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QCAT Industry and Research Report 2007-08

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.

Government occupants

CSIRO

- Energy Technology
- Exploration & Mining
- ICT Centre
- Materials Science and Engineering
- Minerals
- Minerals Down Under National Research Flagship
- Energy Transformed National Research Flagship
- Light Metals National Research Flagship
- Wealth from Oceans National Research Flagship
- Climate Adaption National Research Flagship

Defence Science and Technology Organisation

Centre for Low Emission Technology

Commercial occupants

Applied Mining Technologies Pty Ltd

Carbon Energy Pty Ltd

CET Group

GeoTek Solutions

Rio Tinto Alcan Queensland Research and Development Centre

Teakle Composites

CSIRO

Queensland Government

QCAT Industry and Research Report 2007-08

■ *denotes QCAT Commercial tenants*

Foreword

The resources industry is vital to Australia's continuing prosperity, contributing 8 per cent to GDP and boasting exports of $91.3 billion.

Australia is in the midst of a resources boom. We have many innovative companies developing technology and software for the minerals industry but quality research is still essential to provide the nation with a truly global competitive advantage.

This is where the Queensland Centre for Advanced Technologies (QCAT) comes in. QCAT, a joint venture between CSIRO and the Queensland Government, is delivering world-class research and technology to the Australian exploration, mining, minerals processing and manufacturing industries.

In our climate-challenged world, partners at QCAT are also developing new clean coal technologies to dramatically reduce greenhouse gas emissions in combination with techniques to capture carbon dioxide from emissions and store it safely.

Coal will continue to play a key role in the global electricity mix well into the future and Australia's key challenge is to use it in a responsible, smarter and environmentally-sustainable way.

Australia is a small country by global standards but we're big business when it comes to resources.

We're also big on ideas and research through successful collaboration between government, industry and business to optimise our research and development. QCAT is an outstanding example of collaboration between CSIRO, the Queensland Government, cooperative research centres, universities and industry partners.

Importantly, QCAT is not just about gaining new knowledge. It's also about technology transfer and commercialisation leading to high value products and processes which will eventually benefit all Australians.

I commend QCAT for its leadership, science and strong performance enhancing Australia's international competitiveness in this vitally important industry.

The Hon. Geoff Wilson MP

Queensland Minister for Mines and Energy

Executive Manager's Report

It is my pleasure to present you with the 2007-08 QCAT Industry and Research Report as a record of the precinct's fifteenth year of operation and an overview of the current research directions at the site.

Across QCAT, research and technology is being delivered to meet the challenges of a fast changing Australia. Fewer entrants to the workforce, increased environmental focus and a continued emphasis on safety are some of the main drivers of our research.

To achieve our research goals QCAT continues to strengthen its engagement with industries and research organisations both nationally and internationally, as recognised by over 4000 visitors to the site in the past year.

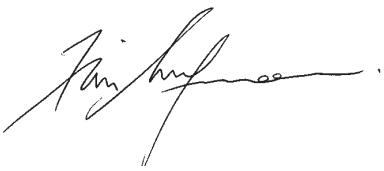
The Innovation and Excellence Day brings together opinion leaders from industry, government and research to showcase QCAT's research. The 2007 day was a great success with over 70 guests attending. With the strong emphasis now being seen on low emission coal technologies, The Hon. Geoff Wilson M.P, Queensland Minister for Mines and Energy, chaired a forum 'Clean Coal Technology; Where to from here' that was well received and provided a platform for discussion on the issue.

A major contributor to the knowledge enabling a move towards low emission coal for energy was the Cooperative Research Centre for Coal in Sustainable Development that completed operations in June 2008. I congratulate the staff on their work in this sector.

On the commercial front the successful commercialisation of Carbon Energy Pty Ltd was achieved as Metex Resources acquired CSIRO's 50% share in the company. This is an exciting new Australian company focused on underground coal gasification technologies. The ICT Centre has also successfully commercialised the Wireless Sensor Network technology, dubbed 'Fleck' to Powercom in Tasmania.

I would also like to congratulate the teams and individuals who received recognition for their research including Patrick Glynn's Australian Coal Association Research Program Research Excellence Award for his work on mine truck collision detection and avoidance systems; Kelly Thambimuthu an author with the Intergovernmental Panel on Climate Change, which received the 2007 Nobel Peace Prize; the Automated Systems Laboratory team for being finalists in the 4th International IEEE-IFR Invention & Entrepreneurship Award; Tim Wark for the CSIRO Office of the Chief Executive's Julius Career Award; and the Energy Futures Forum Project Team for receiving a CSIRO Partnership Excellence Award.

In 2008-09 I look forward to seeing QCAT's innovative science continuing to impact on our industry and community as we provide solutions for the energy, resource and processing sectors.



Tim McLennan

Executive Manager, QCAT

Mining

Coal and metalliferous mining are cornerstones of the Australian economy, contributing $91.3 billion or 40% of the total trade for the nation. However, our share of the world coal and key metal production has been decreasing while world demand is rapidly rising. To maintain our place on the world resource market, Australia's mining industry has to become more sophisticated. Researching and delivering these technologies to industry are fundamental goals of QCAT.

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.

Mining geoscience

Borehole logging

Research into borehole, surface, and offline logging technologies has applications in the study of elemental and material properties in all commodity areas such as coal, iron and copper. To meet growing industry demand for improved nuclear techniques the group is expanding its client base and the number of collaborating organisations.

There is considerable interest in the application of prompt gamma and delayed gamma techniques, as well as fast neutron techniques, in the coal and base metal industries for the measurement of trace elements in borehole and other geometries. CSIRO's long-term goal is to develop higher resolution instruments that use non-isotopic sources and higher spectral sensitivity detectors for the measurement of trace elements such as phosphorous, potassium, and arsenic. The first phase of these projects provided feasibility and industry-needs analysis for trace elements. These projects were funded by the Minerals Down Under National Research Flagship and the Australian Coal Association Research Program (ACARP) for the metals and coal applications respectively.

A successful collaboration with the Australian Nuclear Science and Technology Organisation will develop with the signing of a research agreement in the near future. The first project under the collaboration will assess the Prompt Gamma Neutron Activation Analysis technique for the measurement of hydrological parameters in a borehole.

The nuclear group has been contributing to meetings and training courses for the International Atomic Energy Agency. Presentations have been delivered in Vietnam and Vienna on nuclear equipment and its application to off-line analysis of coal and on in situ analysis respectively. These meetings involved participants from a diverse range of countries such as Australia, UK, South Africa, Niger, Germany, and Columbia, and are part of CSIRO's assistance with technical development in developing countries.

Coal characterisation

Researchers from CSIRO Exploration and Mining and CSIRO Energy Technology are working with the coal industry to improve the efficiency of fine coal recovery and the performance of coal during coke making.

Supported by ACARP and the coal producers, the group is using advanced optical microscopy imaging to obtain quantitative information on the organic constituents in individual coal particles. This information is being used to select flotation reagents that either enhance or suppress the floatability of specific grain types, and hence improve product recovery or reduce product ash.

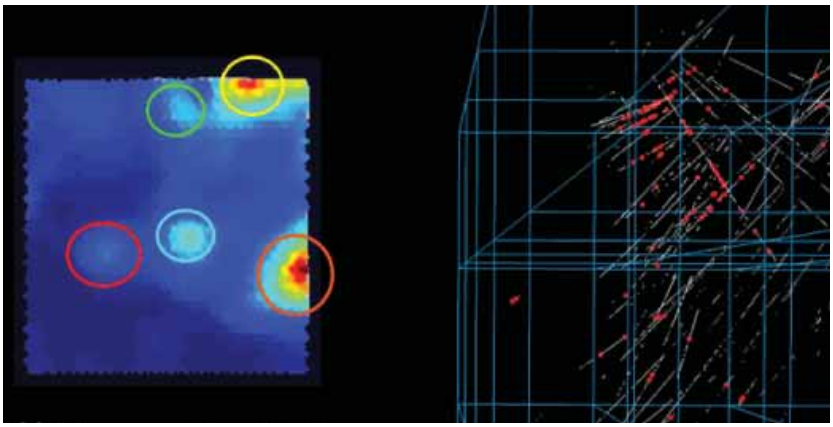
Optical microscopy characterisation is being used to develop milling strategies that optimise the quality of coke made from different coals. This project is in collaboration with BHP Innovation in Newcastle, with significant support from ACARP, BHP Billiton, Anglo Coal and BMA.

3D imaging and data analysis

The development of CSIRO Exploration and Mining's three dimensional (3D) imaging capability is occurring through extensive work on the 3D modelling and analysis of a rock mass. This technology is now being used in the Large Open Pit project. In addition, the 3D imaging technology is being applied to automation/machine vision projects. The 3D images created in the machine vision system are used in a virtual reality modelling language environment to enable remote machine control. The prototype system has produced excellent results and is being enhanced to improve the speed of data delivery using new components developed for Sirovision®.

Sirovision® is a high precision 3D imaging technology that supports fast, accurate geotechnical and geological mapping of rock and terrain surfaces. It has significant implications for mine safety, as detailed spatial and orientation information can be collected without staff positioning themselves in high-risk situations. Sirovision® has now been incorporated in the mine planning software system developed and marketed by Datamine (UK).

CSIRO's 3D imaging and data analysis team has extended the implementation of the networking of individual 3D images from the Sirovision® system into one composite 3D image – a mosaic – with the addition of advanced analysis to improve the accuracy of the result. Extensive field testing at West Angeles has produced excellent results. The creation of extended mosaics is being further enhanced with the development of mesh merging algorithms that will support more advanced applications.



The 3D imaging group has developed techniques for measuring surface roughness of rock mass discontinuities – a critical parameter in estimating shear strength. This is now being extended to support estimation of the anisotropy of roughness at the pixel level, to support remote mapping of rock masses.

Mining geoscience researchers are adapting the most up-to-date analytics and data processing techniques to improve mining and exploration performance and procedures. This work aims to develop the use of analytics in the mining and exploration industry.

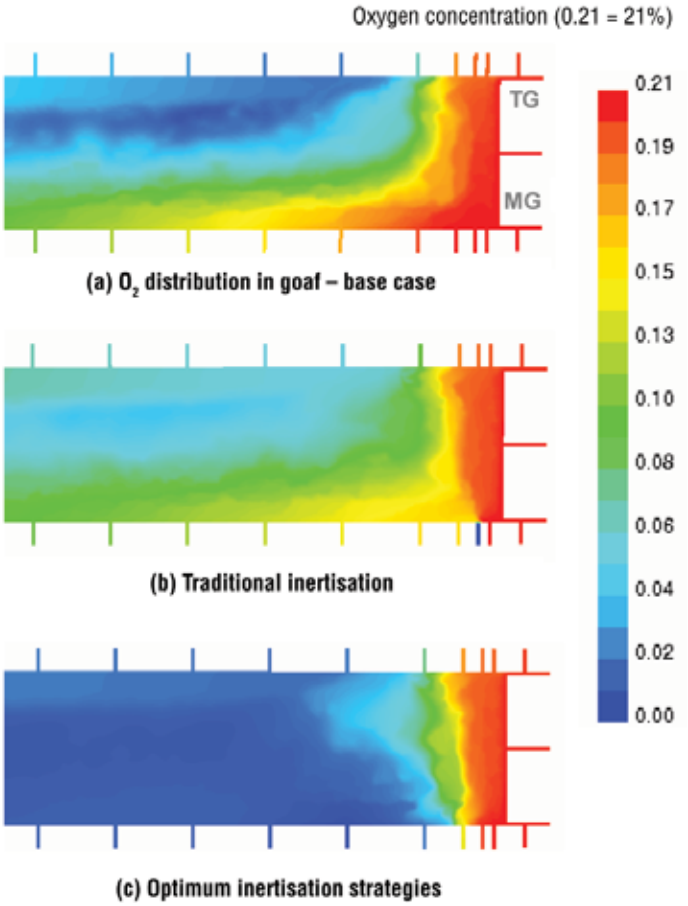
Demand for suitable data analysis methods in mining and exploration industries has increased as technological advances have enhanced data collection and storage capabilities. CSIRO Mining and Exploration has continued to improve methodologies for the industry and in the last 12 – 18 months has been involved with both detailed and broad scale analysis of geophysical, geochemical and geotechnical analyses for exploration targeting, mining and metallurgical issues. Working with several geological surveys around the world, the data analytics team has been able to confirm pre-existing models as well as identify new exploration targets in volcanogenic massive sulphides, kimberlite and gold-bearing terranes. The team has also been involved in coal-mine interburden modelling and CO_2 geosequestration research. We are assisting forestry researchers identify variations in soil-type by integrating airborne remotely sensed geochemical data with the terrain characteristics of plantations.

