographic mapping of geological structures to sufficient accuracy for practical purposes, without the need for precise survey. These results were first publicised to the Bowen Basin Geology Group.

The relationship between GTS and CSIRO via QCAT remains important to GTS as a means of tapping into and promoting CSIRO technologies to the people in the field who can use them day-to-day.

Processing

Australia is the world's largest exporter of alumina, iron ore and coal, and a major producer and exporter of other mineral commodities. To maintain and expand the competitive position of the Australian resources industry, innovative and cost effective processing of our mineral wealth is essential. Researchers from CSIRO, Rio Tinto Alcan Queensland Research and Development and BHP Billiton's Carbon Steel Materials Group form QCAT's minerals processing cluster and are working closely with the industry in Australia and overseas.

Iron ore processing

CSIRO provides world-class expertise in iron ore processing, product evaluation and product optimisation, including detailed mineralogical, beneficiation and agglomeration evaluations of new and existing ore types and deposits.
Of particular interests are:

- characterisation of new ore resources
- predicting beneficiation performance and optimising sinter, pellets and lump in blast furnaces and other downstream processes
- removal of alumina, silica and phosphorus from the lower grade Australian iron ores either currently being developed or likely to be developed in the future.

Ore characterisation and predicting processing performance

CSIRO continues to investigate the mineralogy, petrology and processing characteristics of new and existing ore deposits as well as new ore blends derived from these deposits. The ability to predict processing performance from ore mineralogy and petrology ultimately allows industry to speed up assessment of the likely viability of new ore deposits by minimising expensive laboratory and pilot-scale research on ores that do not show promise.

Work on the automation of optical image analysis and ore characterisation has now been completed and a number of licences to use the CSIRO image analysis and 'recognition' software system are currently under negotiation. This capability is now being extended to manganese ores as well as metallurgical coal and coke. Development of robust methods for linking mineralogy and petrology to metallurgical performance is continuing, the ultimate vision being to predict beneficiation and sintering performance from ore characteristics. For this purpose, a number of mineralogy-based models have already been developed for a range of unit operations, such as hydrocycloning, magnetic separation and reverse flotation.

More effective beneficiation strategies

Alternative lower grade iron ore resources, such as Marra Mamba, high-phosphorus Brockman, Channel Iron and magnetite ores, are now being exploited in Australia to replace resources that are being depleted and to meet ongoing market demand for iron ore, particularly from China. However, these ores usually contain higher levels of impurities, such as alumina, silica and phosphorus, that need to be reduced either by blending, or in the longer term, removed. This has triggered the establishment of an iron ore impurity removal project under which a range of options are under investigation for beneficiation of Australian iron ore, including:

- heat treatment and leaching for removal of alumina and phosphorus
- utilisation of techniques used overseas in China and India for treating low grade ores
- microbial induced flotation and flocculation for selective removal of impurities.

To assist with this research, capital funding has been approved for purchasing additional beneficiation equipment suitable for iron ore applications, including a pilot-scale jig, a Floatex density separator and a Jig/WHIMS.

The international demand for iron ore and shortfall in supply of traditional hematite/goethite ores has also created a growing interest in developing Australia's substantial magnetite ore resources. Characterisation and beneficiation research on magnetite resources is therefore continuing with a number of Queensland, Western Australian and South Australian ores. A key focus of the research has been on reducing grinding costs for liberating magnetite from the gangue minerals, and control of impurity levels in the final magnetite concentrate, particularly the silica content, using tailored combinations of screening, magnetic separation and reverse flotation.

Iron ore sintering and blast furnace burden characterisation

The sintering research conducted at QCAT continues to play a pivotal role in proving up new Australian iron ore resources for export to supplement Australia's depleting resources of high grade Brockman ore. At the fundamental level, ongoing laboratory scale research is being conducted to better understand interfacial and wetting phenomena in iron ore sintering, and minimise the effect of increasing alumina and goethite in Australian ores on sinter quality. In addition, the granulation and sintering characteristics of the new ore types and their impact on sintering performance continue to be investigated, including magnetite concentrates, the focus being on improving the permeability of the sinter bed and maximising sinter quality and productivity. This research is crucial as Australian iron ores become more diverse.

The CSIRO state-of-the-art pilot-scale sinter rig (~80–100 kg samples) at QCAT is a key facility for investigating sintering performance at sinter bed depths of up to 860 mm, which is consistent with industry practice. Following the decommissioning of the BHP Billiton pilot-scale sinter rig in Newcastle, the CSIRO sinter rig is now the only facility in Australia for conducting sintering research at pilot scale.

In the blast furnace burden characterisation area, the CSIRO softening and melting furnace is now getting much more use as new raw materials are being brought to market. The furnace was recently upgraded with improved data logging capabilities, better atmosphere control and the ability to measure waste gas concentrations, including CO, CO_2, O_2 and H_2.

Iron ore pelletising

Upgrading of the CSIRO pilot-scale iron ore pelletising facility at QCAT is almost complete. A rotary kiln has been installed and commissioned, and a system for hot transfer of pellets from the pot-grate to the kiln is currently being constructed. The enhanced facility will be able to simulate grate kiln cooler pelletising machines in addition to straight-grate machines. Together with laboratory and pilot-scale drum and disk balling equipment, the facility is suitable for optimising balling, drying and induration of iron ore pellets, particularly for magnetite ores.

The laboratory-scale infra-red image furnace at QCAT continues to attract international interest. It is used for investigating and understanding oxidation/reduction reactions during the firing of iron ore pellets.

Although no further development has taken place over the last year, the Siro–Indur computer-based simulator developed by CSIRO continues to be available for optimising straight-grate and grate-kiln pellet induration. It has already been applied in Australia, North America and Brazil.

Manganese ore processing

Plant optimisation

Following the relocation of the BHP Billiton Carbon Steel Materials Group to QCAT, research has been reactivated on the characterisation and beneficiation of low-grade and difficult-to-treat manganese ores, including tailings and waste materials. In addition, agglomerations options, including sintering and pelletising, are being evaluated for the beneficiated products.

Coke making

As part of the growing strategic partnership between BHP Billiton and CSIRO, the BHP Billiton pilot-scale recovery and non-recovery coke ovens in the Newcastle Technology Centre are to be relocated to an existing process bay at QCAT. The process bay is currently being extended to accommodate the coke ovens. BHP Billiton is funding the extensions as well as the relocation, installation and functional commissioning of the pilot-scale coke ovens for operation by CSIRO.

Because Australia's resources of hard metallurgical coal are declining, effective ways of utilising softer metallurgical coals in coke making need to be developed, e.g., by blending them with harder metallurgical coals for production of coke that provides the required reductants, heat and burden support in blast furnaces. Research is therefore being initiated on metallurgical coal and coke characterisation and development of robust models for optimising metallurgical coal blends to improve coke making performance and coke quality. In additon, wall pressure and wall-gangue need to be minimised in commercial coke ovens, because they seriously affect their working life before refractory reline. This will effectively expand Australia's resource base through utilisation of higher tonnages of soft metallurgical coals.

Standards development

Our researchers continue to play a leading role in the development of International (ISO) and Australian Standards for international trade in iron ore, base metals and coal. Current efforts are aimed at improving methods for the sampling of iron ores, coal and copper, lead, zinc and nickel concentrates, while new methods are under development for sampling smelter products and residues. Work is continuing on development of improved ISO methods for physical testing of blast furnace and direct reduction feedstocks for iron and steel making.

