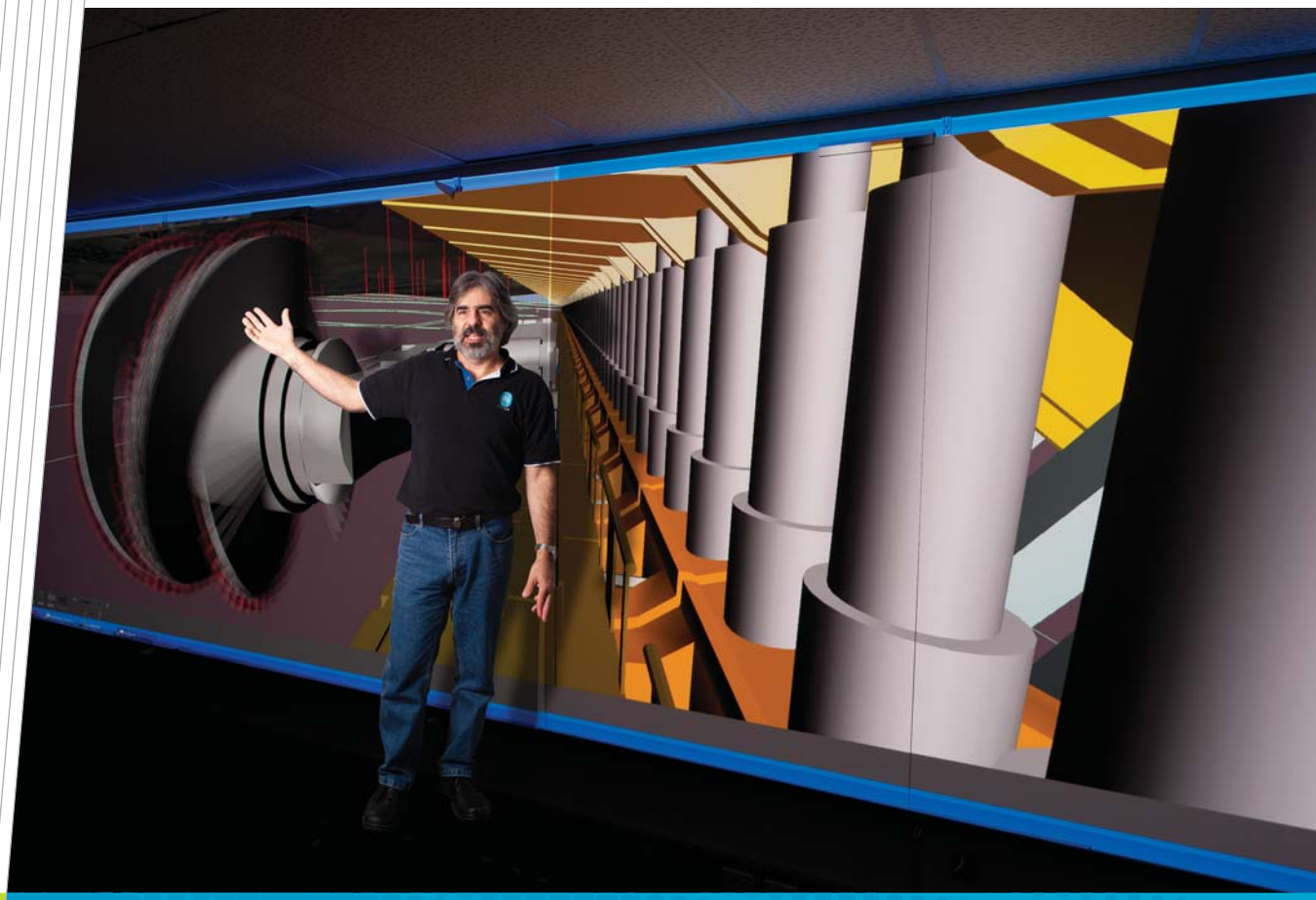
CSIRO



www.csiro.au

QCAT Industry and Research Report 2010-2011

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 with the Stage Three expansion currently underway.

Government occupants

CSIRO

- Energy Technology
- Earth Science and Resource Engineering
- ICT Centre
- Process Science and Engineering
- Advanced Coal Technology
- Energy Transformed 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

CSIRO

Queensland Government

QCAT Industry and Research Report 2010-11

Foreword

The past year has affirmed the vital contribution of technology to the biggest commodity boom in Australian history. University and research agencies are not merely a powerful competitive edge for the resources sector today, they are building the industries and firms that will ensure Australia's prosperity in a post-resources boom world.

In its eighteenth year, the Queensland Centre for Advanced Technologies (QCAT) remains in the front-line of this nation-building endeavour. It is a source of knowledge and an engine of innovation for Australia's mining, minerals processing and energy industries.

Research and development across the QCAT precinct is bolstering the case for new investment and addressing the national priority to create a sustainable environment. Low emissions technologies that reduce greenhouse gas emissions associated with mining, processing and utilising coal are being developed, along with systems that improve mining safety and productivity, ensuring continued export success and vital earnings for the nation over the coming decades.

QCAT is a testament to the strong capabilities developed across industry and the research sector through many years of experience in resources projects. It unites the strengths of many prominent institutions, including the Commonwealth Scientific and Industrial Research Organisation, the Defence Science and Technology Organisation, Rio Tinto Alcan and BHP Billiton's coal coking and magnesium research capability.

Collaboration has allowed QCAT to respond to industry needs today, whilst maintaining the diversity to identify and pursue new opportunities.

I commend QCAT for its continual enhancement of Australia's international competitiveness and wish it every success in its future endeavours.

Senator the Hon Chris Evans

Minister for Tertiary Education, Skills, Science and Research, Leader of the Government in the Senate

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.

Nine of the top ten Australian exports are natural resources, representing 67 per cent of our total export revenue. Our economy derives great benefit from our rich endowment of resources, but Australia's position as a resource and resource services-based technology supplier to the world is not guaranteed. Research of the highest quality is essential to sustaining Australia's global competitive advantage.

QCAT is a joint venture between the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Queensland Government to deliver research and technology to the Australian exploration, mining, minerals processing and manufacturing industries as well as low-emission energy solutions and advanced aeronautics.

QCAT continues to evolve, providing Australia and the global resources sector with quality research and technology. This year we commissioned research coking ovens in a $30 million joint venture with BHP Billiton, the Virtual Mining Centre advanced to become an integral tool for automation and mine planning, and CSIRO's Social Science grew to more than 25 staff helping to understand the social dimensions to technology development in areas ranging from sustainable agriculture to mining and climate adaptation. QCAT as a precinct continues to grow with more than 350 staff onsite engaging with over 3000 visitors throughout the year.

QCAT exists to gain new knowledge, build new technologies and deliver to industry where it can have real impact. Our work has resulted in a significant flow of innovative, leading edge technologies and high value products and processes.

I am very pleased and proud of the quality of research and technology under development at QCAT and congratulate all our staff for their professionalism and dedication.

Mike McWilliams
Executive Manager, QCAT

Mining

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, underground and open cut systems. Research aims to improve safety, increase productivity and reduce environmental impact by providing applied technological and robust solutions.

CSIRO Mining geoscience

Geology and geophysics

Geological knowledge underpins all mining decisions. CSIRO's geoscience research spans the energy domain: coal, coal seam gas, CO_2 storage, 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 digital data delivers a diverse range of outcome, from understanding basin controls on coal deposit formation to the development of new computational tools for analysing and interpreting complex, spatial data.

It is crucial to be able to analyse and determine relationships in the often vast, complex and disparate, spatial and non-spatial geoscience datasets. New computational tools are being developed that will provide geoscientists with an improved capacity to understand subtle clues and discover new relationships within diverse datasets.

At the operational level, data from the complex system of the natural and built environments of the dynamic mine site are used in multi-criteria analysis. This provides priorities for investment and action to reduce vulnerabilities to climate extremes which helps mines to reduce downtime and hazards during and after extreme events.

Advanced microseismic monitoring systems and data interpretation software packages have been developed for coal mining. These systems have been used for longwall geomechanical 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) have been demonstrated for use in rock mass characterisation and geomechanic imaging.