SiroSOM has been a vital component in many of the projects. This tool has been developed further. SiroSOM is currently being developed for imagery analysis and has also been integrated into several systems that require autonomous and instant data scrutiny where non-linear and unsupervised analysis is required. SiroSOM has also played a major role in data integration for several private companies whose main objective has been to refine exploration methods and improve targeting success rates. By the integration of disparate and multi-disciplinary datasets to provide improved knowledge of geological and geotechnical systems, SiroSOM has a multiplicity of uses in mining and exploration. The data analytics facility provides new and innovative methods to get the most from data. It provides an important connection between the diverse divisions of the geosciences, and the mining and exploration industries.

Microseismics

A real-time microseismic system is currently being developed for underground coal mines. It will allow the location of rock fractures and will predict impending hazards such as roof falls and rock bursts. The acquisition hardware consumes little power allowing use of solar cells. Wireless links and new algorithms have replaced cables, which are time consuming to lay and prone to damage, allowing seismic events to be processed and located automatically, then displayed real-time in the mine office.

CSIRO researchers have completed a project examining the possibility of



using a coal longwall shearer as an energy source for imaging the rock mass ahead of mining. Geophones deployed in a gate road were used to detect vibrations created by the shearer, and cross-correlation techniques then enabled the determination of relative travel times. This gave an image of the rock velocity, which can be related to stress conditions and other potential mining hazards ahead of the face.

Accurate drill-bit location with respect to the coal seam is especially useful for coal-bed methane applications. CSIRO researchers have begun a new project using seismic instruments to locate the position of a drill bit, by analysing the vibrations caused by the drilling.

Research is continuing in passive seismics: the use of noise for imaging the earth. Sources of energy can be man-made such as mining machinery or road traffic, or mining-induced microseismic fractures, or earthquakes. Researchers are looking at using passive seismics to image geological structure, as well as geotechnical properties such as stress and fracture state. Collaborative work with the US National Institute for Occupational Safety and Health is using these techniques for detecting trapped miners.

Several new projects have been initiated in the microseismic research group. Microseismic monitoring techniques have been proposed for mapping the burn front of underground coalfield fires and a collaborative research plan has been established with the National Institute of Rock Mechanics of India to have a field trial at an Indian site. A project to develop intrinsically safe geophones has been submitted to ACARP. The availability of intrinsically safe geophones will significantly improve seismic capability in Australian underground coal mining and thus allow many advanced seismic methods to be safely and efficiently applied in such mines.

Coal mining

Longwall top coal caving

Currently longwall extraction heights in Australia are limited to 4.8 meters but the adaption of longwall top coal caving (LTCC) techniques allow for the recovery of more than 80% of a thick (4.8 – 12m) seam.

With support from ACARP, CSIRO recently completed a research project on the accurate characterisation and assessment of caving conditions in conjunction with the impacts of ventilation, gas, dust and spontaneous combustion on LTCC operations.

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 waste areas (goaves). CSIRO has been working with several major mining companies to assess the potential of LTCC implementation at three mine sites in Australia.

Goaf inertisation and heating location

The increased frequency of fire incidents in longwall panels in recent years has led CSIRO, in conjunction with ACARP and the Australian coal industry, to develop proactive goaf inertisation strategies. Heatings/fires in underground longwall mines are a major industry issue resulting in safety risks and production losses.

CSIRO has completed two ACARP-funded studies addressing this issue. The first aimed at developing new inertisation techniques that can be applied cost effectively to avoid the occurrence of spontaneous combustion. These new techniques can be used in conjunction with existing inertisation methods, increasing their effectiveness during active longwall mining, and in prolonged mining stoppages. The second project is aimed at improving the early detection, location and subsequent control of goaf heatings. Involving extensive field and numerical modelling, this project investigated the behaviour of heating-related gases such as carbon monoxide and hydrogen under a variety of operating conditions and the impact of different goaf inertisation techniques on effective dilution of heating gases.

Longwall dust

Operator dust exposure on longwall faces remains a challenging issue for mine management. With the support of ACARP and industry, several CSIRO projects based on 3D computational fluid dynamics will model the respirable dust dispersion patterns on longwall faces, and will involve the application of a range of dust control options. A major outcome from these studies will be the application of a new shearer scrubber system to reduce dust roll-up towards the walkway area. The shearer scrubber system has been developed as a stand-alone module that can be fitted to any shearer onsite. CSIRO is currently working with industry partners to fabricate the shearer scrubber system and carry out field trials at Broadmeadow Mine. CSIRO is also working on the application of water mist technologies for dust suppression.

Integrated approach to coalmine strata caving, mine water inflow and mine gas emission simulations

The Australian coal mining industry social licence is under intense public and political scrutiny due to unprecedented environmental accountability. The absence of robust and accurate predictive tools affects industry ability to gain mining approval and licences where significant aquifers, surface water or flooded workings are involved. Current research will improve the ability to characterise ground conditions, produce a better understanding of rock deformation and make more accurate predictions of hydrogeological response, groundwater inflow including aquifer interference, and mine gas emission. This work will reduce risk and environmental impact, positively influencing mining safety, productivity and coal resource recovery by providing industry with a generic site hydrogeological assessment methodology.

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

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

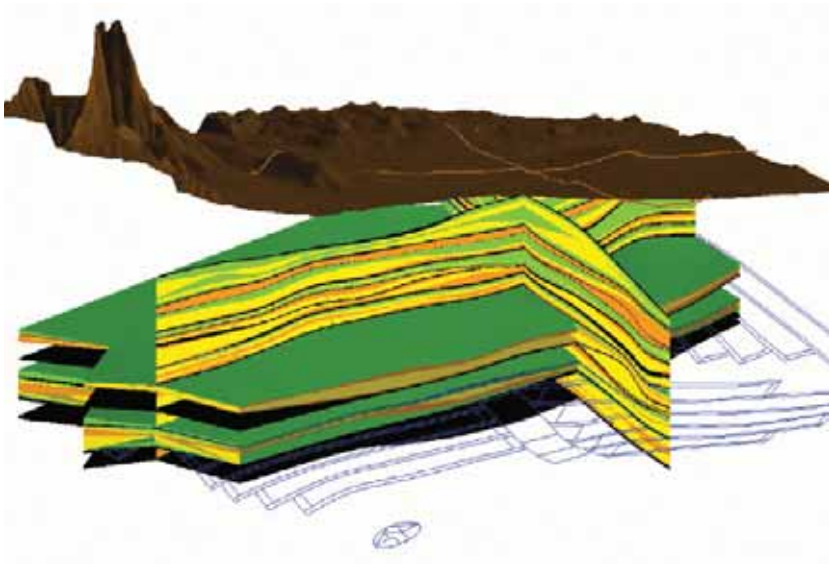
Comprehensive fieldwork is ongoing at Springvale colliery to understand the in situ hydrogeological environment and to determine the extent and magnitude of induced hydrogeological changes in the surrounding strata during longwall mining. Similar work is about to start at the BHP Billiton Dendrobium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

Another project at Singareni Colliery in India will involve selection of reliable site characterising tools and methods, and will undertake geological and geotechnical characterisation work, and assessment of strata caving characteristics. The results will assess the viability of introducing highly mechanised longwall mining (including LTCC), and the recommendation of a suitable longwall mining system.

Similar work is being undertaken for a number of mines in China, where the main focus is to study the geotechnical aspects (including gas emission and mine stability) of longwall mining in difficult conditions at greater depths and high gas contents.

Mine subsidence control

Increasingly, mine subsidence is becoming a major community concern. Longwall mining under river systems, gorges, cliffs, power lines, pipelines, communication cables, major roads and bridges, and other significant



surface facilities has occurred at a number of underground mines in Australia. Overburden grout injection is a technology used to control coal mine subsidence by injecting waste material (e.g. fly-ash) into the overburden during longwall mining. This technology has great potential for wide implementation in the Australian mining industry because it is cost effective and environmentally friendly.

Over the past six years, through an ACARP project and two BHP Billiton-sponsored projects, an integrated method of feasibility assessment in grout optimisation and site specific injection design has been developed. A pilot injection trial was carried out at Baal Bone Colliery using fly-ash grout. The trial provided data on grout flow in underground fractures which is essential for operational injection design.

A new ACARP research project is aiming for a full scale trial of this technology. The project includes comprehensive pre-trial feasibility studies at three targeted mines by means of field monitoring, laboratory simulation and numerical modelling. The key site monitoring program at West Cliff Colliery has produced excellent data that is helping to evaluate the feasibility of applying the technology at this mine. A total movement of more than one metre was recorded in the targeted overburden strata, which implies a significant expected subsidence reduction through using this technology at West Cliff.

In the long term, this research will lead to an innovative method that not only reduces mine subsidence but also utilises mine waste (coal wash and fly-ash), resulting in less environmental impact from coal mining activities.

Deep mining

The depth of underground coal mines is increasing in both Australia and overseas, resulting in a range of challenges including high stress, high gas pressure, low permeability and high rock temperature. To assist the future development of mining deep coal safely and more 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. Using a 700 m deep Chinese mine as the experimental focus, a systematic research program including comprehensive geotechnical field monitoring, tracer tests for gas flow patterns, and 3D coupled numerical modelling, has been carried out.

The interim results have revealed the fluid flow characteristics of the fractured zone above the seam 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.

Metalliferous mining

The establishment of the Minerals Down Under National Research Flagship has provided a renewed focused investment into metalliferous mining in three areas:

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

This research will transform the way that mining is undertaken across a number of key mining domains.

Enhancing knowledge from drilling

Drilling is essential to locate, quantify and determine the critical characteristics of mineralisation and rock, and provides the means of placing explosives for extraction. Research in this area is targeted at significantly reducing the cost of drilling and enhancing the quality and quantity of information obtained from boreholes through the design, testing and delivery of more effective drilling and down-hole data acquisition technologies.

CSIRO is sponsoring and jointly planning an application from AMIRA International to establish a new Co-operative Research Centre for Deep Exploration that will bring together international mining companies, equipment suppliers and researchers to deliver step-changes in drilling and logging technology.

Boart Longyear has joined with CSIRO to test a new drill control system and develop a number of technologies for full drill rig automation. CSIRO has collaborated with another drilling company and successfully demonstrated a method using the seismic noise created by a rock drill to steer the drill toward a defined target. A further stage, to be undertaken in 2008-09, will deliver additional improvements in the technology.