Non ferrous mineral processing

Research for the non-ferrous mining industry on SAG mill optimisation and fine (<38 micron) and ultrafine (<10 micron) grinding is continuing. Work on a three year extension of the AMIRA SAG mill project to monitor mill performance via surface vibrations is now well advanced. A ruggedised prototype monitor with an inertial power supply for continuous operation continues to operate successfully at the Rio Tinto Northparkes mine in NSW and a second unit will be installed at Anglo Platinum's Waterval operation in South Africa in the last quarter of 2010. The monitor can track the toe and shoulder positions of the charge, mill load and charge size inside the mill, as well as other operating parameters.

To assist industry in optimising fine grinding operations, a wide range of laboratory and pilot-scale stirred milling equipment from various manufacturers has been assembled at QCAT. This equipment, including a tower mill, a vertical pin mill and an IsaMill, continues to provide a unique capability for conducting side-by-side comparisons of the relative performance of these machines, including mill wear and the performance of various fine grinding media.

Collaboration

BHP Billiton Carbon Steel Materials

In May 2010, a "Heads of Agreement" between BHP Billiton and CSIRO was signed, which signalled a long-term, strategic partnership between BHP Billiton and CSIRO to deliver significant benefit to both organisations. As part of this agreement, BHP Billiton has provided funding for a new wing at QCAT to accommodate the BHP Billiton Carbon Steel Materials Group which relocated into temporary premises at QCAT in July 2009.

Coal processing

Researchers from CSIRO Energy Technology are working with the coal industry to improve the quality and competitiveness of Australian coal on international markets.

Supported by ACARP and the coal producers themselves, the group is developing components for the conceptual intelligent plant system. New hardware and software developments will allow a processing plant to compare its current operational performance, in real time, to optimal standards. This will improve efficiencies and long-term operating costs in coal production plants.

Research is also ongoing to identify factors controlling the efficiency of fluid recovery, partition curves and magnetite recovery. Industry funding has been obtained to continue the work with focused plant trials. Ludowici Mineral Processing Equipment Pty. Ltd. has signed a contract to commercialise three recently developed instruments.

A new research area is investigating the production of low ash coals. These coals would be suitable for new coal technologies such as coal to liquids, coal injection into diesel engines and coal into fuel cells.

Rio Tinto Alcan

Rio Tinto Alcan Queensland Research and Development Centre

Since the opening of the Queensland R&D Centre (QRDC) building on the QCAT campus in 2005 by Rio Tinto Alcan, the centre has been steadily developing capability and extending its R&D programme. From a group of three scientists in the early days of 2002, the group has now reached 20 chemists, engineers, and specialists across several disciplines.

The centre has developed world class R&D capabilities in alumina refining (Bayer process) technology development. The group supports Rio Tinto Alcan's Australian assets including the Gove bauxite mine and alumina refinery in the Northern Territory, the Weipa bauxite mine in Queensland, and the Yarwun and Queensland Alumina refineries in Gladstone, Queensland.

QRDC has programmes in bauxite characterisation, digestion and desilication technology, gibbsite precipitation and alumina product quality, process impurities, corrosion and scale, bauxite residue management, analytical technology, and environmental management.

A current strategic project is investigating sustainable and economic processes for treating impending high silica Cape York bauxite ore reserves. Rio Tinto Alcan and the CSIRO are collaborating in this area.

The bauxite residue management programme at QRDC takes a holistic approach to tailings management in the Bayer industry. The objective of the programme is to reduce residue volume and remediate existing storage areas for future closure. This work is undertaken both in-house and with leading external research organisations, including the CSIRO.

An important part of this programme is to improve performance of our global alumina operations. Subsequently, there have been several significant improvements in the alumina business in recent years, particularly in the areas of product quality.

The QRDC also heads up an Environment Programme, which aims to provide innovative and effective environmental solutions for site-specific issues. This has translated into the design, planning, implementation and management of a range of environmental monitoring programmes, support to incident investigations and practical application of research outcomes. Furthermore, in alignment with Rio Tinto policies, there is a strong focus in applying in-house expertise to reduce operational impact and footprint, closure costs and post-closure liability.

Finally, the Rio Tinto Alcan Analytical Programme managed at QRDC has multiple focuses. The research projects that are carried out are aimed at developing new methods of analysis using new instrument technologies, and refinement of existing methods. Current project work includes bauxite characterisation, and particle sizing techniques. A major focus of this programme is to maintain open communication across Rio Tinto Alcan's laboratories through our Analytical Laboratories Quality Assurance Network. Also managed from the QRDC site are the organisation of lab audits and benchmarking samples for Rio Tinto Alcan and some external customers.

Throughout 2009 and 2010, Rio Tinto Alcan has continued its long history of collaboration with Australian research organisations. Rio Tinto Alcan's commitment to A J Parker Cooperative Research Centre (CRC) for Integrated Hydrometallurgy Solutions is a key partnership, as well as a number of collaborative research initiatives involving CSIRO or CRCs with CSIRO participation, including several Australian Mineral Industry Research Association (AMIRA) projects. Projects continue to be developed and initiated on an annual basis.

Present on six continents, Rio Tinto Alcan is the global leader in the aluminium industry. We supply high quality bauxite, alumina and aluminium worldwide and our AP smelting technology is the industry benchmark. Our enviable hydroelectric power position delivers significant competitive advantages in today's carbon-constrained world.

Rio Tinto Alcan is the aluminium product group of Rio Tinto, a leading international business involved in each stage of metal and mineral production.

The group is listed on the London Stock Exchange and Australian Securities Exchange under the symbol RIO. Rio Tinto's products are aluminium, copper, diamonds, coal, iron ore, uranium, gold and industrial minerals.

Advanced materials engineering

The advanced materials engineering R&D cluster at QCAT includes researchers from CSIRO Process Science and Engineering, CSIRO Earth Sciences and Resource Engineering and Teakle Composites, a niche manufacturing and design company located in the Technology Transfer Centre. Research in the cluster focuses on light metals and fibre composites, both growing sectors in Queensland's developing manufacturing industry.

Manufacturing with light metals

Australia is the world's leading producer of bauxite and alumina making light metals a vital component of the Australian economy. Alumina and aluminium production, the core of Queensland's light metals industry, is sustained by the continuing need for weight reduction in the automotive industry, driven by the need for greater fuel economy.

Light metals fatigue

Recent research on the fatigue properties of castings has focused on parts manufactured by the high-pressure diecasting process. This process accounts for the majority of light-alloy parts especially for automotive applications. However, it is usually perceived to produce parts with lower reliability than other casting processes and so has limited use in safety-critical components.

A novel heat treatment process for diecastings is being developed in the CSIRO Light Metals National Research Flagship, and work at QCAT and CSIRO's Clayton campus has shown it can deliver improvements in strength, ductility and fatigue life. The optimum alloy compositions have been determined, and the alloys and heat treamtments are being evaluated for production parts.