Geophysical imaging is undergoing a revolution with new 2D and 3D seismic reflection surveying techniques and borehole tomography surveying and analysis using seismic, electromagnetic 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 3D distributions of geophysical, geochemical, geological, geotechnical, petrophysical, physical, mining and metallurgical information into a 'common mine model'. These datasets 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 used to obtain textural, density and chemical information of individual coal particles. This coal grain information is used to develop processing strategies that optimise coal recovery and improve understanding of coal usage. 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 coal to liquid fuels or coal water feedstock for large scale diesel engines. Coal grain information is also used to track the flotation response and 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

Instruments and analysis methods are developed and used to obtain ore quality information that is used at all steps in the mining chain. Borehole logging tools that use Prompt Gamma Neutron Activation (PGNAA) isotopic source or a switchable neutron generator are used to obtain ore quality information from drill and blast holes.

The Australian Nuclear Science and Technology Organisation has used CSIRO PGNAA logging technology 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 removing water from aquifers. CSIRO PGNAA logging technology is also being used in mine development and grade control applications in developing countries such as Bangladesh and Pakistan.

3D imaging and 3D data processing

Sirovision® generates high-precision 3D images of the exposed rock mass surfaces in open pit and underground mining environments. The spatial and visual data in the 3D images support precise and previously unachievable capability for mapping and analysing 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 and on-line monitoring of mining processes.

The efficiency, ease of use and support of Sirovision® have made it a leading technology to generate and analyse high-precision 3D images of rock mass surfaces in mines around the world. CSIRO has now undertaken full commercialisation of Sirovision® with the signing of an agreement with CAE Mining (Datamine). CAE Mining will undertake all user level product development, marketing, sales and support with CSIRO providing ongoing research support. This process of improvement follows the major reengineering of the architecture and user interface performed as a precursor to commercialisation and will ensure that new facilities in Sirovision® will continue to support operations in open pit and underground environments.

The visualisation technology developed for Sirovision® has been extended to support registration and visualisation of airborne hyperspectral imagery with 3D spatial data. In addition, machine vision-based applications are being developed, and the image processing support developed for Sirovision® is being applied to other areas such as coal characterisation.

Coal mining

Thick seam mining

Longwall Top Coal Caving (LTCC) techniques allow for the recovery of more than 80 per cent of a thick (4.8 to 12 metre) seam, significantly exceeding the current longwall extraction heights in Australia of 4.8 metres.

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 using LTCC for thick seam (up to 10 metres) in Singareni Collieries in India.

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 the Australian Coal Association Research Program (ACARP) and strong support from Australian coal mines, has carried out several projects in 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

goaf inertisation techniques on effective dilution of heating gases.

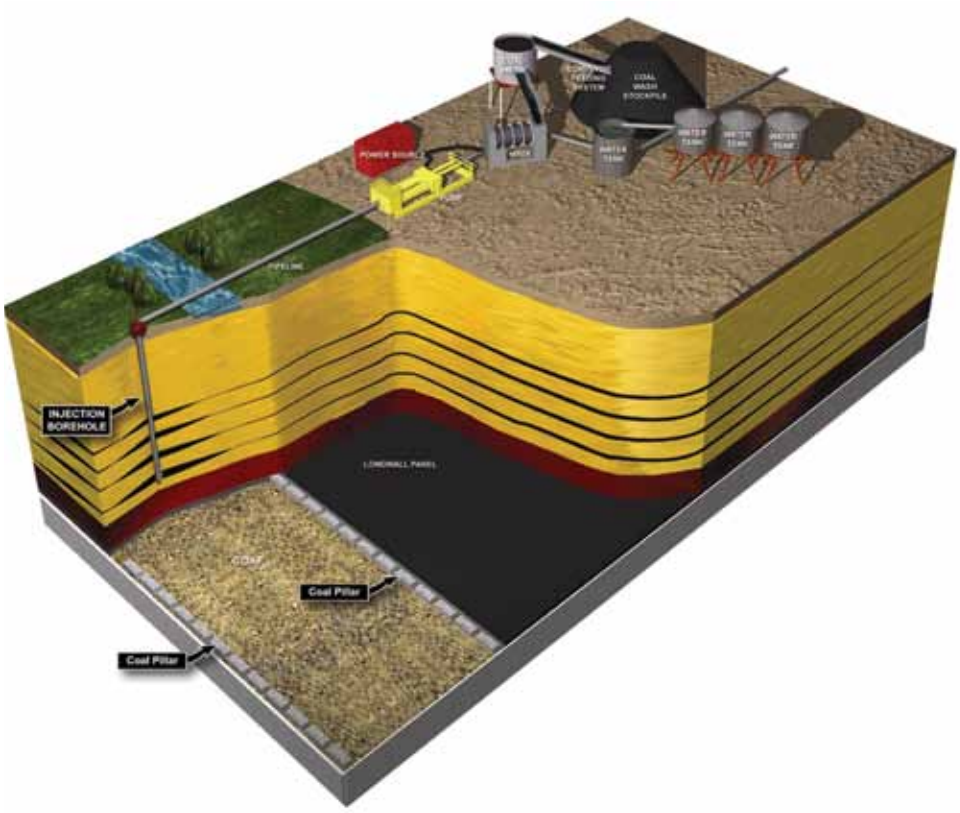
Recent projects have been aimed at developing optimum technologies and strategies for control and prevention of spontaneous combustion, heatings and fires in longwall goaf areas. Field studies conducted at a number of underground coalmines in Australia have shown that these strategies were successful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

Research has been 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 Collieries in India.

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 in the past few years. The projects involved 3D computational fluid dynamics modelling of respirable dust dispersion patterns on longwall faces, with the consequent development 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. CSIRO is also working on the application of water mist technologies for dust suppression.



3D mine scale simulations of coalmine geotechnical and environmental issues

The Australian coal mining industry's licence to operate is under increasingly intense social accountability and environmental scrutiny. The absence of robust and accurate predictive tools for impact assessment and management may significantly affect industry ability to gain mining approval where 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, improving mining safety, productivity and coal resource recovery by providing industry with a generic site hydrogeological assessment methodology.

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

CSIRO is working on an ACARP-funded 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 fieldwork is continuing 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 also being carried out at the BHP Billiton Dendrobium Mine and Peabody Metropolitan Colliery in NSW.

Another project, at Singareni Collieries in India, involves selection and application of reliable site characterising tools and methods. Geological and geotechnical characterisation work and assessment of strata caving characteristics are underway. This work will help to assess the viability of introducing highly mechanised longwall mining, and recommend 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 a major community concern. Some old bord and pillar mines in densely populated areas (such as Collingwood Park, 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 a technology used to control coal mine subsidence by injecting waste material (e.g. flyash) 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 due to its cost effectiveness and environmental credentials.

Over the past few years, an integrated method of feasibility assessment in grout optimisation and site-specific injection design has been developed, through ACARP and BHP Billiton-sponsored projects. A pilot injection trial was carried out at Baal Bone Colliery in NSW using flyash grout. The trial provided data regarding 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 using this technology.

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

Within 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 prevent or reduce mine subsidence and utilise mine waste, coal wash and flyash, resulting in less environmental impact.

Deep coal mining

The increasing depth of underground coal mines in Australia and overseas is 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 need to be developed.

CSIRO has established a research program, in collaboration with 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 metres 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 these deep longwall panel. Based on the results from field measurements and 3D numerical modelling using CSIRO's 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

Coal and gas outburst is a poorly understood phenomenon due to its dynamic, sudden and violent nature. This complex interplay is a major safety issue in underground coal mining. The key to effective management and control of outbursts is accurate prediction attained by studying their mechanism and characteristics.

CSIRO has established a research program, in collaboration with Chinese Huainan Coal Mining Group, to develop practical technologies to predict outbursts. Over the past 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 outburst initiation and propagation, development of an innovative coal sampling technology in soft coal seams, and development of a 3D numerical simulator of outbursts. 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, minimising the risk in underground coal mining.

Coupled fracture mechanics

With increasing concerns about environmental issues related to the mining, petroleum and energy sector worldwide, rock mechanics research 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 is to develop knowledge and numerical tools that help to understand coupled fracture mechanics on engineering scales.