Researchers at QCAT have undertaken a collaborative project with the Australian Resource Research Centre in Perth to further explore the fundamental characteristics of how

cutting steel interacts with rock in a drill. This research is heading towards the development of new method 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. Key stages of the technology have been demonstrated at mine sites in the Pilbara and at a quarry close to Brisbane. An efficient communication architecture for mining automation has been developed for one large mining company and work has progressed towards the development of a relevant industry standard.

Non-entry underground mining

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

New technology that uses Wi-Fi to accurately determine and track the position of people and equipment in an underground mine has been successfully demonstrated in a railway tunnel.

QCAT researchers have worked for a number of years to improve the operation of mineral sand mining. Traditionally, surface mining methods are used to recover these minerals that are used in the manufacture of pigments, ceramics and abrasives. Such deposits are typically located near ocean beaches. Australia has considerable resources of mineral sands that lie buried at inland locations in the Murray Darling basin through New South Wales and Victoria, and the Eucla region of South Australia. QCAT researchers have developed underground mining concepts for these deposits. Studies have also been undertaken for the SORD Technologies Company that is developing a new-concept underground sand mining machine. This will minimise disruption of alternative land uses and environmental impact.

SMART*CUT – cutting tools for hard rock

SMART*CUT technology provides effective cutting tools for mining and civil industries and helps to improve productivity and reduce operating costs. SMART*CUT uses a CSIRO worldwide patented bonding technology to join 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 that is unattainable by conventional tools. It also provides significantly reduced tool wear rates resulting in increased tool life, compared with conventional tools. The ability to economically cut hard rock will now enable new mining methods.

In January 2007 CSIRO Exploration and Mining and Fortescue Metals Group signed a contract and started a joint project to conduct field trials with SMART*CUT picks for surface mining of iron ore. Using surface mining with SMART*CUT technology, rather than traditional drilling and blasting, will deliver benefits to the iron ore industry including:

- improved continuity of the mining cycle through reductions in drill and blasting interruptions
- reduced output size of the ore leading to a reduction in or elimination of the need for primary crushing

- improvements in lump/fines ratios
- flatter pit floors which reduce the burden on tyres and operators
- reduced particle size of the ore leading to a reduction in the requirements for heavy armouring in the haulage fleet
- selective extraction of waste seams leading to improvements in grade.

Large open pit mine rock slope stability project

CSIRO is internationally recognised for its expertise in the field of slope stability and open pit mining geomechanics. In 2004 the group initiated a major research project involving the stability of rock slopes in large open pit mines. The project, now in its third year, aims to address critical gaps in the knowledge and understanding of the relationship between the strength and deformability of rock masses and the likely mechanisms of failure in large open pit mines.

An authoritative new generation pit slope 'Design Guidelines' text will be available to sponsors in October 2008 and publicly available in November 2009. The text links innovative geomechanics research with best practice in open pit data collection and management, slope design, mining, slope management and monitoring, and risk management.

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

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

- Anglo American plc, London, England
- Barrick Gold Corporation, Toronto, Canada
- BHP Billiton Innovation Pty Limited, Melbourne, Australia
- Corporacion Naciónal Del Cobre De Chile ('CODELCO'), Santiago, Chile
- 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 Queensland Limited, Brisbane, Australia
- Debswana Diamond Co., Gaborone, Botswana
- The RioTinto Group, Brisbane, Australia
- Vale (CVRD), Rio de Janeiro, Brazil.

Mining automation

CSIRO Exploration and Mining and the ICT Centre provide the capabilities to research and develop novel and robust industrial solutions in the mining automation sector.

During 2007–08 the Autonomous Systems Laboratory of the ICT Centre has delivered field-proven robotics systems that provide the building blocks for future automation of mining equipment in surface and metalliferous underground operations.

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

Remote mining

Mining companies are particularly interested in the control of mining equipment over vast distances. This presents technical challenges including: high latency (the delay in sending data) and low bandwidth (the amount of data that can be sent). In combination, these make conventional remote control very difficult. The Autonomous Systems Laboratory is developing new technologies that improve the safety and productivity of remotely controlled mining along three lines of development:

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

The success of the remote mining system relies on how effectively the human interface projects the operator's presence into the remote space and how effectively they are able to control the remote machine (robot). It is believed this technology will provide significantly higher levels of situational and spatial awareness than conventional technology. These new technologies are now being applied and tested at mining operations across Australia.

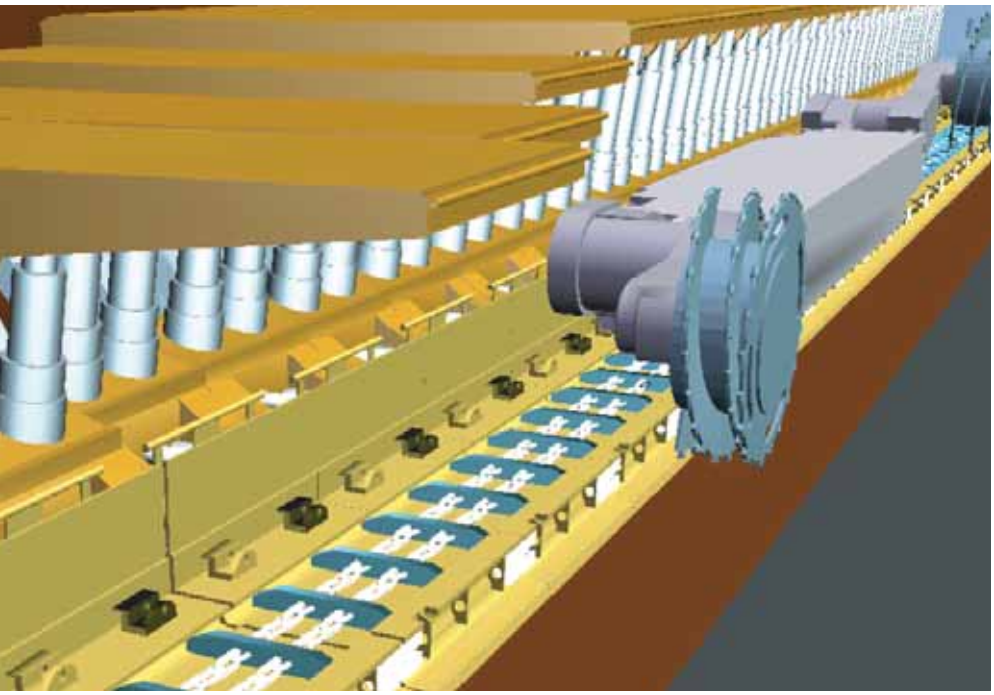
Shovel load assist

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

CSIRO's main contribution to the project is the development of the situational awareness module, which deals with representing the shovel work space and extracting relevant features/ objects. While the operator will still be present, automation of the swing, dump, and return phases of the machine cycle will reduce cycle times and improve efficiency by: allowing faster swings, minimising spillage due to poor dipper placement at dump, and significantly reducing the likelihood of dipper-truck collisions.

Landmark longwall automation

The two year, $2.5m Landmark Extension Project was completed in January 2008. The goal of this ACARP-funded project was to implement an automated longwall face alignment and horizon control system and to demonstrate new sensing, monitoring and information systems at the pre-commercialisation stage. Through this project the underground coal mining industry will now see not only improved safety and productivity but also, with the availability of open standards for underground communications, a strong culture of equipment interoperability.



The commercialisation of the technology continues. Licensing and royalty terms with a number of partners have been negotiated and technology licensing agreements have been concluded with three equipment manufacturers. At least three commercial installations are expected in the next year.

This commercialisation process has been formalised through collaboration with the industry-led Longwall Automation Steering Committee (LASC). The technology will be known as 'LASC longwall automation technology'. An ACARP project to assist industry take-up of the technology commenced. This project will provide a software environment to verify that manufacturers' LASC-compatible systems meet the new industry wide automation standards.

Nexsys: an information system for real-time risk management

The project will introduce step-change in real-time safety and operational management through information capture, data integration, and rule-based and predictive analysis. Intrinsically safe communications hardware will allow the world's underground coal mining industry to fully use the ethernet-based communications systems long enjoyed 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 a common language. 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, Nexsys will use pre-set rules to determine the real-time risk profile present at the mine. Analysis of historical data combined with current conditions and anomaly detection algorithms will allow pre-emptive, corrective and preventative action. All data and risk analysis information, together with the location of workers and equipment, will be displayed in real time using a 3D graphic user interface. This system will provide essential information to mine personnel to enable rapid and efficient decision making, especially in emergencies.

The combination of ethernet-based hardware devices and real-time analysis software systems is undergoing field-trialling and validation in two Australian coal mines (Qld and NSW). A third trial was conducted at a Japanese coal mine in November 2006, with plans for installations in China and India.

An Australian manufacturer is commercialising the hardware devices under agreements signed in 2006–07, while negotiations are continuing for commercialisation of the integrated software system.

Automation technologies

The CSIRO Exploration and Mining automation group continues to extend its reputation as a leading R&D enterprise for the mining industry. The goal is improved productivity, safety and sustainability in mining.

Successful industrial research and applications include:

Navigation: Research and development in inertial-based localisation aims to deliver new levels of navigation capability that are suitable for widespread application in mining and other industries. A key feature of this work has been the successful fusion of multiple data sources within the underlying inertial platform to improve accuracy and robustness.

Automation: Development of longwall mining guidance technologies continues. New coal seam horizon tracking systems (using CSIRO patented technology) were demonstrated at the Broadmeadow Longwall operation. These systems employ machine-mounted thermal infra-red imaging to give real-time information on geological location and trending of the coal seam, and are highly valuable for automated machine guidance.

Profiling: Real-time, high accuracy 3D profiling systems have been developed for transport applications. These include an automated measuring system for remnant coal contained in train wagons, and real-time iron ore profiling to provide a remote operational capability for ship loading tasks.

Mapping: New radar-based imaging technologies have been actively pursued for mining and industrial applications. This technology includes both environmental mapping and subsurface imaging. Key applications include navigation, tracking, resource utilisation, and situational awareness capabilities.

Collision avoidance

Research into collision avoidance technologies for mine haul trucks will lead to significant safety benefits at mine sites. Our research in this area has progressed over a number of years. Successful vehicle trials of a low cost Doppler radar-based system mounted on a Land Cruiser were held on site at QCAT. Subsequent successful vehicle trials were carried out at BMA Goonyella open cut mine, with a full 360° proximity detection system mounted on a Caterpillar 793 haul truck. The prototype Doppler radar proximity detection performed very well and is now going into pre-production by Industrea Ltd, CSIRO's commercial partner in this ACARP-funded project.

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 equipment manufacturers have incorporated AMT's technology into new and existing production systems. This has resulted in significant improvements in production rates and resource recovery, and has provided the enabling technology for ongoing advances in automation.

In collaboration with major equipment manufacturers and suppliers, AMT has developed a complete and integrated highwall monitoring and control package incorporating inertial and horizon control technologies.

CET Group

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

CET aims to promote auger mining technology and to identify and develop opportunities in the Australian surface and underground mining industries through Coal Augering Services Pty Ltd (CAS). In the 2006-07 year CET's primary focus has been the development of CET Resources Pty. Ltd. (CETR). CET, CAS and CETR have common ownership but trade as independent companies from their head office at the QCAT precinct.

Coal Augering Services Pty Ltd

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

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

CET Resources Pty Ltd

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

In November 2006 CETR 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. Since forming in 1999, the company has operated from the QCAT Technology Transfer Centre.

During the past year GTS has worked with Carbon Energy, another CSIRO spin-off occupant of the Transfer Centre. Carbon Energy is implementing a trial of underground coal gasification. GTS provided geotechnical liaison between CSIRO numerical modellers and Carbon Energy.

