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QCAT Industry and Research Report 2008-09

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

Government occupants

CSIRO

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

Defence Science and Technology Organisation

Commercial occupants

Applied Mining Technologies Pty Ltd

BHP Billiton Carbon Steel Materials Technical Marketing

CET Group

GeoTek Solutions

Rio Tinto Alcan Queensland Research and Development Centre

Teakle Composites

CSIRO

Queensland Government

QCAT Industry and Research Report 2008-09

denotes QCAT Commercial tenants

Foreword

The global financial landscape has dramatically changed over the past twelve months. For the resources industry this has brought mine closures and a downturn in production. Coupled with an imperative to address greenhouse gas emissions, the Australian resources sector faces an array of challenges. But these challenges also provide opportunities. Realising opportunities requires research and technology. The Queensland Centre for Advanced Technologies (QCAT) provides this knowledge and helps to deliver a competitive edge to the Australian mining, minerals processing and energy industry.

QCAT is now in its sixteenth year and hosts a variety of research organisations including CSIRO, the Defence Science and Technology Organisation, Rio Tinto Alcan and most recently BHP Billiton's coal coking and magnesium research capability. BHP Billiton's move to Brisbane at QCAT is a testament to the expertise that resides in the precinct and the opportunities for collaborative research. I welcome BHP Billiton's move and hope it will benefit from the collaborative research environment at QCAT.

In 2008-09 the minerals sector contributed $133 billion in export earnings and represented approximately 8 per cent of Australia's GDP. While these are excellent results, we must continue to maintain and strengthen our competitive advantage. Research and development at QCAT is transforming the resources industries, with a focus on sustainable environment. Low emissions coal technologies that reduce greenhouse gas emissions associated with mining, processing and utilising coal are being developed.

At the same time, systems that improve mining safety and productivity will ensure continued export success and earnings for the nation in the coming decades. QCAT's focus on industry-changing research is evidenced by the commercialisation of two important safety drive projects, the Longwall Automation project and the NEXSYS integrated safety management system.

I congratulate QCAT on delivering this world leading technology to Australian industry, which continues to enhance Australia's international competitiveness. I wish continued success in all of QCAT's future endeavours.

Federal Minister for Innovation, Industry, Science and Research

Executive Manager's report

The Queensland Centre for Advanced Technologies has provided research and development services to Australia's resource industries since 1992. This year, QCAT scientists and engineers expanded our partnerships with external organisations and created new technologies that made the energy and minerals sectors more efficient, less carbon intensive and safer.

The 2009 QCAT Industry and Research Report highlights accomplishments in seven areas. Our scientists and engineers contribute to all of CSIRO's National Research Flagships, major programs that address Australia's important technology needs. Our staff are focused on fundamental problems such as secure supplies of clean energy and water, sustainable growth of the minerals industry and climate adaptation.

Many years of research at QCAT culminated this year in commercialisation of two technologies that demonstrate our impact on the resources industry. Our proprietary LASC technology, providing longwall face alignment, horizon control and communications in a single system, was adopted by all major manufacturers of mining equipment, including Bucyrus, Eickhoff Australia, Inbye Mining Services, Joy Australasia and the ZZM-KOPEX Group. Our NEXSYSTM real-time risk management technology was licensed to Mining Logic Systems, providing industry with a system that collects information from sensors and systems, analyses this data and provides rule-based risk decisions that trigger response plans when hazardous conditions are discovered.

Partnerships are fundamental to our work. Approximately one-third of CSIRO's research is funded by external agencies, and that fraction is considerably larger for the disciplines represented at QCAT. Two important partnerships were developed and strengthened during the year. Much of QCAT's mining-related research has been funded by the Australian Coal Association Research Program, a tradition that continued and grew in 2009 with funding for nine new projects representing more than $3 million in research support. And in an important new development, BHP Billiton's Carbon Steel Materials technical marketing research group is a new QCAT partner in the study of iron ore and metallurgical coal processing, dominant Australian export commodities.