Within this project, a thermal-mechanical coupling using fracture mechanics software called FRACOD has been developed. Laboratory investigations on rock strength and fracture toughness within a temperature range from -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 present. An 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 been completed. Future developments 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 has begun to transform the way that mining is undertaken across a number of key mining domains:

- Enhanced knowledge from drilling
- Geologically intelligent surface mining and
- Non-entry underground mining.

Enhancing knowledge from drilling

Drilling is essential to locate mineralisation, 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 through a steering committee to help plan the research program 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, researchers at QCAT are contributing towards the application of seismic technology, down-hole geochemical and geophysical logging and drill rig automation and guidance.

Through the new DET CRC, researchers have undertaken a collaborative project with the Australian Resource Research Centre in Perth to explore the fundamentals of rock and drill-bit interaction during the drilling process. This research is heading towards the development of 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 a skid steer loader. 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 known as SLAM. It requires no instruments or input data other than a scanning laser to build maps in real time from a moving platform such as a mine vehicle. One licence has been issued for the technology and further licences are expected.

To facilitate appropriate adoption and effectiveness of teleremote and automated technologies by the mining industry, investigation into the interaction between people and machines has begun. This involves exploring the human factors involved while operating advanced control interfaces such as immersive, mixed reality, and virtual environments. This will enable real-time remote operational control through advanced knowledge of human-machine-environment interactions.

The inertial-based navigation and localisation systems are 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 has been developed at QCAT which 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 in science and automation, two important international collaborations have begun with the Carnegie Mellon University (USA) and the Scuola Superiore Sant'Anna (Pisa, Italy). Work is also progressing towards the development of relevant industry communication standard in cooperation with the Australian Mineral Industry Research Association (AMIRA), which includes key mining companies and original equipment manufacturers (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 being tested at QCAT prior to 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 underway 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 in an Australian underground mine site. The technology is entering a new phase towards commercialisation.

A new research focus is towards rapid and safe underground mine development (tunnelling). 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 new continuous excavation methods using CSIRO 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 a continuous operation without the secondary damage and subsequent weakening of the surround rock caused 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 now 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 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 aimed 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 new Guidelines For Open Pit Slope Design was officially released at the Slope Stability conference in Santiago, Chile, in late 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 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 most 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 Rio Tinto Group, Brisbane, Australia
- Vale (CVRD), Rio de Janeiro, Brazil.

Mining automation

The CSIRO Earth Science and Resource Engineering and the CSIRO ICT Centre deliver a broad range of R&D capabilities for the mining sector – from pioneering science activities to robust industrial solutions. The value of this mining-focused R&D effort has been evident across the full value chain of mining: resource exploration, mining production, resource transport, logistics and delivery.

Mining Technology

CSIRO continues to conduct world-leading research directed towards enhancing mining technologies in coal and metalliferous domains. These activities focus on improving safety, productivity and sustainability in mining. Major areas of research and application include:

- **Mining navigation:** After initial application to longwall systems, new outcomes in inertial-based localisation have been applied to other mining contexts. Work is continuing successfully on fusion of multiple data sources within the underlying inertial platform to improve accuracy and robustness.
- **Resource sensing:** Research and development of new radar-based imaging continues. This technology includes environmental mapping and subsurface imaging to provide new options for real-time mining equipment control. Work is focussed on the development of resource-aware imaging geological-based machine guidance in coal and metalliferous mining applications.
- **Integrated control:** Real-time, high accuracy 3D profiling systems developed for transport applications are being enhanced through the development of visualisation systems for teleoperation and autonomous control.
- **Telecollaboration:** Innovative, immersive and interactive user environments continue to be developed and demonstrated. This capability is central for providing meaningful representations of complex geological information with multiple collaborations in a real-time, decision making context. Specific R&D continues in advanced visualisation to enhance the effectiveness of human systems interaction technologies.

- **Emergent mining systems:** Focused research is underway to develop ultra-remote and non-entry mining methods for enhanced safety and resource recovery. This effort is targeting the development of new systems for mining under unconsolidated resources, resource-efficient mining solutions, and advanced systems for enhanced remote and non-entry mining.

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

LASC technologies: longwall automation

LASC Technology is the commercial outcome of a major Landmark longwall automation project funded by the Australian coal industry (see http:///www.lasc.org). LASC Technology has emerged as an essential component of modern longwall operations and has had significant uptake in Australia. This initiative successfully demonstrated the use of inertial sensors and advanced navigation algorithms to measure the 3D path of the longwall shearer. The five major global longwall equipment suppliers licensed to exploit CSIRO longwall automation technology are offering commercial LASC longwall automation equipment to the Australian and US coal mining industries. Eight longwall faces utilising LASC automation systems are operational or in manufacture. Further international markets are also being explored.

Continuous miner automation: CM2010

CM2010 is a large scale initiative of the Australian coal industry aimed at a step-change improvement in longwall roadway development rates. This project is central to achieving this goal and an essential step in realising the safe and productive continuous miner of the future. In 2010/11, innovative R&D developments included:

- advanced inertial navigation techniques, which accurately measure the 3D position and orientation miner in real time;
- new navigation algorithms that guide the mining process and provide an accurate position reference for other underground mining components;
- control and remote monitoring systems that achieve autonomous mining in accordance with a mine plan.

Shovel load assist

An ACARP-funded project conducted by CSIRO and CRCMining aims to develop and demonstrate a system for automatically loading haul trucks using electric mining shovels. The system managed aspects of 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.

CSIRO's central contribution to this collaborative project was the development of the situational awareness module for machine control, which enables representation of the shovel work space and extraction of relevant features/objects from the environment. While the operator remained present, automation of the swing, dump and return phases of the machine cycle will reduce cycle times and improve efficiency. The technologies developed by CSIRO have been successfully tested and demonstrated to key stakeholders in the project. The project was completed in May 2011 and the system is undergoing commercial-ready development through CRCMining and its partner P&H. A number of systems will be deployed at mines across Australia and worldwide.

Remnant Coal Wagon Detection System

CSIRO mining technology and Gladstone Ports Corporation have developed a system capable of performing real-time monitoring of coal wagons to warn operators of large coal hang-ups. This new technology ensures that affected wagons can be cleaned before passing the dump station pits, improving the productivity and reliability of the coal terminal in-loading facility. The system consists of:

- rapid processing of laser scanner data in order to detect coal hang-ups;
- threshold-based alarms that inform the dump station operators of large coal deposits;
- long-term data storage of alarm events, matched to camera images that provide a visual reference of each coal hang-up and trigger warning and alarm levels.

New project developments have begun, including an accurate coal volume estimation system and an investigation into automated cleaning options.

Optical Fibre Powered Communications

CSIRO mining technology has completed an emergency underground coal mine communication project funded by the Centre for Disease Control through the US-based National Institute for Occupational Safety and Health to examine options for emergency underground communications. This initiative has led to the development of new communications technology for surviving underground incidents such as fire, flood or roof collapse. Key industry impacts include:

- the invention of an emergency communication device that can be supported exclusively by trenching armoured fibre optic cable into roadways or installation via boreholes;
- a survivable communications system that does not rely on internal batteries or underground mine power;
- new options to improve personnel safety.

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

Nexsys™ introduces a step-change in 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 are displayed in real-time using a 3D graphic user interface. This system provides essential information to mine personnel to enable rapid and efficient decision making, especially in an emergency.

The real-time analysis software system has undergone an extensive pre-commercial field trialling and validation at an Australian coal mine. The commercial version of the Nexsys™ system is available from CSIRO commercial partners worldwide: the Nexsys™ hardware is available from Ampcontrol Pty Ltd and the Nexsys™ integrated software system from Nepean Power Pty Ltd.

Since the commercialisation of the Nexsys™ system, there have been varying requests for the technology from the mining industry largely due to the 4D rules engine and personalised interfaces, which allow Nexsys™ to address and solve the many and differing problems encountered at mine sites. The Nexsys™ system versatility enables a high degree of customisation and industry requirements can be easily matched and range from whole of mine monitoring to specific tasks within the mine:

1) Whole of Mine Monitoring has been demonstrated during the final pre-commercial mine trial raising customer confidence in the capability of Nexsys™ to undertake monitoring and decision support for management and operators.