GTS has continued to work with the CET Group, also a CSIRO spin-off occupant company.

Current projects include investigations for a proposed new coal mine, making use of the research carried out by CSIRO into the application of down hole geophysical data for geotechnical interpretation. It is hoped that improved geotechnical interpretation of geophysical logs will enhance the value of data that currently is gathered routinely but is often only used for limited purposes.

These ongoing relationships show the value of QCAT in helping to transfer technologies out of CSIRO to people who can use them.

Processing

Australia is the largest exporter of alumina, iron ore and black coal. The Australian resources industry is experiencing strong growth and is under pressure to optimise existing operations, develop new ore resources and reduce costs. To maintain the competitive position of the Australian resources industry, innovative and cost effective processing of our mineral wealth is essential. Researchers from CSIRO and the Rio Tinto Alcan Queensland Research and Development Centre form QCAT's minerals processing cluster and are assisting the industry in Australia and overseas.

Iron ore processing

CSIRO provides unique expertise, including detailed mineralogical, beneficiation and agglomeration evaluations of new and existing ore types and deposits. A particular focus is predicting beneficiation performance and optimising sinter, pellets and lump in blast furnaces and other downstream processes.

Predicting processing performance

CSIRO continues to investigate the processing characteristics of new and existing ore deposits as well as new ore blends derived from these deposits. An improved ability to predict processing performance will ultimately allow 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. It will also allow more rapid assessment of processing options.

CSIRO's work on the automation of ore characterisation is continuing, with a focus on the prediction of downstream processing performance by linking ore mineralogy and petrology to metallurgical performance, e.g. beneficiation performance and sintering properties. Technologies developed by CSIRO for predicting processing performance include optical microscopy, computer-based image analysis for in-house use and mineralogy-based models of a range of unit operations, such as hydrocycloning, magnetic separation and reverse flotation. In addition, a stand-alone image analysis and texture recognition software package 'Recognition' is being developed for industry clients.

More effective beneficiation strategies

Alternative iron ore sources of lower grade ore containing impurities, such as Marra Mamba, high-phosphorus Brockman and Channel Iron Deposits, are being exploited to meet market demand from China. The need to develop more effective beneficiation strategies to remove these deleterious elements has triggered the establishment of an iron ore impurity removal project. The project runs under CSIRO's Minerals Down Under National Research Flagship which is underpinning the future of Australia's iron ore industry. A range of new approaches are currently under investigation, including:

- dry separation
- heat treatment and leaching for removal of phosphorus
- utilisation of novel techniques for treating low grade ores,
- microbial induced flotation and flocculation for removal of alumina and silica.

The current iron ore boom and shortfall in supply of traditional hematite/goethite ores has also created a strong interest in Australia's substantial magnetite ore resources. Characterisation and beneficiation research on magnetite resources is continuing with a number of Queensland ores included in the study, with a key focus being the reduction

of grinding costs for liberating the magnetite from the gangue minerals.

The ongoing commissioning of new laboratory and pilot-scale beneficiation equipment has led to a better understanding of the mineralogy and beneficiation potential of magnetite resources, including magnetite tailings. A flotation laboratory was recently established to expand capabilities in this area, which now enables investigation of reverse flotation for removal of silica from magnetite ores. This new knowledge includes ways to target the removal of some of the minor elements that cause problems in subsequent pelletising and iron making operations.

Iron ore sintering and blast furnace burden characterisation

The sintering research conducted at QCAT continues to play a pivotal role in proving up new Australian iron ore resources for export. At the fundamental level, laboratory scale research is being conducted to understand and minimise the effect of increasing alumina and goethite in Australian ores on sinter quality and to better understand the fundamental sintering characteristics of high phosphorus Brockman ores.

In addition, the granulation characteristics of iron ores continue to be investigated, with a focus on the interaction of size distribution and ore mineralogy. This is crucial, because as Australian iron ores become more diverse, a better understanding of granulation properties and their impact on sintering performance is required.

The CSIRO state-of-the-art pilot-scale sinter rig (~80–100 kg samples) is used routinely to investigate sintering performance at sinter bed depths of up to 860 mm, which is consistent with industry practice. The ability to sample and analyse dioxin emissions during sintering has also recently been demonstrated. In addition, a small-scale sinter rig can be used when only small sample masses are available (~5 kg samples).

In the blast furnace burden characterisation area, the CSIRO softening and melting furnace has been successfully commissioned after an extensive upgrade to allow improved data logging and better atmosphere control. Instrumentation has also been added to enable measurement of waste gas concentrations, including CO, CO_2, O_2 and H_2.

Iron ore pelletising

The CSIRO pilot-scale iron ore pelletising facility continues to be used for optimising balling, drying and induration of iron ore pellets, particularly for magnetite ores. Significant international interest has continued in the new laboratory-scale infra-red image furnace at QCAT that is being used for determining reactions during the firing of iron ore pellets.

The Siro–Indur computer-based simulator developed by CSIRO is also available for optimisation of straight-grate and grate-kiln pellet induration. It has already been applied in Australia, North America and Brazil, with potential applications in China.

COLLABORATION

The Centre for Sustainable Resource Processing

CSIRO continues to contribute to the research activities of the Centre for Sustainable Resource Processing, in collaboration with research staff and students from the Julius Kruttschnitt Mineral Research Centre. The main focus of the research at present is to investigate the energy performance of high pressure grinding rolls. The overall objective is to quantify energy efficiency for a three high pressure grinding rolls flowsheet in comparison with a conventional milling circuit.

Non-ferrous minerals processing

Plant optimisation

Research for the non-ferrous mining industry on SAG mill optimisation and both fine (<38 micron) and ultrafine (<10 micron) grinding is continuing. A further three year extension of the AMIRA SAG mill project (P667B) to monitor mill performance via surface vibrations has now commenced. A ruggedised prototype monitor with an inertial power supply for continuous operation continues to operate successfully at the Northparkes mine. Expressions of interest have also been received from other sponsoring companies. The monitor can track the toe and shoulder positions of the charge, mill load and charge size inside the mill as well as other operating parameters.

In the fine grinding area, a wide range of laboratory and pilot-scale stirred milling equipment from various manufacturers has been assembled at QCAT, including a tower mill, a vertical pin mill and an IsaMill. This provides a unique capability for conducting side-by-side comparisons of the relative performance of these fine grinding machines, including mill wear properties and the performance of various fine grinding media.

Finally, the recent establishment of a flotation laboratory for beneficiation of iron ores has opened up opportunities for optimisation of flotation operations in the non-ferrous mining industry.

Standards development

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

Coal processing

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

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

Research is also ongoing to identify factors controlling the efficiency of fluid recovery, partition curves and magnetite recovery. In addition, the potential of electrical impedance spectroscopy as a new tool for monitoring unit operations in coal preparation plants is being explored. A number of proof-of-concept projects were completed with dense medium cyclones and coal flotation systems at the pilot scale. Industry funding has been obtained to continue the work with focused plant trials. Ludowici Mineral Processing Equipment Pty. Ltd. has signed a contract to commercialise three recently developed instruments which will enter the marketplace in the next year.

Rio Tinto Alcan Queensland Research and Development Centre

As part of a long-term commitment to bauxite mining and alumina production in Australia, Alcan relocated a significant part of its bauxite and alumina research and development efforts to Australia in 2002

The Alcan Queensland R&D Centre (QRDC) was established at the QCAT campus in 2005. The centre, now Rio Tinto Alcan QRDC has since been steadily developing capability and extending its R&D program. Recently it has been recertified for ISO 14001 and 18001 after continuing reviews and fine-tuning of environmental health and safety policies and procedures.

The new laboratory has developed world class R&D capability in alumina refining (Bayer process). It has put Brisbane and the QCAT campus on the world stage in the alumina industry. In February 2006, QRDC's Manager, Mr Steven Healy, was appointed to the role of Global R&D Director for Alcan's (now Rio Tinto Alcan's) Bauxite and Alumina business group, further promoting QRDC and QCAT as a premier facility for Rio Tinto Alcan and the Australian alumina industry. In July 2007, Dr Lyndon Armstrong was appointed QRDC Manager.

QRDC supports Rio Tinto Alcan's Australian assets including the Gove bauxite mine and alumina refinery in the Northern Territory (100 % ownership), the Weipa bauxite mine in Queensland (100 % ownership), Queensland Alumina Limited (80 per cent ownership) and Boyne Island Smelter (100 % ownership) both located in Gladstone, Queensland, and the Tomago Aluminium smelter in New South Wales (51.55 % ownership).

Much of the effort at QRDC in the last year has supported the 1.8 million tonne, $2.4 billion Gove Expansion in the Northern Territory. Technical assistance to Yarwun and QAL refineries, other Rio Tinto Alcan operations, technology sales customers, and strategic research and development projects provide the balance of value-added activities.

In the last year Rio Tinto Alcan has continued to expand its collaborations with Australian research organisations. Rio Tinto Alcan's commitment to the seven year Parker CRC for Integrated Hydrometallurgy Solutions has been formalised. It supports a number of collaborative research initiatives involving CSIRO or CRCs with CSIRO participation, including several AMIRA projects. Other projects are being developed or initiated in the coming year.

Present on six continents, Rio Tinto Alcan is a world leading mining organisation.

We have outstanding bauxite reserves, competitive alumina refining, low-cost hydro power, leading smelter technology and an exceptional talent pool of over 26,000 employees operating on a global scale.

Our extensive bauxite, alumina and aluminium development portfolio, which includes 16 large scale and attractive projects in 13 countries, provides us with unrivalled reach worldwide.

Rio Tinto Alcan is the aluminium product group of Rio Tinto, a leading international mining group headquartered in the UK. Rio Tinto is listed on the London, New York and Australian securities exchanges.

Advanced materials engineering

Advanced Materials Engineering is a growing R&D cluster at the QCAT precinct that includes researchers from the CSIRO Divisions of Materials Science and Engineering, and Exploration and Mining, and in this last year has grown to include a new company, Teakle Composites, located in the Technology Transfer Centre. Research in the cluster focuses on light metals and fibre composites, both growing sectors in Queensland's developing manufacturing industry.

Manufacturing with light metals

Light metals are a vital component of the Australian economy. Australia is the world's leading producer of bauxite and alumina. Plans to expand Queensland's alumina production, aluminium smelting and magnesium alloy technologies combined with increased demand for products, especially in the automotive industry, are driving the growth of Queensland's light metals industry.

Light metals fatigue

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

A novel heat-treatment process for die castings is being developed in the CSIRO Light Metals National Research Flagship, and work at QCAT and CSIRO's Clayton campus has shown it can deliver improvements in strength, ductility and fatigue life. Current experiments are aimed at determining whether the property improvements are maintained for castings made under less than optimum casting conditions. A separate project is under way to optimise heat treatments of aluminium alloys to promote self-healing during fatigue crack growth.

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, and also for a magnesium alloy with excellent extrusion properties.

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 to produce an improved coating alloy.

Fibre composites

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

New lightweight corrosion-resistant fibreglass piping system

Mining and industrial supplier AC Whalan will work with CSIRO to research and develop a lightweight, reusable piping system which is expected to replace corrodible steel piping in many coal mines.

The project was awarded a $A335,000 grant under the Queensland Government's Research-Industry Partnerships Program.

Researchers have begun the third stage of four in this project and are testing prototype fibreglass pipes. The fibre composite material had already been tested in corrosive environments and proved effective.

Fire suppression duct

Queensland underground coal mines need to be designed to be compatible with a GAG Unit – a jet engine with an afterburner and water injection that pumps oxygen-depleted gas at about 85ºC into mines to extinguish fires and reduce the risk of explosions.