Research results are seldom useful in vacuo. It is imperative that we communicate our results to sponsors and citizens, and it is equally imperative that we clearly understand the needs of our partners and sponsors. As described elsewhere in this report, QCAT hosted more than 4000 visitors from ten countries in 2009. Our Open Day attracted more than 1500 visitors to QCAT and the Innovation and Excellence Day brought 80 leaders from industry, government and research to QCAT for a program that highlighted our work.

On 1 December 2009, the divisions of Exploration & Mining and Petroleum Resources will merge to form a new Division of Earth Science and Resource Engineering. The division will be based at QCAT, a most excellent place from which to guide CSIRO's staff working in earth sciences and the energy and mineral resources sectors. On a personal note, I thank those who made my transition to QCAT practically effortless–you have made me feel very welcome.

Mike McWilliams
Executive Manager, QCAT

Mining

The past financial year has seen major upheavals in the mining and mining services domain across the world mainly due to restricted export markets and a decline in resource prices. Maintaining our place in the world resource market is becoming ever more difficult as Australian resources become deeper, lower grade and harder to mine and process. In a changing market, Australia's mining industry has to become more sophisticated. A fundamental goal of QCAT is to research and deliver technologies to address these industrial challenges.

The smart mining cluster at QCAT incorporates CSIRO and a number of small to medium enterprises from the mining services sector. Collaborative R&D at the precinct covers a broad range of mining activities from coal to hard rock and sand, 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

The Mining Geoscience group is built around staff possessing diversified research and industry experience, with a strong foundation of geology, chemistry, physics and mathematics, supplemented by software development, electronics and engineering. As a consequence, the group is well placed to deliver a relevant, high quality research service to the Australian and international mining industry. Some 27 staff are based at QCAT.

Our research goal is "to provide solutions that reduce uncertainty associated with the knowledge of the minescale geological environment" and to improve the recovery and use of minerals and energy products. Our goal will be achieved through the development of new technologies and systems to better delineate and characterise mineral resources and mining conditions before, during and after mining. Our success depends on the maintenance of strong collaborative relationships with all stakeholders including government, industry organisations (eg ACARP, AMIRA), companies, other research providers, commercial partners and the community.

Four research areas have been defined based on consultation with industry and represent key areas of uncertainty associated with coal/ore and rock characterisation for mining.

Geology and geophysics

Geological knowledge underpins all mining decisions. We continue to provide expertise in structural and sedimentological modelling, coal basin analysis, integration of geological, geochemical and geophysical data sets, mineralisation controls, geotechnical hazard assessment and regional structural frameworks. We are reaching new levels of understanding rock integrity and ground condition through microseismic analysis. This will allow the location of rock fractures and the prediction of impending hazards, such as roof falls, rock bursts, water ingress, working area stability, fault reactivation and gas and steam emission. We are now heading towards a real-time microseismic monitoring system for longwall coal mining.

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

Geoscience interpretations are routinely provided to non-geoscience staff and used to plan, design, develop and operate mining projects, having major impact on safety, technical viability, operating framework and financial performance. We are developing new systems to document, convey and communicate the level of uncertainty inherent in a geological interpretation.

Mining and exploration companies access and generate vast amounts of geoscience data, from which they extract critical information and knowledge. Core capabilities in the collection, manipulation, modelling and visualisation of digital data allow us to be involved in research activities ranging from understanding basinal controls on coal deposit formation, through to the development of new computational tools for analysing and interpreting complex spatial data.