2) Multiple Mine Monitoring allows data and information exchange and reporting in real time among a number of company sites and/or directly to the corporate office. Data and information flow includes localisation and monitoring of personnel underground as well as production and safety statistics. Any major (red) alarms can be shown in real time to the relevant manager in the corporate office.

3) Pit to Port Capability extends the Nexsys™ capability beyond the mining operation and includes a number of Nexsys™ servers linking the pit, loading and rail systems, and port infrastructure to a remote operations centre. The remote operations centre, hosting equipment specialists and managers, will enable the use of information from the business operation to increase efficiency and safety throughout the supply chain by eliminating or reducing bottlenecks and quick, specialised responses to alarms and breakdowns in real time.

4) Specific Tasks within the Mine rely on the Nexsys™ capability to be scaled down to provide support in specific areas that the mine hopes to improve.

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 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 per cent 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 per cent with very little reduction in engine efficiency. A second project using a triple chamber acoustic agglomerator has been approved and is aiming to remove 99 per cent 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 incorporated AMT technology into new and existing production systems. This has resulted in significant improvements in production rates and resource recovery and provided 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.

CET Group

Cutting Edge Technology

Cutting Edge Technology Pty Ltd (CET) was established at QCAT in 1995 as a mining consultancy that specialises in 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 2010/2011 CET's 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

In order 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

CET Resources Pty Ltd was formed to participate in mine ownership, building on its 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 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 1999. Most of its activities are with Queensland projects or companies based in Queensland.

GTS has continued to work with CSIRO technologies. During the past year additional projects were undertaken to identify potential underground coal gasification projects.

Sirovision remains an important part of GTS's suite of technology. It is used for the remote mapping of geological structures. GTS and CSIRO staff members were co-authors of a paper that demonstrated an important practical development in Sirovision. This paper was presented at the Bowen Basin Symposium.

GTS has co-supervised a University of Queensland honours year student. The project is based in the Galilee Basin and has utilised HyLogger™, another CSIRO developed technology, to help identify clay minerals which are of great significance to mining in this new province.

These projects demonstrate the ongoing value of the CSIRO-UQ-Queensland mining hub and its importance to SMEs.

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.

CSIRO

Historically, the focus of mineral processing research at QCAT has been on iron ore and non-ferrous mineral processing. However, following the relocation of the BHP Billiton Carbon Steel Materials group from Newcastle to QCAT in July 2009 and the development of a strategic alliance with BHP Billiton, the scope of CSIRO's ferrous mineral processing research continues to be extended from iron ore into manganese ore processing and coke making, with the latter to expand substantially following installation of the BHP Billiton pilot-scale coke ovens at QCAT and the handover to CSIRO on 19 August 2011. Commissioning of the coke ovens is now in progress, including running calibration charges.

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 focus are:

- characterisation of new ore resources;
- predicting beneficiation and downstream processing performance, including optimising sinter, pellets and lump in blast furnaces and other iron making processes; and
- removal of alumina, silica and phosphorus from the lower grade Australian iron ores being developed or likely to be developed in the future, including Australia's magnetite resources that are attracting intense interest.

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 iron ore characterisation has now been largely completed and one licence to use the CSIRO image analysis and 'Recognition' software system has been granted with negotiation of another licence close to finalisation. This capability is 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 still the longer-term objective, with the ultimate vision to predict beneficiation and sintering performance from ore characteristics. For this purpose, the objective is to develop mineralogy-based models for a range of unit operations in addition to preliminary models already developed for 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 being exploited in Australia to replace resources that are being depleted and to meet increasing market demand for iron ore, particularly from China. However, the levels of impurities in these ore, such as alumina, silica and phosphorus, are gradually rising and need to be controlled by blending or in the longer term removed. This has triggered the establishment of an iron ore impurity removal project in which a range of options for beneficiation of Australian iron ore is being investigated including:

- heat treatment and leaching for removal of alumina and phosphorus;
- evaluation of techniques used in China and India for treating low grade ores;
- acquisition of new beneficiation equipment such as an Allmineral jig and Floatex density separator, for trials on Australian ores;
- microbial-induced flotation and flocculation for selective removal of impurities.

The international demand for iron ore and shortfall in supply of traditional hematite/goethite ores continues to create a growing interest in developing Australia's substantial magnetite ore resources. Characterisation and beneficiation research on magnetite resources is continuing on a number of West Australian, South Australian and Queensland ores. The research aims to reduce grinding costs for liberating magnetite from the gangue minerals (for example, by using stirred milling), and control 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 plays a pivotal role in proving up new Australian iron ore resources for export to supplement Australia's depleting resources of high grade Brockman ore. Laboratory-scale research continues to be 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. The granulation and sintering characteristics of the new ore types and their impact on sintering performance continue to be investigated, including magnetite concentrates, with the focus being on improving the permeability of the sinter bed and maximising sinter quality and productivity. This research is crucial to marketing Australian iron ores as they become more diverse in nature.

The CSIRO 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 millimetres, which covers a large part of industry practice. The CSIRO sinter rig is 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 getting more use as new raw materials are being brought to market. The furnace has good datalogging capabilities and atmosphere control, and waste gas concentrations can be measured, including CO, CO_2, O_2 and H_2.

Iron ore pelletising

Upgrading of the CSIRO pilot-scale iron ore pelletising facility at QCAT has been completed. A rotary kiln has been installed and commissioned, and a system for hot transfer of pellets from the pot-grate to the kiln constructed and commissioned. The enhanced facility enables simulation of 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 the magnetite ore under development in Australia.

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

Manganese ore processing

To expand industry links in the manganese area and develop a better understanding of the issues facing the industry, a workshop on the geology and processing of manganese ores was held in Perth in November 2010.

Technical presentations from industry and CSIRO focused on the geology/mineralogy and beneficiation of manganese ores, together with pyrometallurgical options for impurity removal and the importance of manganese in the steel-making process. The workshop concluded with a round table discussion on the technical challenges facing the industry during exploration and processing of manganese ores and how CSIRO capabilities could best be used to address these challenges.

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 have been relocated to QCAT. The relocation, installation and commissioning of the pilot-scale coke ovens were funded by BHP Billiton, resulting in the establishment of a world-class pilot-scale coke making facility with a replacement value of

Collaboration

BHP Billiton Carbon Steel Materials

In May 2010, BHP Billiton and CSIRO signed a 'Heads of Agreement', which signalled a long-term, strategic partnership to significantly benefit 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. Construction of the new wing is progressing.

BHP Billiton also funded the extension of M Block at QCAT as well as the relocation, installation and commissioning of BHP Billiton's two pilot-scale coke ovens. The pilot-scale coke ovens will be operated by CSIRO under a long-term agreement with BHP Billiton.

about $15 million. The facility was officially handed over to CSIRO on 19 August 2011.

The coke ovens will be operated by CSIRO for BHP Billiton under a long-term agreement, and will also be available for coke-making R&D for third parties.

The need for coke making R&D is driven by the decline in Australia's resources of hard metallurgical coal, so effective ways of utilising softer metallurgical coals in coke-making need to be developed, for example by blending them with harder metallurgical coals for production of coke that provides the required reductants, heat and burden support in blast furnaces.

Research has been initiated on metallurgical coal and coke characterisation and the development of robust models for optimising metallurgical coal blends to improve coke making performance and coke quality. In addition, wall pressure and wall-gangue interactions need to be minimised in commercial coke ovens, because they seriously affect the working life of refractories prior to reline. This will effectively expand Australia's resource base through utilisation of higher tonnages of the softer 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 sampling iron ores, coal and copper, lead, zinc and nickel concentrates, while methods are under development for sampling smelter products and residues. Work on the development of improved ISO methods for physical testing of blast furnace and direct reduction feedstocks for iron and steel making is continuing.

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 nearing completion. A ruggedised prototype monitor with an inertial power supply for continuous operation is operating successfully at the Rio Tinto Northparkes mine in NSW and a second unit also powered by an inertial power supply was successfully installed on a ball mill at Anglo Platinum's Waterval operation in South Africa. The monitor can track the toe and shoulder positions of the charge as well as the mill load, and potentially the charge size inside the mill and other operating parameters. Work is in progress to establish correlations between vibration signals and key operating parameters for mill control.