One Queensland mine client ducts GAG Unit gas into its mine via a 900 mm diameter steel-lined hole, bored 80 m from the surface through soil and rock to the mine. When the mine

moves to the next coal panel, a new hole is bored and lined. The steel linings are not reusable, and the cost of boring holes is very high.

CSIRO was commissioned to design a better solution, a lightweight reusable duct where the bulk capital cost is incurred just once and the duct is moved from panel to panel as the mine develops. Small changes in length or direction may have to be made, but the this cost should be much less than building a new duct and very much less than boring another steel-lined hole.

To minimise the work in shifting the duct, and to span uneven or steep ground, widely spaced supports are needed. To achieve this, most of the glass fibres are aligned lengthwise, providing great strength and stiffness for the large bending loads between supports. The material is E-glass fibres within vinyl ester resin, a combination giving the best mechanical properties under the hot and wet conditions at the least cost.

If the same product was made from steel, it would be about 30% heavier, have larger thermal expansion stresses and would require significant corrosion protection.

Borehole sensor housing and composite coiled tubing

CSIRO is collaborating with Teakle Composites to develop a composite housing for sensing instruments that determine the properties of the rock mass surrounding a borehole and which monitor the condition of the drilling equipment. One of the instruments being developed by CSIRO uses a neutron generator 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 at more than one kilometre underground. Previously, the group used aluminium tube housings that were machined, anodised, 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, no machining and no coatings. This design created cheaper, lighter and stronger instrument housing.

Investigations are also under way to determine the potential for drilling using continuous coiled composite tubing. If realised, this concept would enable drillers to minimise the need for handling steel tubes, reducing the amount of time not spent productively drilling and leading to improvements in health and safety.

Teakle Composites

Teakle Composites is a new company specialising in product development using fibre composite materials. The company moved into the Technology Transfer Building in February 2008. The location provides ready access to some of the company's major clients and to workshop and laboratory facilities for making and testing prototypes. It also provides access to hundreds of scientists and technicians and their facilities which greatly increases the company's capacity to find solutions.

The company has been working on four main projects since the beginning of 2008:

- design, test and manufacture of a fibreglass borehole liner for Thomas & Coffey Ltd
- development of a lightweight corrosion-resistant piping system for underground coal mines for AC Whalan & Co, CSIRO and the Qld State Government
- development of fibre composite drill rod, coiled tubing and casing-while-drilling technology for the Minerals Down Under Flagship
- fabrication of a carbon fibre scramjet intake for the University of Queensland.

The company has also sponsored and supervised several undergraduate and postgraduate projects including:

- mechanical characterisation of inert solid rocket propellant formulations
- design, construction and testing a lightweight fibreglass rocket payload fairing
- strength testing of composite threaded connections
- development of a drag-separation system for two-stage rockets
- development of high-temperature composite materials for scramjet applications.

Low Emissions Coal

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

Coal mine methane capture and utilisation

Bilateral Climate Change Partnerships Programme

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

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

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%. Ventilation Air Methane Catalytic Turbine (VAMCAT) utilises these low methane concentrations providing greenhouse gas reductions and generating clean power through the heat released by methane oxidation of mine ventilation air methane and poor drainage gas.

During 2007_08, as part of the Bilateral Climate Change Partnerships Programme between Australia and China, construction of the 25kWe prototype demonstration unit was completed. The turbine block was commissioned, meeting the design parameters. The Chinese partners for this project are: Shanghai Jiaotong University and Huainan Coal Mining (Group) Co. Ltd.

Coal mine methane resources and potential project development

CSIRO is working with the China Coal Information Institute (CCII) to investigate potential CMM resources and emissions developing in the next five years across key coal mining areas in China. The study will also investigate the potential for CMM/VAM capture and utilisation in these areas. The two parties are conducting a case study aimed at predicting future CMM emissions and production. This will inform the development and planning of methane mitigation and utilisation plants at mine sites. The project will contribute to the development of a policy framework for CMM development projects in China. The Chinese partners for this project are: CCII, and five key coal mining groups in China. 2007–08 has seen the completion of the mine site investigation, successful ventilation air methane mitigation and utilisation, in addition to the completion of the methane prediction case study.

Coal mine methane capture maximisation

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

CSIRO is also working with the CCII to identify opportunities for improved mine methane capture and utilisation. Site specific implementation strategies are being 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 the energy output of captured drainage gas with conventional gas utilisation technologies.

Low emissions electricity

Demand for electricity in Australia is growing strongly and the demand for Australian coal in world markets is at unprecedented high levels. The demonstration of low emissions coal technologies internationally is increasing, and as these new technologies are adopted, the export market for Australian coals will change Furthermore, generation of electricity in Australia will be required to increase efficiencies and decrease emissions of pollutants, at a large scale and at an acceptable cost

Research undertaken at QCAT is increasing the scientific understanding of the gasification process, supporting the Australian export coal industry as they adapt to a changing marketplace, and helping the Australian electricity industry reduce the risks of selecting and implementing advanced power generation technologies. Our research also contributes to the expertise required to evaluate fuel and energy strategies for sustainable energy conversion technologies in this country.

Coal gasification

As part of CSIRO's participation in the Cooperative Research Centre for Coal in Sustainable Development (CCSD), it operates an advanced gasification research facility at QCAT. The facility investigates the coal gasification process at a scientific level, identifying key performance criteria and providing a sound basis for the development of gasification and process models. This allows evaluation of the performance of Australian coals under high temperature, high pressure gasification conditions, and contribute to developments in the design and optimisation of advanced gasification technologies.

By 'deconstructing' the gasification process, and understanding the scientific principles underlying the important stages in gasification, CSIRO's research is providing the detailed technical information required to support the adoption of low emissions coal technologies in Australia Furthermore, by 'reconstructing' the process, in part using our high pressure entrained flow reactor, impacts of coal properties and other variables can be assessed This work was recently extended and validated at the industrial scale when a team of QCAT researchers trialled four Australian coals in a pilot-scale gasification facility in Germany This work confirmed that the key aspects of the laboratory work are reflected in the performance and operation of the larger scale gasifier, and will provide an important reference study for implementation of the gasification research work

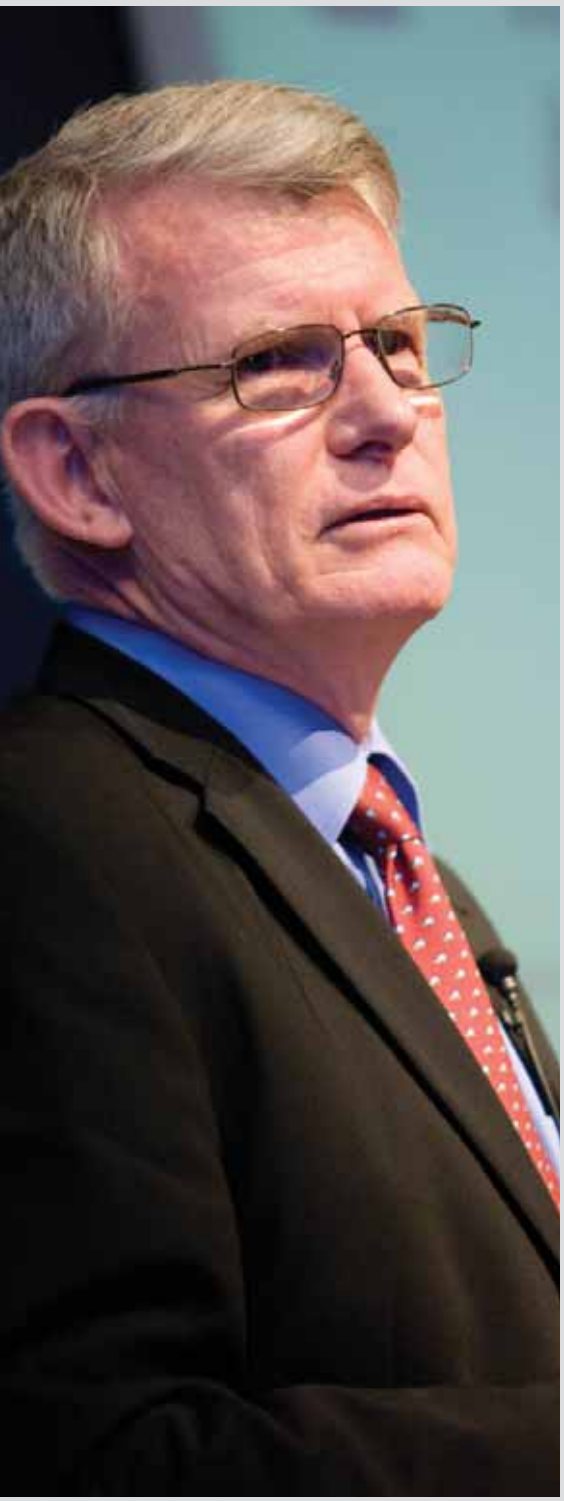
Syngas processing and gas separation technologies

CSIRO is the major research contributor to the Centre for Low Emission Technology (cLET). cLET's research focus is on the gas cleaning, processing and separation technologies that will be enabling technologies for the development of commercially feasible, coal gasification based power systems that incorporate large scale CO_2 capture and hydrogen production.

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

This world-class facility and research program is an important part of a broader national effort to address long-term efficiency and emissions goals for the coal, power and energy industries.

Cooperative Research Centre for Coal in Sustainable Development Final Report



CCSD completed operations on 30 June 2008. Headquartered at QCAT the Centre brought together the majority of Australia's coal research skill base as well as experts in sustainability who are recognised internationally as being at the forefront of coal research. Government and industry committed $63 million over the 2001-2008 period to identify and investigate opportunities for coal chain efficiencies and reducing carbon intensity in energy systems by providing a better understanding of Australian coal performance in combustion, gasification and emerging sustainable coal utilisation technologies. Other research areas included environmental and social assessment, iron making, and by-product and waste utilisation.

In addition to wrapping up its research program and bringing all research projects to conclusion during the year, the Centre also completed several significant activities to support its industry participants.

CCSD achievements

CCSD Achievements 2001–2008, a documentation of the major deliverables from the Centre, was launched at the CCSD annual conference in April 2008. A selection of technology highlights delivered by the Centre over its term includes:

- The CCSD *oxy-fuel feasibility study* outlines a 'first-of-type' retrofit design of the technology to a 30MW power plant and a reference design for deploying new-build power plant. The study drew on historical research and personal relationships of the Centre scientists to assemble an international working group. Completing the study provided the basis for successful application to the Commonwealth Low Emission Technology Demonstration Fund to contribute $50 million to the $200 million investment that has been established to demonstrate the technology in Australia.
- The Centre's development of *Portfolio options for electricity generation in Australia* provided early recognition that if CO_2 emissions were to meet proposed national targets, more than 80 % of CO_2 emissions from power generation would require capture and storage. This was followed by an examination of the *Impact of carbon price uncertainty on investment in selected power generation options* – a report that uses fresh research methods to articulate the risk and opportunities facing strategic business and regulatory decisions.
- *Techno-economic assessment of power generation options for Australia* provided the Centre with a context to frame favourable options for 'step-change' reductions in CO_2 from coal-fired power generation. The work enhanced interest and research into oxy-fuel combustion, coal gasification in integrated gasification combined cycle and the Centre's early work in post combustion capture technology. Industry recognised its value as the technical basis that underpinned the 2004 COAL21 National Action Plan.

While the preceding paragraphs highlight research of immediate utility, the Centre has also delivered scientific capability for the longer term.