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

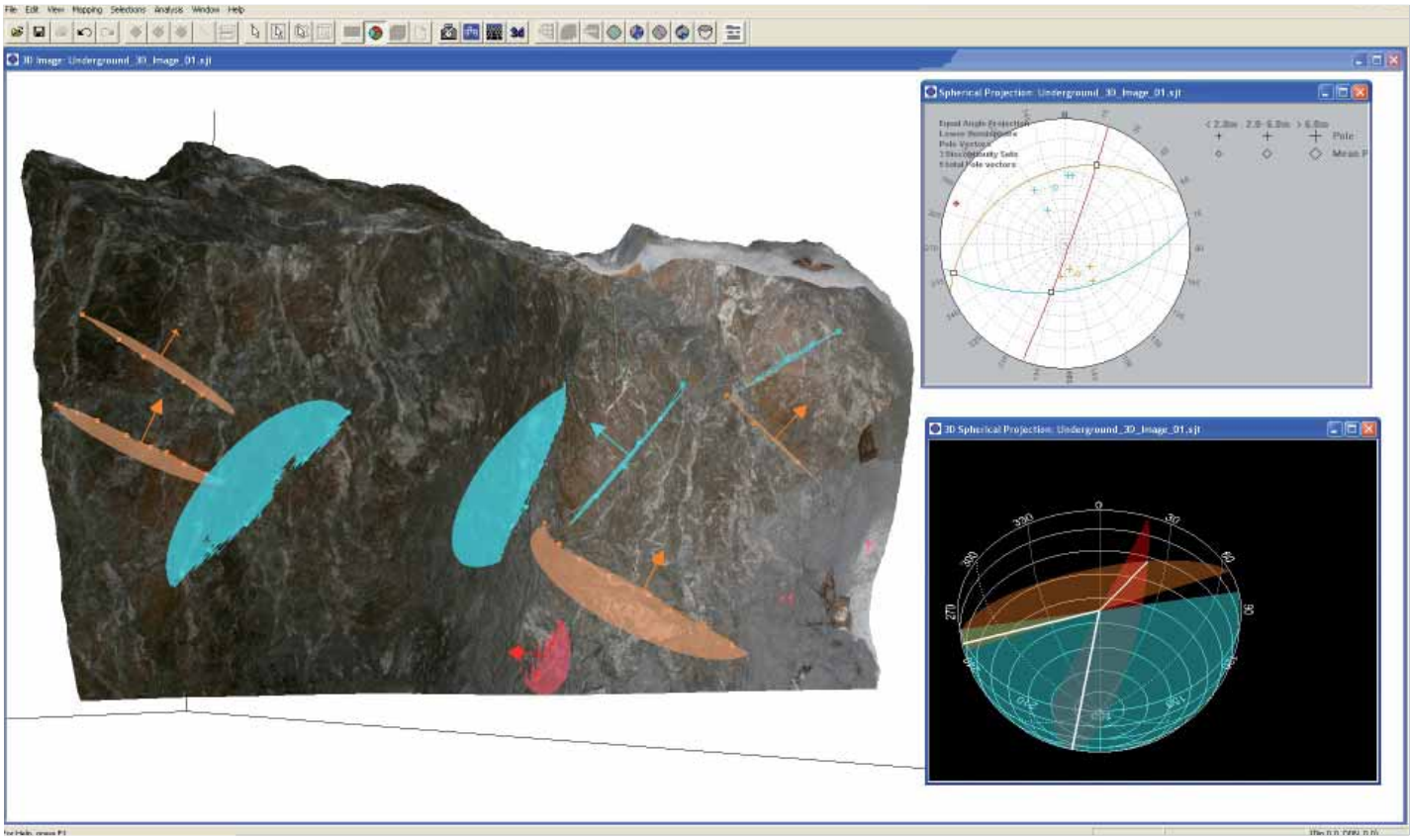
Nuclear science: borehole logging

Research is being undertaken on development of borehole logging technologies and methods for analysis and interpretation of disparate borehole logging data.

Nuclear borehole instrumentation is being upgraded to give a higher resolution spectrometric response, improved count rate statistics, greater logging depth and increased automation.

New instrumentation is being developed in response to industry needs for in-situ estimation of trace element abundance for process control, utilisation and environmental management.

Sophisticated data analysis methods are being employed to process disparate borehole geological, geophysical and geochemical data sets to deliver improved interpretations of all available data in an integrated approach.



3D imaging and 3D data processing

The development and exploitation of 3D imaging draws on and exploits advanced development in image processing, image analysis and computational geometry that have been pursued by the group. These include the development of unique polyhedral 3D modelling techniques and the implementation of algorithms designed for execution by massively parallel computing architectures. These techniques can be used to support other applications such as seismic data processing.

Generation and analysis of high-precision 3D images of rock mass surfaces for open pit and underground environments is being used for mine mapping, slope stability analyses, blast optimisation, fragmentation and real-time input abilities.