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.

Coal processing

Researchers from CSIRO Energy Technology division 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. One ACARP-supported project has recently been completed at New Hope's New Acland mine, and another one at the same locality has just begun. This will improve efficiencies and long-term operating costs in coal production plants.

Research is also continuing to identify factors controlling the efficiency of dense medium cyclone medium stabilities, partition curves and magnetite recovery. Industry funding has been obtained to continue the work with focused plant trials. Ludowici Mineral Processing Equipment 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.

BHP Billiton Technical Marketing

In June 2009, BHP Billiton relocated its Technical Marketing groups for Metallurgical Coal, Iron Ore and Manganese Ore/Alloys from Newcastle Technology Centre to QCAT. The group's purpose is to technically understand, evaluate and improve the use of new and existing raw materials for the manufacture of steel. It was identified that a key to achieving this role was to develop and grow collaborations and partnerships with world leading Universities and Research Organisations in the area of steelmaking raw materials and processes.

BHP Billiton's long term commitment to CSIRO and the QCAT site has been underpinned by the funding of the construction of R wing north office block and the extension of M block for the housing of the pilot cokemaking facilities.

Iron Ore

BHP Billiton aims to continually build its knowledge of iron ore products and how to optimise their use in steel mill ironmaking processes. This endeavour is well supported by utilising the world class expertise and facilities for research into iron ores, sintering, pelletising and ironmaking that exist within CSIRO. To further enhance QCAT's capabilities, BHP Billiton relocated specialised equipment here such as waste gas analysers and isokinetic sampling for environmental studies and high temperature furnaces for fundamental iron ore sintering investigations. Projects areas include the physical and metallurgical characterisation of Australian and global iron ores - existing and new; fundamental ore property and sintering investigations; pilot-scale sintering process improvement and blend optimisation studies; and techno-economic analysis. An important role of BHP Billiton technical marketing is to develop relationships with steel mill customers to better understand their processes and future challenges. We engage in a range of technical exchanges and joint research programs to enable this. Steel mills are regularly invited to visit the QCAT site to observe and review the research being undertaken. For some programs this includes international steel mill researchers spending an extended period joining with us and CSIRO to work together on projects.

Metallurgical Coal

To facilitate the long term coal and coke research partnership between BHPBilliton and CSIRO, BHPBilliton has relocated it's industry-leading pilot coke testing equipment and capabilities to QCAT. The equipment, which will be operated by CSIRO personnel, will be used to produce industrial-quality metallurgical cokes, using conventional and alternate cokemaking technologies. The ovens' abilities to produce cokes under carefully controlled conditions, and to allow monitoring of at various stages of the coking process, underpin research studies of the coal properties and carbonisation mechanisms that control coke formation and strength.

These studies are used to develop coal blending and coke strength predictive models, which are used to optimise the use of Australian coals to make cokes with the qualities required by current and future blast furnace ironmaking applications.

Manganese Ore

Manganese Technical marketing located at QCAT work on both technologies for producing new ore products as well as understanding the utilisation of our products by customers.

Manganese ore generally has complex mineralogy and textures making it important to understand the variations present and how these may impact our customer's ability to use them. Sophisticated methods at QCAT have been used to further understand the variability of our products and how these impact the behaviour of our products in mineral and metallurgical processes.

As the demand for ore increases, improved beneficiation is required to maximise the available product from our mines resources. To do this, part of a selection phase study beneficiation experiments were recently conducted to review the suitability of a technology for producing a new manganese product from previously low-grade waste. Encouraging results have led to further testing at our mine site at a larger scale for commercial consideration.

One major process that uses our fine manganese ore is sintering. The QCAT sintering facility, although designed originally for investigating iron ores, is equally as effective for studying the sinterability of manganese ores. Sintering tests enabled the measurement of critical operating parameters and sinter characteristics for new manganese blends under consideration. These results have enabled a strong understanding of how particular manganese ores can be used in commercial sinter plants.

Rio Tinto Alcan Queensland Research and Development Centre

2012 will mark 10 years since Rio Tinto Alcan opened a research and development centre on the QCAT campus - the Queensland R&D Centre (QRDC) - and seven years since the opening of its own building in 2005. The group is currently made up of nearly 25 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.

The objective of the bauxite residue management 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.

The QRDC also heads up an environment programme, which aims to provide innovative and effective environmental solutions for site-specific issues. In alignment with Rio Tinto policies, there is a strong focus on applying in-house expertise to reduce operational impact and footprint, closure costs and post-closure liability.

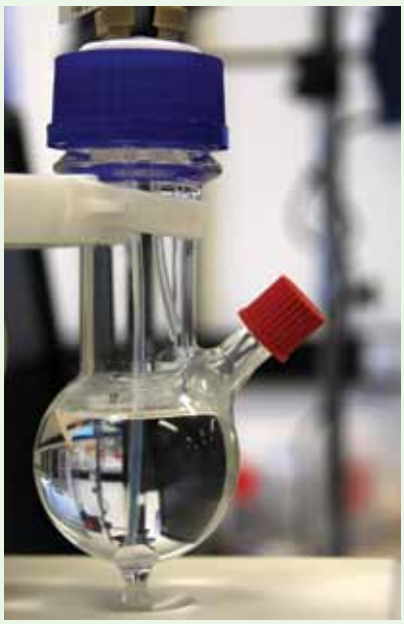
Finally, the analytical programme has two main focuses: developing new methods of analysis using new instrument technologies; and refinement of existing methods. Current project work includes bauxite characterisation, and particle sizing techniques. A major focus of this programme is to maintain open 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 2011, Rio Tinto Alcan has continued its long history of collaboration with Australian research organisations, such as its commitment to A J Parker Cooperative Research Centre (CRC) for Integrated Hydrometallurgy Solutions. It also is involved with a number of collaborative research initiatives involving CSIRO or CRCs with CSIRO participation, including several Australian Mineral Industry Research Association (AMIRA) projects.

With a presence 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.

Rio Tinto 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 material engineering R&D cluster at QCAT includes researchers from CSIRO Process Science and Engineering and CSIRO Earth Science and Resource Engineering divisions. Research within the cluster focuses on light metals and fibre composites, both growing sectors in Queensland's manufacturing industry.

CSIRO

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, which needs continually 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. A novel heat-treatment process for die-castings developed at CSIRO can deliver improvements in strength, ductility and fatigue life. A proof-of-concept project has been initiated by the Auto-CRC together with a major automotive manufacturer to trial the process as a new production method for certain components. The promise is for cheaper components with improved properties, and fatigue property evaluation will be a crucial part of the evaluation.

The group is also evaluating the fatigue properties of titanium materials prepared by novel processes.

Magnesium alloy development

Magnesium, alloyed with a few per cent 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, suitable for automotive engine components. QCAT's researchers are assisting the licence-holder in scaling up the alloy production processes in its own plant.

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 their coating alloys, with the eventual aim of improving life and quality of the manufactured product. The project is producing and evaluating a coating material with potential for 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 developing composite housing for sensing instruments that determine the properties of the rock mass surrounding a borehole. One of the instruments being developed by CSIRO uses a neutron source and sensitive detectors requiring an instrument housing that does not interfere with measurements, yet is strong and stable enough to resist the external pressures caused by water and muds more than one kilometre underground. Previously, the group used aluminium tube housings that were machined, anodised and coated with enriched boron to prevent interference from the aluminium, and then wrapped with a protective fibre composite material layer. These housings were very expensive and susceptible to buckling at great depth.

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

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. Researchers in QCAT's low emissions coal technology cluster are supported by the Queensland and Federal governments, universities, industry and international partners.

CSIRO

Coal mine methane capture and utilisation

The Bilateral Climate Change Partnerships Program aims to develop and implement 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 program from the Department of Climate Change and are being undertaken with Chinese partners to investigate coal mine methane (CMM) capture and utilisation.

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 per cent, or on drainage gas with methane concentrations lower than 25 per cent. 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.