The Centre validated thirteen years of IGCC coal gasification and oxy-fuel combustion research with studies at pilot scale. These activities required significant additional investment in the Centre that has already proven beneficial and will continue to deliver value as the results are studied in more detail.

Commencing as an investigation of ash leaching behaviour and an assessment of the appropriateness of standard test methods, during the term of the Centre these results were integrated into hydro-geochemical models that delivered the capability to assess the behaviour of ash in mine backfill applications.

CCSD brought together industry and research contributors to develop four handbooks (outlined below) that provide easy access for industry application of the knowledge created and delivered by CCSD.

The legacy of the CCSD research must itself be viewed in all its dimensions which include – though are not necessarily limited to – the documented resources of knowledge created in its publications, the education and training in its scientists and graduates, and most importantly the relationships established and flourishing through the benefits of intellectual cooperation and collaboration.

Progress in 2007–08

Forty-one reports were published for limited circulation to participants during the year, including seven technical notes and six discussion papers.

Coal-biomass cofiring handbook

A CCSD handbook on cofiring of Australian coals and biomass in pulverised fuel boilers compiles the most up-to-date information on:

- Australian biomass feedstocks
- technical issues related to fuel processing, combustion, emissions and by-products of cofiring in pulverised fuel boilers
- commercial aspects of cofiring
- states and federal government policies and legislation.

Coal combustion products handbook

This handbook delivers a comprehensive resource of ash characterisation and utilisation options for fly-ash derived from Australian coals. The project was undertaken in collaboration with the Ash Development Association of Australia which also retains distribution rights on the handbook, to ensure wide access and distribution of the information.

CCSD coal utilisation compendium

This compendium provides access to the Centre's major research outputs under the following topics:

- coal matter performance
- mineral matter performance
- environmental effects
- coal performance in gasification
- coal power technology
- power systems planning
- coal performance in combustion
- sustainability issues
- coal performance in iron making.

Improving mill performance through de-sanding

Through its West Australian participants, CCSD has developed solutions to mitigate mill wear caused by heavy minerals such as free quartz and pyrite contained in coal. The Centre has negotiated the licensed application of its share of intellectual property arising from this project. The approach involves extraction of partially milled coal particles that are enriched with heavy minerals, followed by separation of the minerals for disposal, and finally return of the recovered coal into the mill system. The engineering solution has been tested at commercial scale and has proven successful.

"…the work appears to be a very comprehensive compilation…"

Overseas industry comment 2008

CCSD gasification study tour

The Centre completed activities for the Commonwealth Government's Low Emissions Technology Abatement program. The grant provided the opportunity to visit several coal gasification facilities and receive relevant information to obtain a more detailed knowledge of the IGCC coal gasification technology.

Some conclusions from this activity were:

- For early adoption of IGCC, it is particularly important to ensure the early development of clear guidelines for the technology, market and regulatory regimes that will be central to the deployment of new, advanced power generation technologies.
- Several of the current gasification demonstration plants whose capital was supplemented through subsidy arrangements continue to operate commercially after their demonstration period. An Australian demonstration of IGCC with carbon capture and storage (CCS) could aspire to the same outcome.
- There would need to be sound and compelling reasons why IGCC should not be deployed at least at the scale offered by a vendor's reference plant.
- Gasification proponents may consider deployment of IGCC at a commercial scale with phased introduction of CCS.
- Membrane wall gasifiers are considered to be a good candidate technology for a dynamic electricity market application because it offers faster start-up and shut-down, greater capability for load ramping and lower requirements for outages.
- Industry, government and R&D groups could consider nominating a lead body/agency to coordinate the future R&D and up skilling efforts for the uptake and deployment of IGCC.
- The future focus of research should include significant effort in the following four key areas:

– optimising whatever plant and technology is selected to be demonstrated in Australia

– developing technologies for, and testing the viability of, deeper CO_2 removal and storage through improved performance and integration of CCS technology units

– developing new enabling technologies to improve the performance and/or reduce the cost of CCS for IGCC systems

– supporting and optimising coal use in IGCC technologies in Australia and internationally.

CCSD coal gasification pilot test program

The Centre completed its major pilot testing of four Australian coals during this year. The technology transfer program coordinated the resourcing and planning to perform coal gasification tests at the Siemens coal gasification pilot facility in Germany. Pilot testing of Australian coal for gasification was required to validate the Centre's extensive research and capability for discriminating coal performance in gasification. The pilot test program has been completed and the results published.

Commercial application of CCSD research

In 2007–2008 CCSD received $674,000 in contract, commercial and additional participant income to enhance Centre research activities. This includes $176,000 in licence fees for the technology to improve mill performance through de-sanding. The Centre has also appointed Verve Energy as Commercial Agent to seek further commercialisation opportunities.

Servicing coal industry research

During the last year the Centre continued to progress research contracts for several clients.

- characterising fine particle concentrations – Extended ACARP
- QEMScan for coal utilisation by-products – ACARP
- mercury speciation – ACARP
- CCSD pilot gasification trials – Various
- coal reactivity in oxy-fuel conditions – Vattenfall AB
- skills enhancement in coal gasification – Commonwealth Department of Environment, Water, Heritage and the Arts.

Commercial income amounted to about $183,000 and contract income amounted to $491,000 which contained additional participant contributions to the value of $150,000 (for gasification trials).

"What CCSD did was to harness a significant research effort into coal and its future use, which has really set the industry up well to meet the challenges of the future."

Industry participant, 2008

Industry seminar

At a seminar held on 15 November 2007, the Centre's industry steering groups met to communicate research progress and results to CCSD stakeholders. The program covered topics across all of the Centre's outcome themes of informing strategic decisions, improving environmental performance and understanding coal performance.

Sustainability seminar

Following on from CCSD research undertaken on sustainability and impacts and led by the Centre's Sustainability Advisory Committee, a structured energy policy workshop was held on 19–20 November 2007. The workshop was facilitated by Dr John Cole and run by Centre scientists Prof Cliff Hooker and Dr Thomas Brinsmead. The seminar applied CCSD's research on adaptive energy policy to the Queensland context and tested the merits of this approach against the practical working perspectives of the participants. As a result, the Centre has reported on an exemplar adaptive energy policy for Queensland.

CCSD annual conference 2008

The final CCSD annual conference was held on 3-4 April 2008 at the Royal Pines Resort on the Gold Coast. The program was specifically designed to celebrate the achievements of the Centre and its scientists. Highlights of the conference included a keynote address by Mr Peter Coates, Chairman of Xstrata Coal Australia and an invited presentation from Dr Tomohisa Fukada of the Central Research Institute of the Electric Power Industry in Japan. Each of the Centre's project leaders delivered their outcomes and achievements over the life of the Centre. The Chairman of CCSD Mr Russell Higgins launched the Centre's *biomass cofiring* and *coal combustion products* handbooks. The event was attended by 110 delegates. Feedback from the event suggested that it was well received.

Thank you and farewell

The staff of CCSD take this opportunity to thank all those who have contributed to make the CRC for Coal in Sustainable Development a success.

We wish all at the Queensland Centre for Advanced Technologies every success in the future.

Centre for Low Emission Technology

cLET continues R&D into utilisation of Australia's coal resources to produce near-zero carbon emission electricity and hydrogen, to allow a smoother transition between the current energy infrastructure and a low carbon emission energy infrastructure of the future.

Headquartered at QCAT, cLET is an unincorporated joint venture of the Queensland Government through the Department of Mines and Energy, CSIRO's Energy Technology and Energy Transformed Flagship, Stanwell Corporation, Tarong Energy, ACARP, and the University of Queensland. Focussing on coal gasification and advanced gas processing these partners have combined their resources to develop the technologies needed to enable the production of low emission electricity and hydrogen from coal.

National low emissions gasification test facility

The project is developing a proposal to build a 5 MWt pilot scale gasifier in Australia The aim is to provide a facility for comprehensive testing of coal performance, assisting in gasifier and gas cleaning technology selection, supporting a gasifier demonstration plant and testing the scale-up of gas processing concepts (such as those under development by cLET). The facility would also have the potential to test biomass blending with the coal feed, and utilisation options such as fuel cells, hydrogen combustion and storage and coal to liquids technology. Legal agreements between ZeroGen and GE Energy have been negotiated to enable an outline design and costing for the plant to be obtained. A scoping study to estimate the cost of a 7-year program to build and operate the plant is nearing completion.

Syngas generator

This project was revised in 2007 to deliver a facility to simulate syngas from coal gasification. Construction of the simulation facility is nearing completion.

Dry gas cleaning

Dry gas cleaning research looks at methods for filtering gas to protect downstream process units, with less water consumption and loss of power. An integrated filtration and sorbent system rig has been designed and built to the process on syngas.

Stakeholder perspectives to low emission technologies

In this financial year cLET has continued to collaborate successfully with QCAT's social research team to continue discussions with a range of stakeholders around climate change and low emission technologies. In November 2007, Rio Tinto sponsored the cLET facilitated workshop process to research stakeholder perceptions to climate change and energy technologies in Muswellbrook and Singleton in New South Wales. Follow up workshops in these areas will be held in the 2008-09 financial year.

The social research also expanded the facilitated workshop into a large group process and resulted in successful workshops being carried out with a random sample of the population from South East Queensland and Melbourne. The process was also trialled with a younger stakeholder group, 18-25 year-old, as this target group is often a difficult one to access.

The findings from all of these workshops reinforced that the general public shows strong preference for renewable technologies, in particular solar energy and that process of information provision used does help to enhance individuals' understanding of the technologies available and their potential role they might play in reducing greenhouse gas emissions.

On the international scene, the Carbon Capture and Storage Social Research Network has continued to grow. The Canadian Climate Change Council convened a workshop to identify strategies for communicating to a range of stakeholders about carbon dioxide capture and storage. The group will meet again at the Greenhouse Gas Technologies conference in Washington in November 2008. Peta Ashworth will present the results of the large group process at this conference as well two posters. The first, on the Integrated Roadmap of Communication Activities around Carbon Capture and Storage in Australia and Beyond, sponsored by the ACARP and secondly, a joint poster with Zerogen on their community engagement framework which included cLET's facilitated workshops.

Carbon Energy Ltd

Water gas shift catalysts

cLET researchers are testing the performance of water gas shift reaction catalysts on coal-derived syngas. Currently available reaction catalysts, operating at temperatures below 300°C, were developed for use with natural gas. Their performance remains largely unproven or is less than optimum with coal-derived syngas streams that contain higher CO, CO_2 and H_2S concentrations in the feed and product streams.

High temperature catalytic membrane reactor

cLET researchers are investigating a high temperature catalytic membrane reactor with the aim of developing a separator module that combines the shift reaction and hydrogen separation in one integrated unit. This will simplify syngas processing and hydrogen production and recovery relative to current operating practice.

Molecular sieve silica membrane systems

A lower cost ceramic separator is being developed to separate hydrogen from shifted syngas. This will provide new opportunities for H_2 separation that replace the use of physical solvents for CO_2 capture from a syngas stream.

Metal membranes for hydrogen separation

This project addresses hydrogen separation from syngas streams at high temperature (up to 880°C) through the development of thin film metal membranes that are not Palladium based; Palladium is currently an expensive and scarce rare metal resource.

Carbon Energy Ltd (CNX) was formed by renaming Metex Resources Pty Ltd following a complete acquisition of Carbon Energy Pty Ltd (CEPL). Previously CEPL was a joint venture between CSIRO and Metex Resources Pty Ltd, owning unique intellectual property in underground coal gasification (UCG) and a range of associated technologies developed by CSIRO. CNX retains the full research support of CSIRO in UCG.