Magnesium alloy development

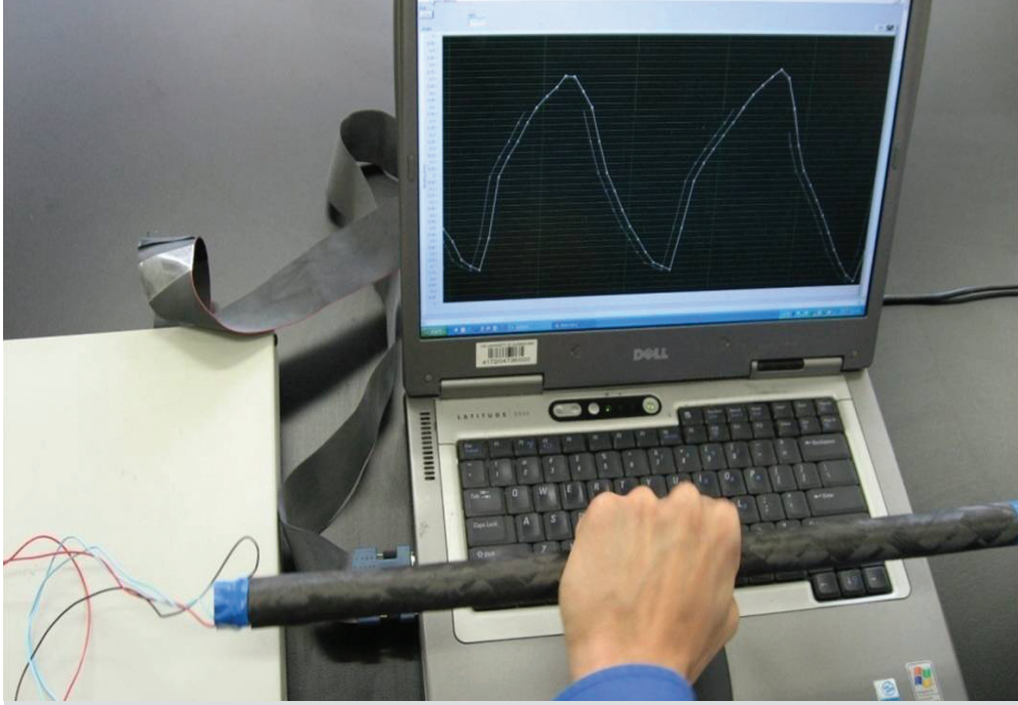
Magnesium, alloyed with a few percent of rare earth (lanthanide) elements, has proven to give light castings excellent properties at the typical temperatures found in car engines. QCAT is working towards optimising manufacturing processes for economical production of this alloy. These procedures are about to be applied to manufacture commercial quantities of material.

Steel coating improvements

Aluminium-zinc alloys have been used for many years to coat steel sheeting material for increased corrosion resistance. Researchers at QCAT and the University of Queensland are collaborating with BlueScope Steel, through the CAST CRC. The purpose is to understand the fundamental characteristics of coating alloys, with the eventual aim of improving life and quality of the manufactured product. A new project has started with the aim of identifying a coating material with radically improved performance.

Fibre composites

Modern fibre composite materials are made by embedding high strength fibres in plastic. Researchers are using the properties of fibre composites to improve existing designs and create new products that would be impossible using other materials.



Borehole sensor housing and composite coiled tubing

CSIRO is collaborating with Teakle Composites to develop a composite housing for sensing instruments that determine the properties of the rock mass surrounding a borehole. One of the instruments being developed by CSIRO requires an instrument housing that does not interfere with measurements, yet is strong and stable enough to resist the external pressures at more than one kilometre underground. Previously, the group used aluminium tube housings that were machined, anodised, coated with enriched boron, to prevent interference and then wrapped with a protective fibre composite material layer. These housings were very expensive and susceptible to buckling at great depth.

CSIRO designed tubes of carbon-epoxy composite, a material that does not interfere with the measurements and therefore requires no boron, no machining and no coatings. This design created cheaper, lighter and stronger instrument housing.

Investigations are also under way to determine the potential for drilling using continuous coiled composite tubing. If realised, this concept would enable drillers to minimise the need for handling steel tubes, reducing drill times and leading to improvements in health and safety.

Teakle Composites

Teakle Composites specialises in product development using fibre composite materials. Its office is located in the Technology Transfer Building, which provides ready access to some of the company's major clients, workshop and laboratory facilities and hundreds of scientists and technicians.

In 2009–10 the company's achievements included:

- manufacture and delivery of a fibreglass borehole liner with special properties for Thomas & Coffey Ltd
- completion of development of a prototype lightweight corrosion resistant piping system for underground coal mines for AC Whalan & Co, CSIRO and the Queensland Government
- manufacture of a lightweight expansion tube nozzle for gas flows of approximately 10 km/s
- manufacture and delivery of two carbon fibre lightweight instrumentation pods for BAE Systems Australia
- wrapping experimental beams with a fibreglass laminate for the Australian Defence Force Academy
- export of thick-walled carbon fibre tubes for an offshore client
- testing of ageing rocket motors for the Australian Space Research Institute
- commencement of the design of a radiotransparent flameproof enclosure for underground coal mines
- Manufacture of high strength prototype borehole probe housings for CSIRO.

The company is presently expanding its capabilities with the installation of a large filament winding machine.

Low emissions coal

The coal and power industries face the challenge of reducing greenhouse gas emissions while continuing to meet the growing energy and resource demands of our society. Low emissions coal technologies aim to reduce emissions and improve efficiencies right through the coal cycle. R&D at QCAT addresses these issues, from mining and preparation to utilisation as a low emission energy source. The researchers forming QCAT's low emissions coal technology cluster are supported by the State and Federal government, universities, industry and international partners.

Coal mine methane capture and utilisation

The Bilateral Climate Change Partnerships Programme aims to develop and implement a range of projects that deliver mutual practical benefits for Australia and partner countries and help build the capacity of developing nations to take action on climate change.

The following three research projects have received funding through the Programme from the Department of Climate Change and are being undertaken with Chinese partners to investigate coal mine methane (CMM) capture and utilisation.

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VAMCAT – generating power from low percentage mine methane

Conventional gas utilisation technologies will not work on ventilation air methane at concentrations of less than one percent, or on drainage gas with methane concentrations lower than 25%. The ventilation air methane catalytic turbine (VAMCAT) utilises these low methane concentrations providing greenhouse gas reductions and generating clean power through the heat released by methane oxidation of mine ventilation air methane and poor drainage gas.

During 2009/10 a 25 kWe prototype demonstration unit was successfully constructed, commissioned and has demonstrated the viability of VAMCAT technology. Mine site trials of the prototype unit project started at a Huainan coal mine, China, in March 2010, and will be completed by June

2011. The Chinese partners for this project are: Shanghai Jiaotong University and Huainan Coal Mining (Group) Co. Ltd.

Coal mine methane resources and potential project development

CSIRO has worked with the China Coal Information Institute to investigate potential CMM resources and emission reduction across key coal mining areas in China. The study also investigated the potential for CMM/VAM capture and utilisation in these areas. The case study was aimed at predicting future CMM emissions and production. The project contributed to the development of a policy framework for CMM development projects in China. In the last year, the project team completed its studies and submitted the final reportd.

Coal mine methane capture maximisation

CSIRO is working with Huainan Coal Mining (Group) Co. Ltd to design and optimise drainage gas systems based on CSIRO's advanced gas capture techniques and strategies. The design is being implemented at a mine in Huainan to demonstrate improved CMM capture. Design and optimisation of the positioning and sealing of gas drainage boreholes has been successful, with mine site implementation under way.

CSIRO has worked with the China Coal Information Institute to identify opportunities for improved mine methane capture and utilisation. Site specific implementation strategies have been investigated at five Chinese mine sites. The techniques and strategies developed through this collaboration can be applied at a large number of gassy underground coal mines in China to maximise efficiency of captured drainage gas with conventional gas utilisation technologies.