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

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

Coal characterisation

Optical microscopy is being used to provide textural, density and chemical information on individual grains of coal and rock from cores, stockpiles and on-line sampling. Imaging techniques are used to determine the area abundances of the different maceral (organic) and mineral (inorganic) constituents in each individual grain. This information enables the density and ash value of each grain to be estimated.

The coal grain analysis information is usually obtained on samples that have been crushed to a topsize of 1mm. Coarser coke oven feed samples (80% passing 3mm) and finer power station feed samples (80% passing 75 microns) have also been successfully analysed. In addition the technique has been used to analyse samples, such as exploration samples and coal tailings with a high mineral content.

Coal grain analysis information is being used to better understand the impact that mining practices and crushing will have on the liberation of the minerals from the organic material and to improve the recovery of fine coal using flotation techniques. Coal grain analysis information has enabled us to better understand coal performance in coke making, conventional power generation, and the production of liquid fuels for use in fuel cells.

The density distribution (washability characteristics) of coal can be determined by this method. The uptake of this method has the potential to significantly reduce the coal industry's reliance on organic solvents for obtaining this information.

Coal mining

Thick seam mining

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

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

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

Mine fire control

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

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

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

Longwall dust control

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

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

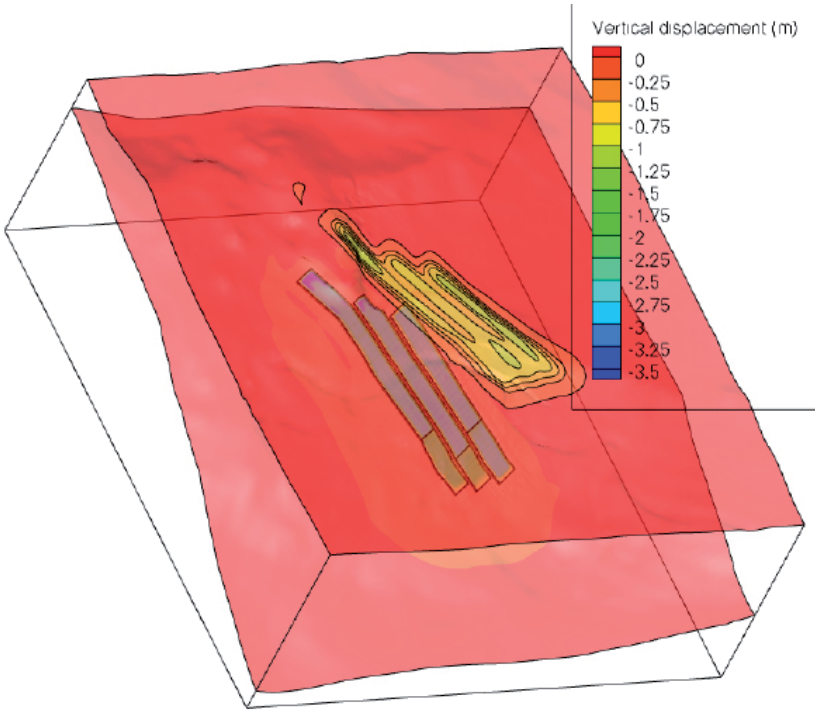
3D mine scale simulations of coalmine geotechnical and environmental issues

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

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

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

CSIRO has recently started a two year ACARP-funded research project aimed at advancing 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 field work is ongoing at Springvale colliery to understand the in situ hydrogeological environment and to determine the extent and magnitude of induced hydrogeological changes in the surrounding strata during longwall mining. Similar work is about to start at the BHP Billiton Dendrobium Mine and Peabody Metropolitan Colliery in NSW.

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

Mine subsidence control and remediation

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. Some old bord and pillar mines in densely populated areas (e.g. Collingwood Park in Ipswich) have encountered sudden ground failure and subsidence many years after the completion of mining. New cost-effective technologies are required to prevent, control and remediate the subsidence related to either longwall mining or old bord and pillar mining.

Grout injection is a technology used to control coal mine subsidence by injecting waste material (e.g. flyash) into the mining voids and/or the overburden bed separations. This technology has great potential for implementation in the Australian mining industry and the communities affected by old mines because it is cost effective and environmentally friendly.

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

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

In the long term, this research will lead to an innovative method that not only prevents or reduces mine subsidence but also utilises mine waste (coal wash and flyash), reducing the environmental impact of coal mining activities.