During 2010 a 25kWe prototype demonstration unit was successfully constructed and commissioned, validating the viability of VAMCAT technology. Mine site trials of the prototype unit started at Huainan coal mine site in China will be completed by December 2011. The prototype unit has been transported and fully installed at the mine site with the connection to the mine site infrastructure designed and built in 2010/11. The Chinese partners for this project are Shanghai Jiaotong University, Huainan Coal Mining (Group) Co. Ltd and Chongqing Jiangjina Machinery Company.

Coal mine methane resources and potential project development

CSIRO has worked with the China Coal Information Institute (CCII) 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 CMM emissions and production. The project contributed to the development of a policy framework for CMM development projects in China. In the past year, the project team has successfully completed all the studies, and the final report has been submitted with the site investigation data and study results for the development and planning of methane mitigation and utilisation plants at the mine sites.

Coal mine methane capture maximisation

CSIRO has worked 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 has been implemented at a mine in Huainan to demonstrate improved CMM capture. CSIRO has worked with the CCII 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. This project has been successfully completed, and the final report has been submitted.

Low emissions electricity

Coal is Australia's largest export and a major contributor to the national economy. Coal is also 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 the coming decades, it is imperative to 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 coal will change.

CSIRO's research programs support a range of energy technologies that enable a transition to high efficiency power systems, which are capable of capturing most of their CO_2 emissions. Research undertaken at QCAT is increasing the 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. This research also contributes to the expertise required to evaluate fuel and energy strategies for sustainable energy conversion technologies in Australia.

Coal gasification

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

The gasification process reacts fuel 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, for example, 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.

QCAT researchers are working closely with industry to address some of the barriers to the deployment of gasification-based power systems in Australia. IGCC systems operate at temperatures significantly higher than traditional combustion technologies, so the mineral matter in the coals is mostly discharged as a glassy slag. QCAT researchers are working with Australian National Low Emissions Coal R&D (ANLEC R&D) to understand how this material might behave during storage and utilisation, to ensure that the environmental impacts of new IGCC plant are minimised and well managed.

QCAT gasification scientists are also working with the Australian coal industry to develop accurate and detailed models of the gasification process, so impacts of fuel variation and technology advances can be better understood. CSIRO has considerable expertise in understanding the fundamentals of the gasification process; this modelling work is an important means by which this detailed science can be applied to solving real problems for Australian industry.

QCAT is also the new focus for CSIRO's experimental biomass gasification research. While the underlying science of biomass and coal gasification are similar, there are some important fuel-specific challenges associated with the use of biomass and waste materials in gasification processes. QCAT researchers are studying the gasification behaviour of biomass and waste materials, which has important implications for local industries such as the sugar industry.

Syngas processing and gas separation technologies

There are strong efficiency and cost drivers to develop syngas technologies which can be integrated into coal- based gasification and IGCC systems. These technologies will produce hydrogen for power generation while capturing carbon dioxide in a form ready for sequestration.

CSIRO's research in this area covers fundamental (basic materials discovery) and applied (device engineering) aspects of technology development including:

- novel catalysts for producing hydrogen from coal with greater efficiency and reduced steam requirements than conventional catalysts;
- alloy membranes that can separate hydrogen from carbon dioxide at high temperature and pressure;
- membrane reactors that combine catalysts and membranes in a single device to efficiently produce hydrogen fuel while simultaneously capturing carbon dioxide emissions from gasified coal.

QCAT scientists partner with external agencies, including ANLEC R&D, the US Department of Energy and a number of US-based universities and research institutions. Existing partnerships with CSIRO scientists at other sites around Australia also remain a key part of CSIRO's competitive advantage.

CSIRO's experimental capability is continually evolving to meet new research challenges. New equipment has recently been installed that, in addition to the existing state-of-the-art syngas facilities and capabilities, will allow more detailed examination of how hydrogen interacts with these new membrane and catalyst materials. Among these are a new mass spectrometer for gas analysis, and a system for measuring hydrogen absorption by alloy membranes.

Social science research team

The CSIRO Science into Society Group (SISG) specialises in applied social research focusing on issues that are often socially contested. Areas of interest include sustainable industry and community development, assessment of technology, social licence to operate and the investigation of related behavioural change. By working with leaders in government, industry, civil society and other relevant stakeholders, this research helps to inform decisions and improve scientific understanding.

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.

Energy

Global Carbon Capture and Storage Institute

The SISG is working closely with the Global Carbon Capture and Storage Institute (the Institute) on a series of projects focusing on information dissemination, public outreach, community engagement, and perceptions and attitudes around carbon dioxide capture and storage (CCS) technology. In 2010/11, several project milestones were achieved.

- Finalising the Communication/ Engagement Toolkit, a universal toolkit for CCS industry proponents seeking to engage with the public and communities about the technology.
- Working closely with colleagues in the USA to gain a better understanding of the ways in which people view risk, focusing on the personal rather than technical or scientific perspectives.
- Working closely with Cambridge University on two projects including the development of a database on public communication materials on CCS and a report on the culmination of research focusing on the opposition to CCS and looking at activist activities and the impetus that drives them.
- Developing a series of risk assessment factsheets around CCS.
- Conducting interviews and questionnaires in the Netherlands, Japan and Australia seeking to understand how people perceive carbon dioxide.
- Undertaking large group process workshops in Canada and the Netherlands, designed to provide factual information on energy technologies to help educate the public towards informed decision making.
- Working with CSIRO Education to release a report on availability and quality of existing CCS education materials and the development of an education database.
- A stakeholder workshop, hosted in Harvey, Western Australia, on behalf of the Western Australian Department of Mines and Petroleum, to engage local community members around the Collie Hub CCS project under development in the Harvey region.

All reports from this work have been launched by the Institute on its website. Our work with the Institute is set to continue with:

- A third large group process scheduled to take place in Edinburgh, Scotland.
- The development and trial of a set of CCS Educational Units and Teaching Support Notes with 13 Australian and 6 international schools.
- Additional stakeholder workshops are being scoped for future research and the Wandoan and CarbonNet projects are being considered.
- Working with colleagues in the Netherlands on a project to develop an Australian context information choice questionnaire to address an Australian policy problem. Upon finalisation, the survey will be trialled in the Netherlands before being delivered to the Australian public in an online fun and interactive information resource.
- A new project under consideration by the Institute, *How Australians Value Water,* aims to define a comprehensive set of values in managing Australia's groundwater resources.

Energymark

Energymark works through small community-based networks meeting to discuss attitudes and ideas surrounding energy and climate change. Peer reviewed information is provided by CSIRO to support the discussions. A national pilot of the project found significant changes in knowledge, attitudes, and behaviour towards

climate change. The 1092 participants in the trial reduced their carbon footprint by an average 19 per cent in 8 months.

As a result of the pilot project, CSIRO is working in partnership with the Office of Environment and Heritage in New South Wales, engaging more than 1000 households across the State.

CSIRO has also partnered with Brisbane and Redlands city councils to offer Energymark to a further 250 people. The results of these projects will be collated in March 2012.

Exploring community acceptance of rural wind farms in Australia

As part of a larger study by CSIRO to map Australia's existing and potential wind energy sources, the SISG began research on community acceptance of rural wind farms in Australia. The Australian Government's amended Renewable Energy Target (RET) seeks to provide 20 per cent of Australia's electricity generation from renewable energy sources by 2020. As a proven, affordable technology with excellent resources in Australia, it is anticipated that wind power could contribute the majority of renewable energy generated for the large-scale RET. Despite the prevalence of articles in the popular media regarding community acceptance of rural wind farms, there is minimal academic examination of this situation. This research provides new, academically sound information that analyses community acceptance of Australian wind farms from a variety of stakeholder perspectives.

Zero Emission Home

CSIRO's Australian Zero Emission House project is working on ways to bring about a dramatic and significant reduction in greenhouse emissions in Australian housing to mitigate the adverse impacts of a changing climate. As part of this project, the SISG is undertaking research that aims to investigate the household carbon footprint and behavioural change to reduce greenhouse gas emissions in the Australian housing sector.

Climate adaptation

Australian primary industries transforming for a changing climate

This project is working towards understanding the conditions and support required for Australian primary industry to make transformative changes to their practices in the face of a changing climate. The first stage of data collection and analysis is complete. Emerging findings across the case studies show that climate change is just one driver of change in the community and primary industries researched (peanut, livestock, Sunraysia and Mildura communities and wine). Nevertheless, many adaptations for climate are already occurring and there is a need for information sharing and support to improve knowledge and uptake of adaptations across the sectors.