Low emissions electricity

Coal is Australia's largest export and a major contributor to the national economy. It is the primary fuel for power generation worldwide and provides more than 80 per cent of Australia's electricity supply. Coal however is a major contributor to the world's greenhouse gas emissions. Current coal-based power technologies account for more than one third of Australia's carbon dioxide emissions.

CSIRO's coal technology research is focused on maintaining the benefits that Australia's coal resources bring to the nation while minimising the adverse environmental impacts of coal mining and utilisation.

With coal use worldwide projected to increase significantly over coming decades, it is imperative that we overcome the related challenges. Central to this is the accelerated introduction of low emission coal-based energy technologies that will reduce greenhouse gas emissions.

For Australia to meet increasing energy demand and reach its emissions targets, new technologies are needed to increase the efficiency of coal-fired power generation and significantly lower greenhouse gas emissions at an acceptable cost. The demonstration of low emissions coal technologies internationally is increasing, and as these new technologies are adopted, the export market for Australian coals will change.

CSIRO is developing a range of energy technologies that support a transition to high efficiency coal-based power systems capable of operating at near zero emissions. Research at QCAT is increasing scientific understanding of the gasification process, supporting the Australian export coal industry as it adapts to a changing marketplace, and helping the Australian electricity industry reduce the risks of selecting and implementing advanced power generation technologies. Our research also contributes to the expertise required to evaluate fuel and energy strategies for sustainable energy conversion technologies in this country.

Coal gasification

Gasification is a key technology for advanced, high-efficiency, low-emission energy generation.

The coal gasification process uses the reaction of coal with oxygen and steam to create syngas, a combustible mixture of carbon monoxide and hydrogen. Integrated gasification combined cycle (IGCC) plants combust this syngas in a high efficiency combined-cycle turbine system to produce electricity. Next-generation IGCC systems will incorporate CO_2 capture and will produce hydrogen for use as a fuel, initially using turbine systems, and potentially, in very efficient fuel cells. As syngas is also a valuable feedstock for the production of chemicals and liquid fuels, advanced coal-based energy systems will have the capability of producing power as well as a range of high-value fuel and industrial chemical products.

CSIRO's gasification research program performs fundamental and applied research to support and inform gasification technology development, and facilitate the adoption of high-efficiency power

generation technologies by industry and government.

CSIRO's advanced gasification research facilities at QCAT are used to investigate coal gasification processes at a scientific level, identifying key performance criteria, addressing operational end efficiency limitations and providing a sound basis to support the development and deployment of gasification technologies. CSIRO's research is providing the detailed technical information required to support Australian industry in its adoption of low emissions coal technologies in Australia.

CSIRO undertakes these research activities in partnership with the coal and power generation industries, technology developers and other research collaborators, locally and internationally.

Syngas processing and gas separation technologies

There are strong efficiency and cost drivers of advanced syngas cleaning, processing and gas separation technologies that can be integrated into coal-based gasification and IGCC systems. CSIRO is developing technologies to create significant improvements in capital and operating costs; and to integrate these developments into next generation high efficiency systems that will produce hydrogen for power generation and capture the carbon dioxide in a form ready for sequestration. Through development of advanced materials and novel process configurations, this research will provide key enabling technologies for the development of commercially feasible, coal gasification based power generation systems that incorporate large scale CO_2 capture and storage.

This program is using state-of-the-art facilities and capabilities developed at QCAT for the development and assessment of hot gas cleaning materials, as well as novel catalytic gas processing and membrane separation systems. A syngas simulation facility has been established at QCAT which, in conjunction with the gasification research facilities, allows this work to be scaled up and tested under more realistic coal gasification process conditions.

CSIRO research is developing advanced gas cleaning, processing and separation systems which offer opportunities to reduce costs and increase the energy efficiencies of the gas processing stages that separate hydrogen from CO_2 and other impurities in the syngas. For example, new metal alloy membranes have been fabricated that exceed current international cost and hydrogen flux performance targets. Further research is being conducted to improve the durability of these systems in the hostile environments characteristic of industrial gasification applications.

CSIRO is working with the Australian coal and power industries, local and international research groups, international technology developers and with state and federal government agencies to develop the necessary capabilities and technical programs to support the development, demonstration and deployment of large scale, low emission coal based power generation technologies which will be required to meet our challenging energy and environmental requirements.

Social science research team

The Science into Society group (SISG) grew strongly over the year and is now a stand alone research group in the Earth Science and Resource Engineering division.

The dynamic interplay between science and society's perception and acceptance (or rejection) of a technology is the primary driver for this research group which now inputs into four of the ten CSIRO National Research Flagships. Highlighting the diversity of the Group, a project with Centrelink has recently began to investigate the social value that is achieved through its service delivery.

The SISG continues to be represented at state, national and international conferences as the interest in knowledge brokering about complex issues and science integration grows. Highlights have included presentations at each of the Australian Science Communicators Hot Air Symposiums, which focused on communicating climate change to society; participation at the University of Calgary's International Resource Industries and Sustainability Centre; IEF-GCCSI Symposium on Carbon Capture and Storage in Beijing China; and University College of London's CCS Global Legal Program.

Energy Transformed Flagship

Societal acceptance of energy technologies

The SISG has undertaken research for the Energy Transformed Flagship for several years with a major focus on the perceptions and acceptance of a range of mitigation options from large scale energy technologies, through to local distributed energy options and behaviour change. The breadth of this research has been acknowledged at the highest levels, with submissions requested by the High Level Consultative Committee to the energy white paper as well as contributions to the National Academies Forum Report 'Understanding the formation of attitudes to nuclear power in Australia'.

The SISG has been working closely with the geothermal industry to share the lessons learned in other emerging technologies as a way of finding synergies across energy technology industries. This partnership will continue to grow with a workshop on communication and stakeholder engagement scheduled early in the next financial year.

Another key achievement for the SISG was the co-authorship of CSIRO's Energy Saving Handbook, which was launched in September 2009 and has sold some 15,000 copies.

Global Carbon Capture and Storage Institute

Investigating stakeholder perceptions and awareness of carbon dioxide capture and storage (CCS) is SISG's largest external project. Funded by the Institute, it has established formal research links with a range of international partners including:

- The Energy Research Centre of the Netherlands
- Cambridge University, UK
- Mizuho Research Institution, Japan
- Battelle National Energy Laboratories, USA
- AJW Inc. USA
- Berkeley University, USA
- Discussions are also under way with the University of Calgary, Canada.

Recent project achievements include:

- The first international conference on the development of CCS technology was convened. Ninety-eight international representatives from industry, government, non-government organisations, researchers, and communication practitioners came together to participate in an interactive day tailored to summarise the current global position on communicating for CCS deployment.
  - Theoretical considerations included: need for trust, creating partnerships, creating a vision for CCS, identifying a local value proposition, identifying local benefit, leadership to communicate.
  - Practical considerations included: setting CCS in the context of climate change, importance

of language used, tailoring for different audiences, stability versus instability of opinions, importance of process and early engagement, multiple sources agreeing on information often seen as more credible than a single source.

- The outcome of in-depth analysis of five CCS projects, focusing on the communication activities, has been the development of a practical toolkit of activities that projects can apply in their local context. Workshops will be conducted to share the findings of this work in Europe, North America and Australasia in late 2010.
- Development of a range of fact sheets that focus on the common questions that arise in relation to risk of CCS projects for the lay person. These will be published and be made available through the toolkit at a later date.
- SISG has developed a database of international articles on CCS and is conducting an in-depth analysis of them, the results of which will be due for release towards the end of 2010.
- The FENCO project involves scrutinising the impact of CCS communication on the general and locally affected public. The study will compare the effectiveness of two methods for communicating CCS which will enable lay persons to develop their own well-considered opinions. The two methods are focus groups and a narrower version of the Information-Choice Questionnaire. The collected data will be analysed to guide communication of information on CCS technologies. To date, the international project team (USA, Japan and Australia) has completed data collection and is currently in the analysis phase with individual country reports already completed. The final combined report will be submitted in early 2011.
- Various other research is underway including a review and the development of a database of existing communication materials as well as identifying gaps and recommendations for improvements; development of a social site characterisation tool for inclusion in the toolbox.