Carbon Energy's business is to deliver a new generation of large scale energy projects based on cleaner and greener use of coal. The key to this is coal gasification, which transfers the energy from coal into syngas (hydrogen and carbon monoxide). This can be used directly as a low emission fuel gas for power generation, and as feedstock for catalytic syntheses of liquid fuels, chemicals and fertilisers. It can be further transformed with steam into hydrogen, and carbon dioxide which can be removed, effectively decarbonising the energy to zero emission hydrogen with potential uses in fuel cells, turbines and as a transport fuel.

CNX's advantage lies in its proprietary underground coal gasification technology which can produce syngas from coal in large scale commercial volumes, at much lower cost than surface coal gasification methods. This increases the profitability of projects by reducing source fuel costs and upfront capital requirements. Other important advantages are that UCG can use deep, high ash, conventionally un-mineable coal, and hence has an enormous new resource base to draw on. It also avoids the expense and environmental impact of coal mining, handling, and surface gasification plant. This results in a low cost, low impact, low emission route to clean coal utilisation for power and liquids.

CNX has over 2000 square kilometres of exploration permit covering billions of tonnes of potential coal deposits. The target resource in the Surat Basin of southern Queensland is likely to contain between 50 and 500 million tonnes of high ash coal suitable for UCG production. Exploration in 2007 found many sites with thick coal, and to date one of these has been in-fill drilled to show a JORC inferred coal resource of 100 Mt with ongoing drilling yet to establish the full extent of the deposit. A mineral development licence has been granted over the deposit and CEPL is well advanced in the construction of a 1 petajoule per annum UCG module, to commence gas production from the site in October 2008. CEPL is initially targeting a commercial scale UCG plant feeding a 1000 tonne/day ammonia plant in partnership with Incitec Pivot Ltd, which holds 10.5% equity in CNX.

CEPL aims to develop other power, chemical and synthetic fuel production plants on CEPL's coal deposits, and build the partnerships required to implement and fund such projects. CEPL has signed a MOU with Singareni Collieries Company Limited, India's second largest coal producer, to collaborate in development of UCG projects on SCCL's coal leases in Andhra Pradesh State.

Social science capability

In the past financial year the social science research team, part of CSIRO Exploration and Mining, has been expanding its capability, growing from five to nine staff. The research program focuses on understanding stakeholder perceptions to a range of complex issues of strategic importance to Australia and now expands across four CSIRO National Research Flagships along with a number of external consultancies.

Energy and society

As an early supporter of the social research team, the Energy Transformed National Research Flagship's support has continued with the growing recognition of the importance of individual behaviour change in achieving significant reductions in greenhouse gas emissions in the short to medium term

Research in this area focuses on understanding public perceptions to climate change and energy technologies. The team has been testing the effectiveness of scaling up the workshop process, developed for cLET to engage communities from small to large groups. The results of this work will be presented at the Greenhouse Gas Control Technologies (GHGT9) conference in November 2009.

Carbon Capture and Storage Social Research Network (C2S2RN), an international research group established by the social science research team in 2006, has continued to expand and bring in other countries. In September 2007 a three day workshop was held in conjunction with Climate Change Central, a Canadian environmental NGO, the University of Calgary, and the University of Cambridge. This workshop brought together a range of international researchers to develop ways of communicating carbon dioxide capture and storage (CCS) as well as engaging with a range of industry, government and non-government organisations.

Finally, the Intelligent Grid project is a multidisciplinary research project that has been developing a value proposition for distributed energy in Australia. In addition to a range of case studies the team launched a report detailing the results of their individual surveys to identify stakeholder's propensity to adopt distributed energy concepts. A survey on organisations has been completed and will be published in the 2008-09 financial year.

Climate adaptation and society

The team has been working with the Climate Adaptation National Research Flagship since the beginning of 2008. The initial project identifies principles of best practice in stakeholder engagement, to help inform the Flagship's need to engage with various groups for climate adaptation planning and capacity building. This project has involved interviews with internal and external engagement practitioners, a literature review, and two workshops with CSIRO staff designed to codify the existing knowledge of people who have experience in engagement with stakeholders on issues of climate and natural resource management.

A second project with the Flagship, in collaboration with the Department of Climate Change, is a national adaptation benchmarking survey, which is planned to be repeated every two years. The survey represents an effort to track over time the climate adaptation activities being undertaken by the private sector and all levels of government across Australia. It is envisaged that repeated surveying will identify areas where adaptation is under way, and also areas that are lacking.

Social dimensions of sea floor exploration and mining

The Australian Offshore Minerals Locations Map developed by the Wealth from Oceans National Research Flagship and Geoscience Australia in 2006 illustrates the wide range of minerals and commodity types in Australia's near-shore and deep marine environment. While the economic opportunities are clear, there is limited research that addresses issues such as regulatory context, international precedence and public acceptability. In 2007, the social science research team scoped the social issues that would surround an expansion to the seafloor exploration and mining industry for the Wealth from Oceans National Research Flagship.

The research included three studies to build an understanding of the social issues surrounding any expansion in terms of the regulatory contexts, international precedence and provide an insight into the perspectives various stakeholder groups hold about

expanding the industry in Australia. The results of this research suggest there are some significant data gaps, particularly around environmental impact, which might influence stakeholder reactions to the prospect of sea floor exploration and mining. Three areas were identified as requiring action if the industry were to expand: building an information base; enhancing communication between stakeholders; and improving understanding of the policy and legislative process. The results were launched at the Australian Maritime Museum in Sydney in June 2008 and received considerable media attention.

Minerals and society

A highlight for the Minerals Down Under National Research Flagship's (MDU) social research included a visit from Mr Jeremy Kranowitz, an expert in risk communication, from the Keystone Centre in Colorado. Mr Kranowitz has conducted research to identify the most significant risks likely to affect the social feasibility of in situ leaching in Australia. Mr Kranowitz held a number of risk communication workshops across Australia.

During the year, there was a greater focus on scoping the shape of the Flagship's social research program. A workshop was held with leading CSIRO and university social researchers to develop a clear focus for the social science component. Four key research areas were identified as important to the development of the minerals industry in line with sustainability principles:

- understanding the Australian minerals industry within a global context (global insight)
- exploring the uncertainties of the future through scenarios and the social impacts of new technologies in the minerals industry (strategic foresight)
- understanding and measuring the 'true' cost of a mine and developing strategic decision making tools that incorporate a broader range of inputs (measurement and metrics)
- understanding the social impacts of mining in resource-rich regions (regional futures).

The relationships formed through this workshop, and the ideas generated within it, were developed into the social research agenda over the next three to four years.

In addition, a project examining the key determinants for mining companies to become 'neighbours of choice' in resource intense regions was developed with Curtin University's Alcoa Centre for Sustainable Communities. This project will inform mining companies in sustainable community engagement, assist communities to manage transition within the most sustained commodities boom seen in Australia, and connect and inform components of the social research cluster in the Flagship.

Through all of these activities, greater clarity around the form and nature of a Mineral Futures Forum has also been a key output of 2007-08.

Information and communication technology

Information and Communication Technologies (ICT) enables many areas of development in a diverse range of industries. The CSIRO ICT Centre at QCAT is investigating new technology applications in wireless sensor networks and autonomous vehicles for land, sea and air.

Automation

The CSIRO ICT Centre's Autonomous Systems Laboratory at QCAT has been researching the field of automated ground vehicles since 1999 when a automated load haul dump (LHD) vehicle was demonstrated at North Parkes mine, NSW.

Autonomous Hot Metal Carrier

Hot metal carriers (HMCs) are 20 tonne forklift vehicles that transport molten aluminium in large metal crucibles, from a smelter's potting line to the casting house. They operate 24 hours a day, seven days a week. The main objective of the HMC project is to develop technologies that will allow a fully autonomous vehicle to conduct continuous, safe, dependable operations around a work site containing humans and vehicles, without depending on GPS.

The team has developed algorithms for localisation, navigation, crucible manipulation, obstacle detection and mission planning. The vehicle has operated autonomously for hundreds of hours during testing and demonstrations. The reliability of the fundamental automation system has allowed research to advance into areas of system dependability and redundancy. These are important requirements for autonomous vehicles deployed at industrial sites to ensure safe, consistent and predictable operations. Recent developments in the autonomous HMC project include redundant localisation and odometry systems capable of taking over when the primary system fails or becomes unreliable. Results have been encouraging and further research will be undertaken in the coming year to integrate all systems into a fault-tolerant framework.

In parallel with developments on the QCAT-based HMC, some of its technology components are being trialled on an HMC at an aluminium smelter. The smelter is a challenging real environment where the systems must reliably operate at any hour of the day, in any weather and without human assistance. The systems performed well and further development is continuing to enhance their performance.

The HMC project is part of CSIRO's Light Metals National Research Flagship program.

Mapping and 3D perception

A core requirement for an autonomous vehicle is its ability to sense the environment and to localise itself within that environment.

One of the most versatile sensors used for mapping and localisation is lidar, which uses a sweeping infra-red laser pulse to measure distances to objects. The laser sweeps an area 75 times per second to generate a 2D range map. Successive lidar scans from a moving vehicle are matched for simultaneous localisation and mapping, without the assistance of GPS or inertia measurements.

The mapping software developed for these sensors produced the largest unassisted lidar maps published to date, covering a path of over 165 km. The challenge in building such maps without GPS is recognising revisits to the same

areas after traversing large loops. The ICT Centre's place recognition algorithms quickly and reliably match revisited areas even when the initial location of the vehicle is not provided to the computer.

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

3D mapping and perception can be achieved using the same 2D scanners mounted on a spinning platform Current projects are using these devices mounted on top of automated skid-steer loaders to provide continually updated 3D terrain models and motion estimates.

Wireless sensor & actuator networks

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

Autonomous spatial management of animals

Cattle control via sensor and actuator networks has been a key part of the ICT Centre research program. Initial work has focused on autonomous bull separation to prevent injuries during the breeding season. Our latest work in this area has been undertaken in collaboration with CSIRO Livestock Industries as part of the Food Futures National Research Flagship. The goal of this work has been to develop a methodology for combining scientific knowledge about animal behaviour with computer science techniques to enable autonomous spatial control of cattle via virtual fence lines.

A recent trial successful contained a herd of cattle behind a virtual fence for 13 hours.

Future research in this area is now funded by the Queensland Department of Environment and Water Resources. The application focus has shifted to protection of environmentally sensitive areas such as river banks or riparian zones. This next phase of work seeks to address issues in scalability and exploits information about the state of the herd.

Saltwater intrusion monitoring

Salt water intrusion into coastal aquifers is of concern for water managers globally. The principal decisions to be made in exploiting these coastal groundwater resources are where to place the extraction bores, and how much water can be extracted sustainability. Steadily rising salinity levels have been noticed in a number of production bores adjacent to the coast in the Lower Burdekin in North Queensland. Current concern is that the groundwater resource in these areas may be degrading, however the extent and cause of the problem, as well as management options and their efficacy, are not well understood.

As part of the Water Resources Observation Network initiative in CSIRO, the ICT Centre has developed and deployed a network to monitor the state of bores in the Burdekin region. The project team designed the hardware and software required to deploy a sensor network in this region. Each node in the network measures the volume, rate and conductivity (correlated with salinity) of water being pumped, as well as ground-water depth. The network was deployed in March 2007 and has been providing data on a regular basis since mid-April. The network consists of five sensing nodes,

two relay nodes and a base-station node. The data is available from a web server.

This network has demonstrated the feasibility of using sensor networks in these types of applications. It can be used as a test bed for further work in the use of sensor networks for water management. It also provides a valuable resource for hydrogeologists interested in validating their theories and models of aquifer structure.