Presentations and posters on this research were presented at the International Climate Change Adaptation Conference: Climate Adaptation Futures: preparing for the unavoidable impacts of climate change.

Exploring mining community adaptation to climate change

In this project, the SISG is investigating the vulnerability and adaptive capacity of mining regions to climate change. As part of this research, a workshop was conducted in the Kalgoorlie, Goldfields-Esperance Region of Western Australia with industry, government and community stakeholders. A national survey of mining companies and local government authorities was also conducted to ascertain views on climate change and adaptation planning activities. Research findings were presented at conferences and forums including the AusIMM Sustainable Mining Conference 2010, Greenhouse 2011, the Local Government Association of Queensland Economic and Regional Development Conference 2011, and the Mineral Futures Cluster Public Forum 2011.

Sustainable agriculture

Opportunities and risks for biodiversity management in the high rainfall zone

The SISG is working to understand what changes in farming land are taking place in Australia's high rainfall zone and the implications for biodiversity. The high rainfall zone is situated between the coast and traditional wheat-sheep zone, which is productive farming land and home to significant biodiversity. Mixed farming enterprises (combining crop and livestock) have historically dominated the high rainfall zone, though more recently cropping has been increasing. The social researchers, working alongside ecologists, have analysed past land use data, interviews and surveys of farmers to identify whether this increase is likely to continue, what is motivating the increase and on what types of pasture the increase will take place on. Findings are to be published soon, including what land types are likely to undergo transitions and related opportunities for biodiversity management.

Mining and exploration

Mineral Futures initiative

The Mineral Futures Collaboration Cluster continues to deliver important research on the social sustainability of the minerals industry in Australia. A highlight this year was the launch of the Vision 2040 document (http://resourcefutures.net.au/node/28) by cluster partners, the University of Technology, Sydney. Research with the Cloncurry Shire Council to explore the future of the region alongside mining and explore alternative visions of the future is also continuing.

Social licence to operate

As the minerals industry expands into new areas such as coal-seam gas and seafloor mining, increased attention is needed to understanding the dynamics of social, environmental and economic impacts, especially within communities that previously might not have experienced mining. Under what conditions are communities and society prepared to accept, approve and trust such operations and industries?

In 2010/11, the SISG continued to work with industry to understand what 'social licence to operate' means in theory and practice.

This work has also been applied to the coal-seam gas industry working with a proponent in the Surat Basin to develop its social impact measurement and monitoring framework, and to develop a model of social licence in practice.

The SISG also formed part of the CSIRO partnership with the World Economic Forum and World Bank Institute to deliver a report from the Responsible Mineral Development Initiative.

Assessing the impact of seafloor exploration and mining

Seafloor exploration and mining has been identified as an emerging industry in Australia presenting opportunities but also challenges and responsibilities. While currently a small industry in Australia, regulatory regimes are in place for it to progress. The focus of this research is to understand the potential ecological, geological, technological, social and economic impacts of seafloor exploration in Australia to support future decision-making relating to seafloor mining in Australia.

Information and communication technology

CSIRO ICT Centre at QCAT focuses on research in field robotics and 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 for the energy sector.

CSIRO Automation

Developments in Simultaneous Localisation and Mapping (SLAM)

Simultaneous localisation and mapping (SLAM) is a relatively new and popular technique used in robotics to build a map of an unknown environment or to update a map of a known environment while simultaneously keeping track of the vehicle/robot's location. Because SLAM can provide localisation and mapping perception at the same time, it is a critical enabling technology to the automation of mining. It can provide:

- a live and continuously updated digital terrain map of the mine;
- an independent localisation system that works well in GPS-denied areas of the mine i.e. underground or deep in the pit;
- an independent tracking system that is able to track passive assets around moving vehicles;
- the ability to detect change in the short and long term, acting as a precursor to obstacle detection and long-term mapping of the mine.

SLAM techniques can be applied to a variety of sensors: vision, radar and Lidar (a laser-based range finding device). CSIRO researchers have found Lidar to be an excellent sensor in the mining environment. To test the performance of Lidar-based SLAM in a variety of outdoor environments and conditions, a skid-steer-loader was fitted with a spinning Lidar. This is a commercial sensor that can be used to create a complete 3D digital terrain map of the road ahead.

To create maps from a moving vehicle, QCAT researchers developed a technique called sweep matching to compensate for the sensor's local motion, and a technique called scan registration to compensate for global drift (stitching maps together). Put together, the software is able to create large-scale self-consistent 3D maps of the environment that require no additional sensors such as GPS or odometery.

Since the SLAM technique does not require GPS to create maps, it is possible to use it in areas where GPS signal cannot penetrate i.e. indoors, underground and under infrastructure. To test the performance of such a system, a spinning Lidar was fitted to a small mobile cart and taken into the Jenolan caves in NSW. One of the challenges in this underground environment is the size of the scanning device. To reduce its size, QCAT researchers mounted a small scanning Lidar to a hand-held spring, to use the natural motion of the user to 'nod' the device in the third dimension.

Wireless sensor and actuator networks

Opal hardware platform

Building on several years of experience around low-power, sensor network platforms for environmental monitoring, the past year has seen the development of a new class of sensor network

platform called 'Opal'. Opal is designed to build on advances in microprocessor and radio technology to allow nodes to have greatly increased computational power and transmission range while still achieving extremely low-power operation.

Key features of the Opal platform include:

- a wide set of finely tuneable communication parameters that can be adjusted on the fly;
- multiple radios to allow frequency and spatial diversity;
- on-board Trusted Platform Module chip for encryption of information being sent wirelessly;
- a highly flexible, scaleable processor that goes from extreme energy conservation to high load computational tasks;
- battery recharging under fluorescent light.

Opal sensor nodes have been tested in laboratory environments and outdoors. They are at a mature stage of development with the first 1,000 nodes in production.

Indoor energy monitoring at QCAT

In an effort to understand and reduce energy consumption within an office environment, a network of wireless sensors was deployed at QCAT. The goal was to compare the energy efficiency of office space arrangements, and feed this information to property managers and office occupants to motivate them to save energy. As part of the project, two new sensing platforms based on existing CSIRO sensor network modules were developed including a platform for monitoring personal workspaces including light, temperature, motion, relative air humidity and air humidity sensors; and a plug meter that is integrated with the sensor node to provide fine-grain, personal energy measurements.

The initial trial showed that obtaining and displaying fine-grained information around energy usage was indeed effective in changing some aspects of human behaviour to reduce individual energy use. The project is looking to broaden to a larger trial across CSIRO.

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. The nodes are in areas of open grassland, regenerating rainforest and old rainforest, where they monitor microclimate 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.

Phase 2 of the network is complete, with almost 200 microclimate nodes deployed. The network includes a small number of multimedia nodes to detect various biospecies events and will soon be extended to include further information such as light readings, rainfall, fog and water quality indicators.

iSnet - integrated Sensor network

In partnership with Seqwater, CSIRO has developed an integrated solution for monitoring water storages and catchments. The iSnet (integrated Sensor network) system consists of a wireless sensor network including floating nodes, land-based nodes, sensor nodes worn by cattle grazing in the catchment, and a robotic boat that traverses the water storage taking detailed measurements and investigating potential anomalies identified by the network of static nodes. The complete system includes software for data storage and management, quality control, visualisation and analysis.

iSnet is designed to allow a water management authority to monitor water quality, event flows, and greenhouse gas emissions (methane). Continuous monitoring enables early detection of events and validation of models and predictions against incoming data. It also provides real-time feedback to operators to help them improve the cost-effectiveness of water treatment procedures.

A proof-of-concept iSnet system consisting of 120 static nodes and a robotic catamaran was installed on Lake Wivenhoe, Brisbane's major source of drinking water. Data captured by the sensor network and robotic boat were combined with other datastreams to validate a model of a specific environmental process resulting in a business efficiency decision saving many millions of dollars on a new dam upgrade. The iSnet system won the 2010 Australian Information Industry Association national award for research and development.