Deep coal mining

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

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

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

Outbursts of coal and gas

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

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

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

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, measure and quantify critical rock mass characteristics and parameters at depth, and in particular for providing essential information for resource extraction and processing purposes. 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 delivery of more effective drilling and down-hole data acquisition technologies.

CSIRO is sponsoring and will be a key research provider in a newly proposed Co-operative Research Centre (CRC) for Deep Exploration, which is being co-ordinated by AMIRA International. This proposed CRC bring together international mining companies, equipment suppliers and researchers to deliver step-changes in drilling and logging technology. CSIRO is working on advanced data processing procedures to estimate essential physical and petrophysical properties from geophysical logs and available geochemical assay values. This research is aimed at extracting maximum information and knowledge from holes once they are drilled.

Boart Longyear has joined with CSIRO to test a new drill control system and develop a number of technologies aimed at full drill rig automation. Elsewhere, CSIRO has successfully demonstrated the use of seismic noise created by a rock drill to steer the drill toward a defined target.

Researchers at QCAT have undertaken a collaborative project with the Australian Resource Research Centre in Perth to explore the fundamental characteristics of the rock and drill-bit interaction. This research is heading towards the development of new methods of “exciting” the drill bit to improve performance.

Geologically intelligent surface mining

A new concept for surface mining will transform the industry into an intelligent and remotely controlled operation using smart machines capable of responding automatically to the mineralogy and lithology of geological formations. New cutting technologies combined with superior spatial and mapping systems are being investigated and tested in practical applications.

To ensure appropriate adoption of teleremote and autonomous technologies by the mining industry, scientific investigation of users’ operation, interaction, and collaboration in immersive, mixed reality, and virtual environments, using novel forms of interfaces, are being investigated. Efficient communication architecture for remote mining operations have been developed and tested. Work is also progressing towards the development of a relevant Industry Standard in cooperation with AMIRA.

Key stages of various components necessary for the future geologically intelligent surface mining have been demonstrated at mine sites in the Pilbara and at a quarry near Brisbane.

Non-entry underground mining

The availability of easily recoverable ore underground and openpit is decreasing. This has resulted in mining moving into areas where conditions are becoming more challenging, particularly due to high stress, lower grades, higher temperatures and deeper locations. This move to more challenging conditions is emphasising the need to address the challenges of automated and remote control mining.

Research into new technology that uses Wi-Fi to accurately determine and track the position of people and equipment in an underground mine is being undertaken. Successful trials have now been conducted in surface activities, underground in a railway tunnel and in an operating underground mine. Work is continuing on enhancing the system so that it can be deployed in an underground mine to track production equipment and report on the movement of ore (and waste) for production monitoring and control of equipment and production. The development of this system will be a major step forward in the remote control and monitoring of mining.

Research is also 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.

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 world wide 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 with reduced wear rates resulting in increased tool life compared with conventional tools. The ability to economically cut hard rock will enable new mining methods.

CSIRO Exploration and Mining has signed contracts with two companies to conduct joint projects for applications of SMART*CUT technology to hard rock drilling.

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 fourth 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.

The research resulted in the development of an authoritative new generation pit slope text, 'Guidelines for Open Pit Slope Design'. The text, which was made available to sponsors in October 2008 and will be publically available in November 2009, 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
- the influence of pore pressures
- 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 CSIRO ICT Centre provide the capabilities to research and develop novel and robust industrial solutions in the mining automation sector.

2008–09 has seen the development of field-proven robotics systems that provide the building blocks for future automation of mining equipment in surface and metalliferous underground operations.

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

Remote mining

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

CSIRO's main contribution to this project is the development of the situational awareness module, 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.

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

Automation technologies

CSIRO Exploration and Mining continues to extend its reputation as a leading R&D enterprise making genuine impact in the mining industry. The driving motivation is to improve productivity, safety and sustainability in mining. Successful industrial research and applications have been achieved in several key fields, including:

Navigation: New research and development has been undertaken in the field of inertial-based localisation.