Marine robotics and monitoring

Integrating wireless sensor networks with robotic monitoring tools will greatly improve offshore and inland water operations in areas including environmental and water quality monitoring and industry sectors such as oil and gas. Since 2004, the ICT Centre has been developing and demonstrating combined autonomous underwater vehicles and underwater networking technologies.

In May 2008, as part of the Wealth from Oceans National Research Flagship, a prototype system demonstrated advancements in network-based underwater acoustic location and target tracking. Further developments include extending the system to detect movement of sub sea pipelines Additionally, two Starbug Mark-3 autonomous underwater vehicles were commissioned in March 2007 with one going to Tasmania for environmental monitoring and mapping of the Derwent River.

In June 2008, the ICT Centre embarked on delivering an integrated wireless sensor network and robotic solution for water quality monitoring of inland water storage at Lake Wivenhoe. When fully deployed, the network will consist of 50 floating sensor nodes monitoring critical parameters, such as water temperature, to assist regulatory authorities better assess, model and predict water quality changes throughout the Lake.

A leading advance in this research is the introduction of a mobile sensor node in the form of a robotic boat. This boat interacts with the fixed sensor network nodes by uploading mission data, as well as by sampling a multitude of parameters at off-node locations.

Aviation and aerospace

The success of CSIRO's unmanned aerial vehicle (UAV) group, combined with the strengths of the Defence Science and Technology Organisation (DSTO) Applied Hypersonics Branch, has established Queensland as a world class aviation and aerospace hub in the Asia-Pacific region.

Unmanned aerial vehicles

The ICT Centre's Autonomous Systems Lab is pioneering research on robust autonomous helicopter systems which can operate in unknown environments. This UAV will be used for evaluating new air traffic separation methods and inspecting infrastructure such as bridges, cooling towers, powerlines and pipelines.

ARCAA - Smart Skies

This year a research agreement between CSIRO and Queensland University of Technology was signed forming the Australian Research Centre for Aerospace Automation (ARCAA).

ARCAA's first project, Smart Skies, is in collaboration with Boeing Australia Limited and Boeing Phantom Works. It started in March 2008 and builds on the already strong relationships with Boeing.

Smart Skies has included several collaborative workshops attended by the teams in Brisbane and in the US.

This project is also expanding our UAV research area into the field of air traffic separation. Development has started on a highly autonomous helicopter UAV and an operator interface for flight testing experiments, the first of which is scheduled for February 2009. Integrating hardware and software components into the helicopter will allow it to cooperate with an automated air traffic control system. This platform will allow the demonstration of proof-of-concept separation management algorithms in real-world flight tests.

In research on using UAVs for infrastructure inspection, development has started on a sense-and-act capability to detect fixed ground-based obstacles and navigate around them during predetermined missions.

ARCAA - UAV Outback Challenge

In September 2007 the first UAV Challenge – Outback Rescue – was run at Kingaroy in Queensland. The Challenge is an initiative of ARCAA, the Queensland Government and Boeing Australia Limited. It was a huge success, with many participants in the high school category and several overseas competitors in the open category. The UAV Challenge focuses on civilian applications of UAVs in Australia and aims to provide a valuable experience for students, hobbyists and organisations in designing, building, testing and operating unmanned aircraft. Based on the positive feedback from competitors, media attention and interest from a number of different sponsors, the Challenge will be run again in September 2008.

Defence Science and Technology Organisation

Hypersonics

Flights at hypersonic speeds potentially offer significant advantages in performance for both defence and civilian aerospace applications. Civilian applications include low-cost satellite launch and high-speed aircraft. DSTO activities in hypersonics cover:

- applied research into air-breathing hypersonic propulsion and hypersonic aerodynamics
- interaction and collaboration with Australian universities and industry involved with hypersonics research and development
- maintaining international linkages of relevance to DSTO's hypersonics program
- developing flight hardware and conducting ground and flight testing
- providing an avenue for advanced research in related areas such as materials, guidance and control, structures and sensors.

In November 2006, DSTO and the United States Air Force signed an eight-year, $70 million agreement to advance research into high-speed (hypersonic) flight. The Hypersonics International Flight Research Experimentation (HIFiRE) Agreement will see up to ten hypersonic flight experiments conducted over five years. DSTO will collaborate with the University of Queensland and Boeing Australia in developing some of the flight configurations. This collaboration is supported by the Queensland Government.

In June 2007, DSTO conducted the Hypersonic Collaborative Australian/United States Experiment (HyCAUSE) trial at Woomera. The successful trial completed one of the world's fastest air-breathing engine experiments aimed at demonstrating ignition of a supersonic combustion ramjet (scramjet) engine at speeds close to Mach 10 during re-entry after climbing to an altitude of more than 450 km.

Recent recovery of debris of the scramjet engine marks a significant landmark for DSTO. The find is important in analysing the outcome of the flight experiment and will add to the already huge amounts of data collected during the experiment. Seismic sensors were deployed to help identify the location of the impact. Data gathered was analysed by DSTO Brisbane staff with assistance from industry and state government bodies. The seismic data, when combined with the telemetry and radars that were tracking the experiment, greatly reduced the search area, enabling an aerial reconnaissance team to make visual confirmation and locate the impact area on the first fly-past.

The benefit of the research and recovery expeditions is a broadening of DSTO's understanding of the fundamental physics in the field of hypersonics and the engineering involved, which is on the very fringe of our understanding. The information gathered will be used to build more robust and reliable hypersonic flight vehicles in DSTO's follow-on program, the HIFiRE Project. The next launch is planned for November 2008 from Woomera.

The Technology Transfer Centre

QCAT is a focus for interaction between researchers and industry, and has a strong commitment to furthering technology transfer in the resources industries. The co-location and support of commercial enterprises and other research and development organisations at QCAT's Technology Transfer Centre provides an environment where the exchange of insight, information and technology can thrive.

Tenants at the Technology Transfer Centre change as new research partners set up offices and as commercial enterprises are established, develop, expand and move on to the next phase of their commercial development.

Commercial tenants in the 2007–08 year included:

- Applied Mining Technologies Pty Ltd
- Centre for Low Emission Technologies
- CET Group
- Cooperative Research Centre for Coal in Sustainable Development (operations closed June 2008)
- GeoTek Solutions
- Carbon Energy Pty Ltd
- Defence Science and Technology Organisation.

New Tenants in the 2007–08 year:

- Teakle Composites.

QCAT events

Visiting delegations

The QCAT precinct strives to meet the challenges faced by industry and governments locally and internationally. Providing solutions requires open communication with research partners and potential end users of the technology. QCAT received over 4000 visitors to the site in the 2007–08 financial year. A sample of delegations visiting the site includes:

Australia
- Clunies Ross Foundation
- Queensland Resource Council
- Australian Student Mineral Venture

Botswana
- Botswana Railways and InfraDev

Chile
- Industrial Comercial Chile Ltd.
- Sociedad Minera Varry
- Drillco Tools Ltd.

China
- China Coal Research Institute
- Chongqing Nantong Mine
- Xuan Dong Mine
- China University of Mining and Technology
- Tiefa Coal Group Co. Ltd.
- Xi'an University of Science and Technology
- Taiyuan University of Technology

Germany
- Ministry for Economic Affairs and Energy, North Rhine-Westphalia State Government

Japan
- Japan Coal
- Japanese Government Representative and Industry
- J-POWER
- Sumitomo Corporation

- Toyo University
- Research Institute of Innovative Technology for the Earth
- Nippon Steel Engineering Co. Ltd.

Korea

- Korean Ministry of Commerce, Industry & Energy
- Korea Electric Power Corporation
- Korea Gas Corporation
- Korea Hydro & Nuclear Power Co.
- Korea Advanced Institute of Science & Technology
- Hanwha Corporation
- LG International Corporation

Russia

- Siberian Coal Energy Company
- Tomsk Mining
- Russian Federation Agency for Energy
- Russian Union of Industrialists
- Ilmenite

USA

- Arch Coal Inc.
- Battelle
- General Electric
- Samsung Engineering Co. Ltd.

Following last year's push to establish and strengthen our links with key stakeholders in the Queensland Government, in 2007–08 the QCAT community was pleased to host site visits and briefings for a number of key Ministers and members of the Queensland Government:

- Department of Tourism, Regional Development and Industry
- Department of Mines and Energy
- Department of Infrastructure.

QCAT Innovation and Excellence Day 2007

Innovation and Excellence Day is an annual event that provides the resources industry, government and other research bodies an opportunity to build networks and preview the ground breaking R&D at the QCAT precinct.

The highly successful event showcased fifteen current research projects from QCAT in areas including: clean coal technologies, mine communication, mining automation and minerals processing.

A forum session, opened by the Hon. Geoff Wilson MP, Queensland Minister for Mines and Energy, entitled 'Clean Coal Technology; Where to from here' proved a highlight of the day. Input was provided from leaders in the field included CSIRO, the Australian Coal Association, the Centre for Low Emissions Technology and the CRC for Coal in Sustainable Development.

Public engagement

ICT Centre Open and Schools Day

On Saturday 25th and Monday 27th August the CSIRO ICT Centre at QCAT held two highly successful open days to showcase the research undertaken by the Autonomous Systems Laboratory.

The Public Open Day on a rainy Saturday attracted over 1200 people. Activities included wireless sensor networks, an autonomous submarine (Starbug), autonomous vehicles, unmanned aerial vehicles and computer vision displays. Presentations outlining the research activities of the ICT Centre proved extremely popular with the theatre filled to capacity.

The following Monday over 350 students from schools across Brisbane were invited to the site for a guided tour of the Autonomous Systems Laboratory's projects. Ranging from primary to high school, the students had a chance to drive Starbug submarine and ride the autonomous mini tractor as well as doing a number of guided activities provided by CSIRO Education. QCAT staff where encouraged to see so many young families and students showing a passion for science and the research conducted at QCAT.

Educational engagement

The Queensland Resource Council and CSIRO have joined forces to enhance the development of minerals and energy science education, careers and skills initiatives. A Memorandum of Understanding signed by the

Queensland Resources Council and CSIRO commits to a collaboration and promotion of sector-related science careers, the attraction and retention of women in the resources sector, and the promotion of science in Queensland Minerals and Energy Academy schools.

CSIRO staff at QCAT are also committed to the Scientist in Schools program, a joint initiative of CSIRO Education and the Department of Education, Employment and Workplace Relations. Seven staff from Exploration and Mining, Energy Technology and the ICT Centre donated their time and resources to promote science education in primary and secondary schools, help engage and motivate students in their learning of science, and broaden awareness of the types and variety of exciting careers available in the sciences.

RNA Exhibition

For the ten days of the Royal National Association Show, the Ekka, QCAT assisted CSIRO Education in presenting a range of science activities to the public. With a diverse audience of children and adults, QCAT's presence at the Ekka allowed for public engagement and discussion of the precinct and CSIRO's research. It is estimated that over 25,000 people visited the stand during the Ekka.

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QCAT Steering Committee

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

Members of the QCAT Consultative Steering Committee in 2007-08 were:

The Hon Mike Ahern AO (Chairman)
Special Representative for Queensland (Africa, Middle East and India), Queensland Government Department of Premier and Cabinet

Mr Bob Potter
General Manager Industry Development, Queensland Government Department of Mines and Energy

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

Mr Ray Kelly
Executive Director, Innovation & Emerging Industries, Queensland Government Department of State Development

Mr Michael Roche
CEO Queensland Resources Council

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

Mr Tim McLennan
QCAT Executive Manager and Director - Business Development & Commercialisation
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