Aviation and aerospace

CSIRO

Unmanned aircraft

The ICT Centre's Autonomous Systems Lab is pioneering research on robust autonomous helicopter systems that can operate in unknown environments. The aircraft have been integrated with perception technologies that enable them to fly autonomously near terrain and obstacles such as trees and structures. Along with dependable flight control systems, the obstacle avoidance capabilities have been demonstrated in a test inspection task to capture high-resolution images of a windmill more than 1.5 kilometres from the ground control station and without the possibility of pilot intervention. The system utilised a line scanning laser and custom flight modes to sweep the laser in front of the helicopter to detect and avoid trees while approaching to within 10 metres of the inspection target and maintaining a fixed height above the terrain.

A commercially available multi-rotor helicopter has also been used for research into improving control in windy and turbulent conditions. This eight-rotor platform has been integrated with an airspeed sensor that is used to influence the control of the aircraft and has been shown to improve the ability of the helicopter to hold a fixed GPS position in high winds.

ARCAA - Smart Skies

The Australian Research Centre for Aerospace Automation (ARCAA) is a joint venture between CSIRO and the Queensland University of Technology to promote civil research into unmanned aircraft. A particular focus is on autonomous technologies that support the more efficient and safer utilisation of airspace, and the development of autonomous aircraft and on-board sensor systems for a wide range of commercial applications.

The ARCAA Smart Skies Project was a three-year program ending in March 2011, for developing future technologies to support the efficient utilisation of airspace by manned and unmanned aircraft through the integration of information and communications technologies. The project, involving collaboration between ARCAA, Boeing Research and Technology Australia (BR&TA) and Boeing Research and Technology (BR&T), focused on advancing key technologies that would enable civilian unmanned aircraft to be safely operated in non-segregated airspace, enabling operators to deliver the many emerging applications for unmanned aircraft.

Integrated flight trials conducted near Kingaroy, Queensland, were key to the project. These trials included evaluation of automated separation management algorithms in real-world flight tests where manned and unmanned aircraft operated by ARCAA utilised integrated hardware and software to communicate with the separation management system located in the United States, and follow new flight paths commanded by that system to avoid potential collision scenarios.

ARCAA – UAV Challenge, Outback Rescue

The UAV Challenge, Outback Rescue is a competition aimed at showing how small unmanned aerial vehicles (UAV) can be used to locate lost bushwalkers and drop aid packages to them. The challenge, an initiative of ARCAA and the Queensland Government, is in its fifth year. This year's competition followed a new format with the Airborne Delivery Challenge for high school students run separately from the Search and Rescue Challenge, which was aimed at university students and enthusiast.

The Search and Rescue challenge now operates a two-year schedule that will see teams competing for $50,000 in Kingaroy again in September 2012. Teams failed to complete the mission in previous years, despite getting very close in 2010, but 53 teams have passed the first checkpoint for next year.

Technology Transfer Centre

QCAT 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 2010/11 included:

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

QCAT events

Visiting delegations

QCAT is a hub of collaboration for the mining, processing and energy industries. This collaboration takes on many forms, from hosting international expert speakers and government delegations to national industry and organisation representatives.

QCAT received more than 3000 visitors in 20010/11, including delegations from:

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
- 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

Taiwan
- Australia-Taiwan Joint Energy and Minerals Trade, Investment and Cooperation Consultations
- Australia-Taiwan strategic workshop – energy technologies for a low carbon future

USA
- Governor of Wyoming
- University of Wyoming
- General Electric
- Peabody Energy.

QCAT Innovation and Excellence Day 2010

More than 80 guests from industry, research and government attended the QCAT Innovation and Excellence Day in August 2010. *The Ideas with Impact* theme focused on projects that will underpin CSIRO's major research efforts in energy and mineral resources in the coming decade.

Following an opening statement from the Hon. Mike Ahern AO, presentations were drawn from a diverse background:

- **Dr Michael Glinsky**, Science Leader, CSIRO Earth Science and Resource Engineering Division discussed new science directions within the division
- **Dr Cameron Huddlestone-Holmes**, CSIRO presented his research into accelerating deployment of commercial scale geothermal energy in Australia
- **Dr David Harris**, Research Leader, CSIRO Coal Utilisation, spoke about development and deployment of low emission coal-based power generation
- **Dr Michael Bosse**, CSIRO ICT Centre, presented key developments in simultaneous localisation and mapping using mobile laser systems. This technology is critical to the ongoing development of autonomous vehicles
- **Mr Stephen O'Dowd**, CSIRO SME, discussed engagement that helps small to medium enterprises to find solutions to technical issues and identifies potential commercial partners for CSIRO's research products.

The presentations that have been released to the public are available for viewing on the QCAT website at http://www.cat.csiro.au/InnovationDay/ianде2010.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 Federal Department of Education, Employment and Workplace Relations. Seven staff from Earth Science and Resource Engineering, Energy Technology and 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 careers available in the sciences.

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 2010-11 were:

The Hon Mike Ahern AO
Chair, QCAT ve Committee

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

Mr Michael Roche
CEO Queensland Resources Council

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

replaced by

Dr Calum Drummond
Group Executive, CSIRO Information, Materials and Minerals Group

John Strano
Manufacturing and Investment Executive Director, Department of Employment, Economic Development and Innovation

replaced by

Dr Beth Woods
Chief Scientific Officer, Department of Employment, Economic Development and Innovation

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

QCAT contacts

Queensland Centre for Advanced Technologies
Technology Court, Pullenvale, Brisbane
PO Box 883 Kenmore Queensland 4069
AUSTRALIA

t: +61 7 3327 4444
f: +61 7 3327 4455
www.cat.csiro.au

Dr Mike McWilliams
Executive Manager - QCAT
t: +61 7 3327 4486
e: mike.mcwilliams@csiro.au

CSIRO Energy Technology

Coal Processing
Dr Bruce Firth
t: +61 7 3327 4500
e: bruce.firth@csiro.au

Coal Utilisation
Dr David Harris
t: +61 7 3327 4617
e: david.harris@csiro.au

CSIRO Earth Science and Resource Engineering

Theme Leader – Mining Science and Engineering
Dr Hua Guo
t: +61 7 3327 4608
e: hua.guo@csiro.au

Research Program Manager – Mining Science and Engineering
Dr David Hainsworth
t: +61 7 3327 4420
e: david.hainsworth@csiro.au

Mining Geoscience
Mr Graham O'Brien
t: +61 7 3327 4457
e: graham.obrien@csiro.au

Mining Systems
Dr Rao Balusu
t: +61 7 3327 4614
e: rao.balusu@csiro.au

Mining Automation
Dr Jonathon Ralston
t: +61 7 3327 4702
f: +61 7 3327 4455
e: jonathon.ralston@csiro.au

CSIRO ICT Centre

Autonomous Systems Laboratory
Dr Jonathon Roberts
t: +61 7 3327 4501
e: jonathon.roberts@csiro.au

Sensors and Sensor Networks
Dr Michael Bruenig
t: + 61 7 3327 4431
e: michael.bruenig@csiro.au

CSIRO Process Science and Engineering

Iron Ore and Non-ferrous Mineral Processing
Dr Ralph Holmes
t: +61 7 3327 4452
e: ralph.holmes@csiro.au

Light Metals Engineering
Dr Cameron Davidson
t: +61 7 3327 4535
e: cameron.davidson@csiro.au

Applied Mining Technologies Pty Ltd

Dr David Reid
t: +61 7 3201 2663
e: info@appliedminingtech.com

CET Group

Dr Ian Follington
t: +61 7 3720 1555
e: enquiries@cetresources.com

Defence Science and Technology Organisation Brisbane

Prof Allan Paul
t: +61 7 3212 4400
e: allan.paul@defence.dsto.gov.au

GeoTek Solutions

Mr Paul Maconochie
t: +61 7 3720 1792
e: gts@geoteksolutions.com

For further information:

Queensland Centre for Advanced Technologies
Damian Harris
Phone: +61 7 3327 4477
Email: damian.harris@csiro.au

Contact Us
Phone: 1300 363 400
+61 3 9545 2176
Email: enquiries@csiro.au
Web: www.csiro.au

Your CSIRO

Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills for building prosperity, growth, health and sustainability. It serves governments, industries, business and communities across the nation.