Energymark

Energymark works through a number of small community based networks committing to a series of meetings to discuss attitudes and ideas surrounding energy and climate change. Information, that has been peer reviewed by multiple sources to maintain its objectivity, is provided by CSIRO to support the discussions.

An Australia wide pilot of the project found that significant changes occurred in levels of knowledge, attitudes, and behaviour towards climate change. The 1092 participants in the trial reduced their carbon footprint by an average 19% over an eight month period.

SISG has partnered with the Department of Premier and Cabinet (South Australia) and Local Government South Australia to roll out of the program across a number of local South Australian communities. This trial is almost complete and the final report will be submitted at the end of July 2010.

In addition, SISG recently signed a contract with the New South Wales Department of Environment, Climate Change and Water to conduct a state-wide roll out of Energymark to 7000 households. This project allows testing of the process on a large scale, in many different communities, across New South Wales, experimenting with online delivery and other methods.

Intelligent grid project

The final report of the three year 'Intelligent Grid' research program was released in December 2009. There has been great interest in the results of this work identifying a value proposition for distributed energy in Australia, including local generation as well as demand side management opportunities. The results of this work have been widely disseminated to industry and policy makers across Australia. SISG continues to work closely with the partners in the Intelligent Grid Cluster collaboration to extend the earlier work on decision making as one of the pathways forward for research in coming years.

A related project is the work around the 'Electric Driveway' which is examining the potential for electric vehicles to be connected to the grid for power generation at peak times. Working in conjunction with Sustainability Victoria a number of focus groups have already been conducted with the goal of a national survey to ascertain current thinking about this initiative. This work ties in closely with the Zero Emission Home initiative and the SISG will continue to study how individuals interact with this innovation.

Climate Adaptation

The SISG has been working with the Climate Adaptation National Research Flagship since its inception. Recent projects with the Flagship include:

- a longitudinal survey of the extent of adaptation to climate change that is occurring in vulnerable Australian organisations. This work is being conducted jointly with the federal Department of Climate Change and Energy Efficiency. This survey was first conducted in 2008, and is

being repeated in 2010 to allow an examination of changes over time, and to help identify the drivers of adaptation to climate change in Australia

- an evaluation of the quality and outcomes of CSIRO's engagement with the Flagship's external stakeholders
- involvement in a large-scale survey of the Australian public about perceptions of climate change in general, and adaptation to climate change in particular
- a new project conducted for the federal Department of Climate Change and Energy Efficiency, to help develop national and sector-level indicators of adaptive capacity, to help track Australia's capability in preparing for, and responding to, the impacts of climate change.

Australian primary industries transforming for a changing climate

Primary industries in Australia are highly sensitive to the impacts of climate change. However, adapting farms, fisheries, forests and mines to change will help reduce the negative impacts, and also allow resource managers to take advantage of any opportunities provided by the new conditions. Small, incremental adaptations to management practices and operations are continuously being made in primary industries in response to changes in climate.

The SISG will address the social and economic conditions and processes that drive resource managers to make more significant, transformative shifts.

Transformative shifts could include relocating industries from irrigated and drying areas to higher rainfall zones, or completely changing the industry or land-use mix in a specific location. This five-year project will develop case studies across all Australian primary industries, from industry sectors, large industries and communities, through to small businesses and individual resource managers.

The team will collect qualitative and quantitative data to explore questions like:

- What information or situations motivate people to act?
- What challenges do adapters face?
- How do adapters feel about their decisions afterwards?
- What conditions perpetuate inaction?

Using a number of case studies, the project team will work to better understand why, when and how resource managers from a range of primary industries and communities adapt and transform their practices. The project team will be working to draw broad conclusions about the conditions and support required for primary industry stakeholders to make transformative changes to their practices to improve the sustainability of primary industries in the face of a changing climate.

Another project that focused specifically on exploring climate adaptation for mining operations and their attendant communities began this year as a collaboration between the Climate Adaptation Flagship and the Minerals Down Under Flagship. Key outputs to date include a workshop with CSIRO mining technical specialists, summarised in a Project Introduction and Initial Findings report outlining some of the key adaptation issues for mining industries and their associated communities. This work has also been incorporated in a conference paper to be presented at the AusIMM Sustainable Mining conference in August 2010. Seed funding from a regional development corporation, and early interest from mining companies in the value CSIRO may add in this domain, indicate that this area will grow for both Flagships.

Mining and Exploration

Mineral Futures Initiative

In 2009/10 the Mineral Futures Initiative in the Minerals Down Under Flagship continued to deliver science impact in the area of social sustainability and mining. The Mineral Futures university collaboration cluster officially began work on the 1st of July 2009 and is now delivering significant outputs and impact. One key output was the release of the Peak Minerals Discussion Paper in early 2010 by CSIRO research partner the University of Technology, Sydney, and a Peak Minerals Forum held soon after with a broad array of stakeholders. This work has been received very positively, with media coverage of the forum in particular facilitating discussion around the future sustainability of the minerals industry in Australia. The Mineral Futures team has also been heavily involved in an international foresighting exercise run by the World Economic Forum for the mining and metals sector. CSIRO is seeking to collaborate with the WEF to explore the implications of the scenarios for Australia.

The industry's social licence to operate in Australia has also been a focus of research activity for CSIRO this year, with several projects seeking to elaborate on the nature and form of this construct in a mining context. A discourse analysis of the 'social licence' term in industry sustainability reporting has been conducted and will be submitted for publication early in 2011.

In collaboration with the Wealth from Oceans Flagship, the expectations of the Australian public regarding onshore and offshore mining were explored, with the results to be presented at the 2010 Sustainable Mining conference in Kalgoorlie, and later submitted for publication. This research aims to articulate what a 'social licence' means for communities in resource-rich regions of Australia. This research is assisted by work in the emergent mining region of the Liverpool Plains, tracking dialogue among key stakeholders, and research in the Surat Basin on company and community expectations around the expanding LNG industry in that area.

Assessing the impact of seafloor exploration and mining

Research by CSIRO's Wealth from Oceans Flagship found that the viability of seafloor exploration and mining (SEM) in Australia would be highly dependent on Australia's ability to improve the knowledge base underpinning its regulatory regime, enhanced communication between stakeholders, and improved understanding of the policy and legislative process. To address some of these needs a program of integrated, multi-disciplinary research involving geologists, environmental scientists and social scientists is working to understand the potential impact and acceptability of SEM. The recent focus of the social research component has been to explore stakeholders' reactions to SEM and establish what information they need to answer their questions and concerns.

Interviews and focus groups have been held with representatives of industry, legislative authorities, non-government organisations and community, to explore their reactions and questions relating to SEM. This research was recently accepted for publication in the international journal *Marine Policy*.

Analysis of international regulatory frameworks for marine aggregate exploration and mining has also been carried out through a desktop review and interview study. The research focuses on stakeholder consultation practice for marine aggregate exploration and mining in the United Kingdom, USA and Japan and describes those activities that were seen to lead to more effective outcomes or were considered challenging, difficult or negative.

Finally, in collaboration with the Minerals Down Under Flagship, six workshops were held to compare expectations associated with onshore and offshore mining in Australia. This research provides insight into factors that may affect social licence for onshore and offshore exploration and mining in Australia.

Future research will identify thresholds for unacceptable environmental and social outcomes and lead to a clearer understanding of social values relating to the potential impact of offshore mining. Overall the findings of the social research will inform investigations into the environmental impact of SEM in Australia's ocean territory and help establish a knowledge base to support future decision-making relating to SEM in Australia.

Centrelink

The Human Services Research Delivery Alliance brings together CSIRO's and Centrelink's expertise and knowledge towards developing a national human service delivery system that is sustainable, citizen-centred and connected across government and public dimensions. Centrelink manages programs worth A$70 billion per year and provides services to over 6.5 million Australians. This creates huge challenges and opportunities for improving the long term quality of life and social development of Australians.

In the alliance, the SISG works towards understanding and defining the social value that is achieved through Centrelink's service delivery. The recent focus of the research has been a series of interviews with Centrelink staff and customers which explore their experiences with Centrelink Service delivery and the effects of Centrelink services and programs. Initial findings suggest that Centrelink service delivery has an impact on customers' social inclusion capabilities. We have also been involved in developing an evaluation framework for Centrelink's innovative 'Place Based Services' initiatives, which provides more intensive service delivery to Australians at high risk of disadvantage and exclusion. This research approach was presented at the 2010 International Congress for Language and Applied Social Psychology.

Information and communication technology

The CSIRO ICT Centre at QCAT focuses on research in the areas of field robotics, sensor networks to develop new techniques for 3D perception and localisation, the autonomous control of machines, and the operation of large scale outdoor wireless sensor networks. The team's key strength lies in combining these techniques to produce novel solutions to practical problems in fields such as environmental monitoring, agriculture, mining, manufacturing, and the energy sector.

Automation

Autonomous hot metal carrier

Hot metal carriers (HMCs) are 20 tonne forklift vehicles that operate 24 hours a day, seven days a week transporting molten aluminium from a smelter's potting line to the casting house. The main objective of the HMC project, part of CSIRO's Light Metals National Research Flagship program, is to develop automation technologies that allow continuous, safe, dependable operations around a worksite containing humans and vehicles.

The team has developed, and implemented on the HMC at QCAT, algorithms for localisation, navigation, crucible manipulation, obstacle detection and mission planning. The vehicle has operated autonomously for hundreds of hours during testing and demonstrations. Due to the reliability of the system, research has advanced into areas of system dependability, redundancy, and enhanced safety. These are important requirements for autonomous vehicles deployed at industrial sites to ensure safe, consistent and predictable operations. Recent developments in the autonomous HMC project include pedestrian and vehicle detection and tracking systems. This allows the vehicle to have greater situational awareness of dynamic objects in its surroundings, allowing information to be assimilated into the vehicle's activities.

Mature technology components developed on the QCAT-based HMC have been field trialled on a manned vehicle operating at Bell Bay in Tasmania since 2007. The results from this deployment have demonstrated a high level of component readiness on the path to a fully autonomous materials handling vehicle operating in industrial environments.

Mapping and 3D perception

A core requirement for an autonomous vehicle is its ability to sense the environment and to localize itself within that environment. One of the most versatile sensors used for mapping and localisation is Lidar, which uses a sweeping infrared laser pulse to measure distances to objects.

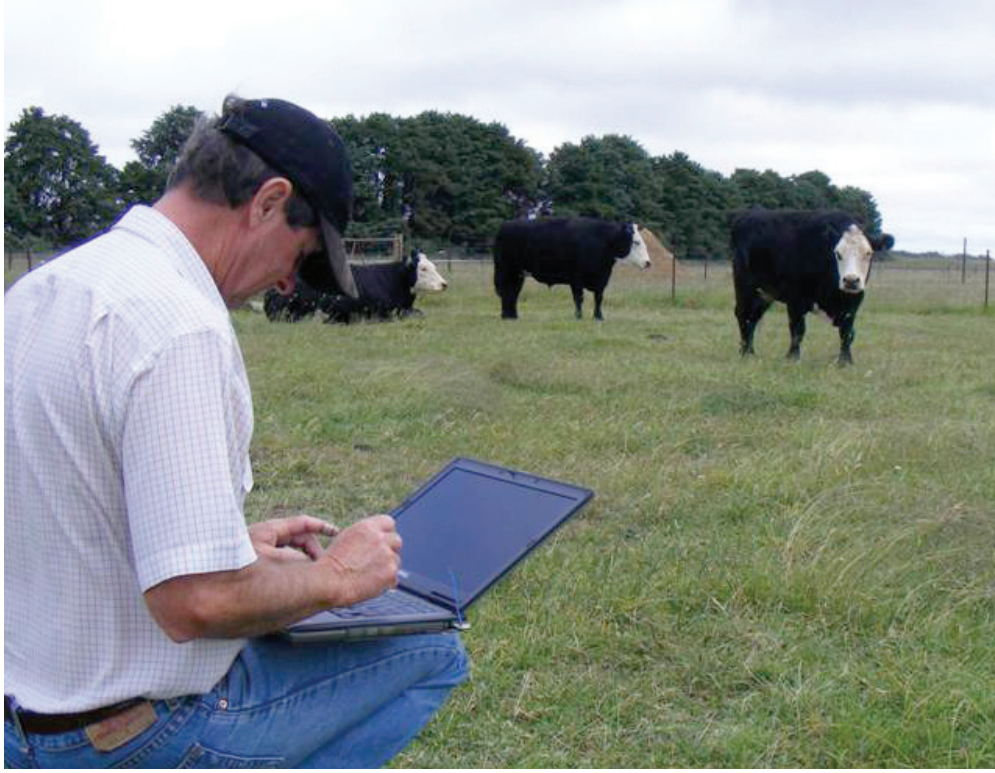
The laser sweeps an area 75 times per second to generate a 2D range map. Successive Lidar scans from a moving vehicle are matched for simultaneous localisation and mapping, without the assistance of GPS or inertia measurements.

The mapping software developed for these sensors has produced the largest unassisted Lidar maps published to date, covering a path of over 165 km. The challenge in building such maps without GPS is recognising revisits to the same areas after traversing large loops. The ICT Centre's place recognition algorithms quickly and reliably match

revisited areas even when the initial location of the vehicle is not provided to the computer.

This technology is very useful for autonomous vehicles in large industrial environments since it removes the need to embed sensors across an entire site for localisation and allows the autonomous vehicle to keep up with changes to the site's layout and avoid any previously unmapped obstructions.

For operations in some environments, including off-road mapping and navigation, 3D perception is required. A 3D Lidar can be constructed using the same 2D laser scanners mounted on a rotating platform. The spinning laser produces a hemispherical point cloud that can be used for mapping, localisation, and scene understanding. However, to obtain sufficiently dense data, the sensor must spin at a slow rate relative to vehicle motion. Such a configuration results in severe distortions of the map if the vehicle motion is not adequately corrected for. A common approach requires stopping the vehicle to perform stationary scans; however, this is unrealistic for practical scenarios. The solution, developed by the ICT Centre incrementally corrects the 3D point cloud and estimate the full vehicle trajectory online without assistance from additional sensors. In combination with a 3D extension of the place recognition algorithm, the system has been applied to generate globally consistent 3D maps in industrial and off-road environments.



Wireless sensor and actuator networks

Wireless sensor and actuator networks (WSANs) provide the means to observe, understand and control the natural environment to a level that has never previously been possible. WSANs comprise networks of nodes, where each node cooperates with its neighbours to sense and share information wirelessly. Tiny microprocessors built into each device enable decisions to be made inside the network, allowing autonomous actuation where needed.

Autonomous spatial management of animals

In CSIRO's virtual fencing technology, cattle wear smart collars that allow monitoring of their location and movements. These collars can be used to restrict the movement of cattle past 'virtual fences' in paddocks or around environmentally sensitive areas.

The collars contain a wireless sensor node, based on CSIRO's Fleck™ technology, and other sensors for inertial and GPS measurement, as well as a power supply, radio transceiver and low power microcontroller that stores the GPS data for the virtual fence lines. If a cow approaches a virtual fence the collar emits a warning sound, and if it continues past the fence line a tactile stimulus is triggered. In trials cattle quickly learn to react to the audio warning and stop before the virtual fence.

The paddock also contains static wireless sensor nodes for environmental monitoring and uploads of GPS location and inertial postural information from the mobile sensors nodes on the cattle. The static nodes also can be used to distribute updated boundary fence line information to the mobile nodes.

Current research is focused on improving the energy efficiency of position localisation. Intelligent duty-cycling techniques combined with distributed information in the herd reduce the energy consumption of the device, allowing for longer duration experiments.

As well as providing a system for containing cattle, the technology also allows for a study of animal behaviour as conditions change in the paddock. Research in this area brings together ICT researchers with scientists from CSIRO's Livestock Industries Division. It is hoped that a better understanding of the dynamics of herd hierarchy will allow herds to be controlled by collaring only some of the animals.

Monitoring rainforest regeneration

A network of wireless sensor nodes in Queensland's Springbrook National Park is being used to monitor the recovery of the regenerating rainforest from previous agricultural grassland.

Nodes are located in areas of open grassland, regenerating rainforest and old rainforest, where they monitor micro-climate indicators including temperature, humidity, leaf wetness, soil moisture, wind speed and wind direction. The sensor network provides a valuable research platform for the study of land-use change, the effects of invasive species on biodiversity, the ecological functioning of rainforests and the impacts of climate change.

To date a network of 50 microclimate nodes has been deployed, with the network to be expanded to 200 nodes over the next three years. Sensor capabilities will be extended to include further information such as light readings, rainfall, fog and water quality indicators as well as multimedia functionality including audio and video sensing.

Listening for frogs

Frog populations are often used as bio-indicators of the health of waterway ecosystems, providing valuable information to water resource managers such as Seqwater, the water service provider for South East Queensland. With the support of Seqwater, CSIRO researchers are working to develop networks of acoustic sensors that can recognise, record, and ultimately classify frog vocalisations.

A trial network of six sensor nodes was established in the upper catchment area of the Somerset Dam near Brisbane. This area is the critical habitat for three species of endangered frogs, with another two species that existed in the area until recently, now presumed extinct. The sensor nodes recorded frog vocalisations and concurrent temperature and humidity readings for two hours each day over the summer.

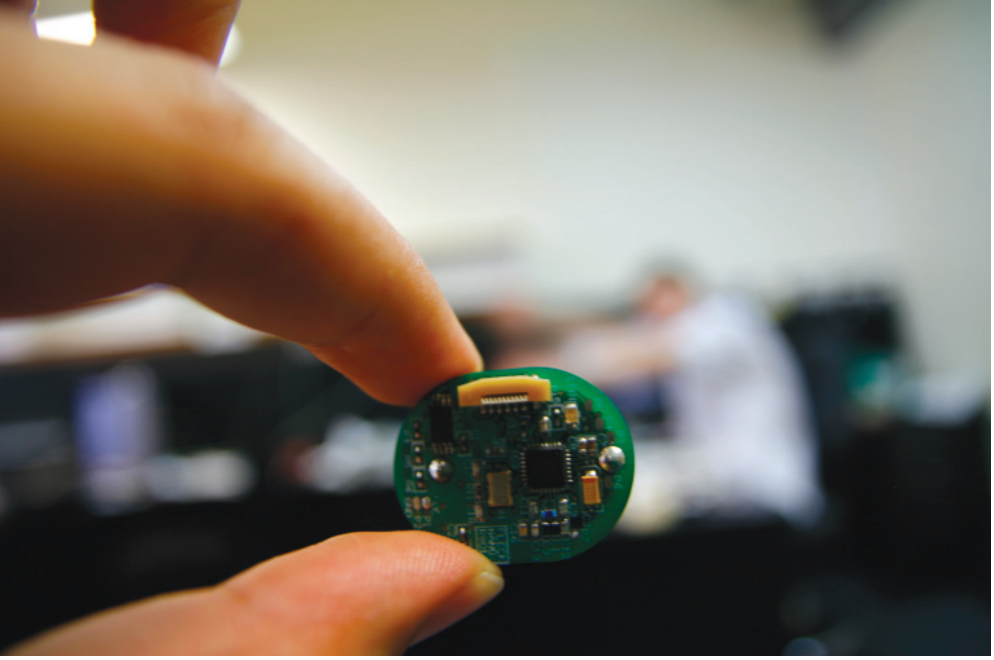
Data from the experiment is now being analysed by Seqwater.

Based on the success of this trial deployment, further research is under way to develop networks that are capable of automatically recognising and classifying frog species in real time. Future research will also investigate the use of video-processing for species recognition and classification.

Monitoring water quality

CSIRO has partnered with Seqwater, to develop Australia's largest integrated intelligent wireless sensor network for monitoring drinking water.

Lake Wivenhoe is the major source of drinking water for south-east Queensland, with a catchment area equivalent to the city of Brisbane and supplies water to the region's 1.5 million residents.



A deployment of over 100 nodes, using CSIRO's Fleck™ smart wireless sensor network technology, is monitoring the environmental conditions on Lake Wivenhoe and in the surrounding catchment.

The network will provide a cost-effective way of integrating different measures such as water quality, event flows, weather, and pasture conditions as well as the movement of cattle in the catchment. This will provide Seqwater with the capacity to monitor in real-time the effects of 'events', such as high rainfall, droughts, or contaminants entering the waterway.

Forty-five floating nodes have been operating on the lake since November 2008, measuring water temperature at varying depths. A further 25 land-based nodes are now installed throughout the surrounding catchment region to measure microclimate (air temperature, humidity, soil moisture, wind speed, and wind direction) with the addition of a further 30 nodes in the form of collars worn by cows grazing in the catchment area (for more information please refer to our autonomous spatial management of animals, above). The nodes operate in a meshed network to wirelessly transfer data back to a central point for collection and analysis.

CSIRO has also designed and built an autonomous solar-powered catamaran that travels between the floating nodes to calibrate their temperature sensors using a retractable underwater arm. As it travels between sensor nodes the catamaran also takes readings of water quality, temperature and bathymetry (depth sounding), as well as performing shore-line mapping. A laser sensor mounted above the boat enables it to avoid obstacles and keep out of shallow water.

Enabling difficult sensing

CSIRO researchers have developed a new architecture for sensor and actuator nodes that are able to cope with the challenging environments that these networks are often deployed in, ranging from industrial settings to dense rainforest.

Besides being able to mitigate interference from other radio frequency transmitters, the nodes can adjust their transmission range and data-rates individually to the application requirements. This adaptation enables energy savings that contribute to the overall longevity of the sensor and actuator network. These results allow transmission ranges of more than 10 k, enabling wide distributed networks, and allowing observations over larger areas.

Enabling secure actuation networks

CSIRO researchers have developed novel techniques to detect the infiltration and manipulation of sensor networks. These techniques will ensure that the data collection and actuation performed by the sensor network is authentic and trustworthy.

This technology is especially important considering the growing application of sensor networks in home automation and industrial monitoring applications requiring a high level of security. By digitally signing the data obtained from the network, it becomes almost impossible to manipulate the data without detection. By introducing industrial strength security, we ensured that the actuation is performed after a valid request from a trustworthy source.

Aviation and aerospace

CSIRO unmanned aerial vehicles

The ICT Centre's Autonomous Systems Lab is pioneering research on robust autonomous helicopter systems that can operate in unknown environments. The unmanned aerial vehicles (UAVs) are being used for evaluating new air traffic separation methods and for testing perception technologies that could be used for the inspection of infrastructure such as bridges, cooling towers, powerlines and pipelines.

ARCAA - Smart Skies

ARCAA, the Australian Research Centre for Aerospace Automation, is a joint venture between CSIRO and the Queensland University of Technology to promote civil research into UAVs. The ARCAA Smart Skies project is a three year collaboration with Boeing Research and Technology, USA and Boeing Research and Technology, Australia to explore and develop technologies for automated air traffic management for manned and unmanned aircraft.

Collaborative workshops have been held in Brisbane and Denver. Six flight trials have been conducted to date with another two planned before the completion of the project in March 2011. These flight trials have included evaluation of the automated separation management algorithms in real-world flight tests where manned and unmanned aircraft operated by ARCAA utilise integrated hardware and software to communicate with the separation management system located in the United States, and follow new flight paths commanded by the system to avoid collisions.

Also tested in the flight trials have been stereo vision and laser based perception technologies to enable the helicopter UAV to autonomously navigate around fixed obstacles such as trees, and vision based technologies to enable fixed wing aircraft to detect and avoid other aircraft. The remaining flight trials will further test the capabilities of the systems in more complex and challenging scenarios.

ARCAA - UAV Outback Challenge

The UAV Challenge, Outback Rescue, is a competition aimed at university students, high school students and hobbyists, with the aim of showing how small UAVs can be used to locate lost bush walkers and drop an aid package to them. The Challenge, an initiative of ARCAA and the Queensland Government, is now in its fourth year. Teams failed to complete the mission in previous years and 41 teams are competing in 2010 for $75,000 in prizes including a $50,000 cash prize for the winner of the Search and Rescue Challenge.

The Technology Transfer Centre

QCAT and has a strong commitment to furthering technology transfer to industry. The co-location of commercial enterprises and other research and development organisations at the Technology Transfer Centre provides an environment where the exchange of insight, information and technology can thrive.

Commercial tenants in the 2009/10 year included:

- Applied Mining Technologies Pty Ltd
- CET Group
- GeoTek Solutions
- Defence Science and Technology Organisation
- Teakle Composites

QCAT events

Visiting delegations

QCAT is a hub of collaboration for the mining, processing, energy and aerospace industries.

Providing solutions requires open communication with research partners and potential end users of the technology. QCAT received over 3000 visitors to the site in the 2009/10 financial year period, a sample of delegations visiting the site includes:

Australia

- Australian Youth Aerospace Forum
- BHP Billiton
- Dow Chemical Australia
- Rio Tinto
- Clunies Ross Foundation
- Queensland Resource Council
- Australian Student Mineral Venture
- Pilbara Iron
- Pluton Resources
- CSIRO Education Double Helix Club
- Australian Industries Group
- International Minerals Processing Council

Brazil

- Delegation from Santa Catarina
- Vale

Canada

- Fracflow
- Canmet

Chile

- Industry Association of Antofagasta

China

- Chinese Consulate
- Australia – China Coal Mine Health and Safety Demonstration Project
- Fengfeng Group of Hebei Jizhong Energy
- Xuandong CMHS Demonstration project

- China Geological Survey
- Tiangong Technology Co

Finland
- Sandvik

India
- Confederation of Indian Industries Delegation

Peru
- Austrade Delegation from Peru

Taiwan
- Australia-Taiwan Joint Energy and Minerals Trade, Investment and Cooperation Consultations
- Australia-Taiwan Strategic Workshop - Energy Technologies for a Low Carbon

United State of America
- Governor of Wyoming
- Wyoming University
- General Electric
- Peabody Energy.

QCAT Innovation and Excellence Day 2009

On 7 August 2009, QCAT hosted the fourth *Innovation and Excellence Day: Resourcing the Future; Looking towards 2030* with a focus on the social, environmental and technological challenges facing the resource industry.

Innovation and Excellence Day brings together opinion leaders from government, industry and research for an annual showcase of ideas and research. The format this year changed from a research showcase to a discussion and debate focused on industry, government and research approaches to tackle the challenges faced by the mining and mining services sector over the next 20 years.

Presenters on the day were drawn from diverse backgrounds:

- Mr. John McGagh – Head of Technology and Innovation, Rio Tinto
- Dr Peter Mayfield – Global Technology Manager, BHP Billiton
- Mr. Paul Russell – Director Enabling Technologies, Department of Employment, Economic Development and Innovation
- Mr Greg Lane – Deputy Chief Executive and Director Skills Policy, Queensland Resources Council
- Dr John Carras – Director, CSIRO Coal Portfolio.

Following these presentations, Queensland's Chief Scientist Professor Peter Andrews chaired a panel discussion of these critical topics in detail. Over 70 guests attended and actively participated in the discussion. The presentations that have been released to the public are available for viewing on the QCAT website at www.cat.csiro.au/InnovationDay/iande2009.html

Public engagement

Educational engagement

CSIRO staff at QCAT for the past three years have committed to the Scientist in Schools program; a joint initiative of CSIRO Education and the Department of Education, Employment and Workplace Relations. Seven staff from Earth Science and Resource Engineering, Energy Technology and the ICT Centre have donated their time and resources to promote science education in primary and secondary schools. Their activities have helped to engage and motivate students in their learning of science, and broaden awareness of the types and variety of exciting careers available in the sciences.

RNA Exhibition

For the ten days of the Royal National Association Show, the Ekka, QCAT assisted CSIRO in presenting a range of science activities to an estimated audience of over 110 000. With a diverse audience of children and adults QCAT's presence at the Ekka allowed for public engagement and discussion of the precinct and CSRIO's research in general.

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QCAT Steering Committee

The QCAT Consultative Steering Committee exists to consult with and provide advice to CSIRO on research directions and other issues relating to the development of the QCAT precinct. The Consultative Steering Committee maintains an independent chair and its members are drawn from Queensland Government, universities, industry and CSIRO.

Members of the QCAT Consultative Steering Committee in 2009-10 were:

The Hon Mike Ahern AO
Chair, QCAT Consultative Committee

Associate Professor John Mott
Strategic Coordinator, Offices of Senior Deputy Vice-Chancellor and Deputy Vice-Chancellor (Research), the University of Queensland

Mr Michael Roche
CEO Queensland Resources Council

Dr Steve Morton
Group Executive, CSIRO Information, Materials and Minerals Group

Mr Dave Mason
Executive Director Geological Survey of Queensland
Department of Employment, Economic Development and Innovation

Mr Tim McLennan
Director Business Development, Minerals Down Under Flagship, CSIRO

Dr Mike McWilliams
QCAT Executive Manager
Chief CSIRO Earth Science and Resource Engineering

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