This effort aims to deliver new levels of navigation capability that are suitable for widespread application in mining and other industrial operations. 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: Longwall mining guidance technologies continue to be developed as part of CSIRO's automation strategy. New coal seam horizon tracking systems (using CSIRO patented technology) were demonstrated at the Broadmeadow Longwall operation. These systems employ machine mounted thermal infrared imaging to give real-time information as to 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 a real-time iron ore profiling system to provide a remote operational capability for ship loading tasks.

Mapping: Development into new radar-based imaging technologies have been actively pursued for a range of mining and industrial applications. This technology includes environmental mapping and subsurface imaging. Key application areas include navigation, tracking, resource utilisation, and situational awareness capabilities.

Many of these key technologies are now being applied across two major projects that the group is currently managing. The first project, funded by ACARP is focused on the automation of continuous miners for coal mine roadway development. The second project, whose client is Rio Tinto, will deliver a teleoperation technology for an iron ore shiploader.

Landmark longwall automation

The two year, $2.5 million 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. Non-exclusive worldwide licensing agreements have been signed with Bucyrus Australia, Eickhoff Australia, Inbye Mining Services, Joy Australasia and the ZZM-KOPEX Group. This group represents all the major global longwall equipment manufacturers.

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 has begun. This project provides 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

NEXSYS will introduce step-change in the areas of real-time safety and operational management through information capture, data integration, and rule-based and predictive analysis. Intrinsically safe communications hardware, developed as part of the NEXSYS project, will allow the world's underground coal mining industry to fully utilise the Ethernet-based communications systems enjoyed for so long by surface and non-hazardous area industries.

The system is capable of monitoring and capturing data from proprietary safety and productivity systems (including proprietary supervisory control and data acquisition systems) over a fibre optic network, integrating and analysing the data as a whole and converting the results into 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, the Nexsys Real-Time Risk Management System will use a series of pre-set rules to determine the real-time risk profile of the mine. Analysis of historical data combined with current conditions and anomaly detection algorithms will allow for 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 an emergency situation.

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

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

Collision avoidance

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

Diesel particulate agglomeration

Recent identification of suspended diesel engine particulates posing a risk to underground miners has led to a project to agglomerate and filter the particles from diesel engines without loss of engine efficiency. Metals and toxic substances from diesel engines adhere to the surfaces of carbon soot particles. Aldehydes, such as formaldehyde and polycyclic aromatic hydrocarbons (carcinogens specifically linked with lung cancer) have been identified on the diesel particles.

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

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

Applied Mining Technologies

Applied Mining Technologies Pty Ltd (AMT) plays a leading role in the 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 with equipment manufacturers incorporating AMT technology into new and existing production systems. This has resulted in significant improvements in production rates and resource recovery and provided the enabling technology for ongoing advances in automation.

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

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 2008-09 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 QCAT.

Coal Augering Services Pty Ltd

To maximise the commercial return from its mining technology CET expanded into contract mining in 2003 as CAS. 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 for Anglo Coal, Centennial Coal, Foxleigh Mining, Vale, Coalpac 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, marking CETR's 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.

GeoTek Solutions

GeoTek Solutions (GTS) is a geotechnical consultancy specialising in slope stability for open cut mines. Since its formation in 1999, the company has operated from the QCAT Technology Transfer Centre.

During the past year GTS has worked with Carbon Energy, a CSIRO spin-off company 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.

Current projects include investigations for a proposed new coal mine, making use of the research carried out by current and former CSIRO staff 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 which currently is gathered routinely but is often used for only limited purposes.

These ongoing relationships show the value of QCAT in helping to transfer technologies from CSIRO to industry.

Processing

Australia is the world's largest exporter of alumina, iron ore and black coal and a major producer and exporter of other mineral commodities. To maintain and expand the competitive position of the Australian resources, industry innovative and cost-effective processing of our mineral wealth is essential. Researchers from CSIRO, Rio Tinto Alcan Queensland Research and Development and, from July 2009, BHP Billiton's Carbon Steel Materials group, form QCAT's minerals processing cluster and are assisting the industry in Australia and overseas.

Iron ore processing

CSIRO provides world-class expertise in iron ore processing, product evaluation and product optimisation, including detailed mineralogical, beneficiation and agglomeration evaluations of new and existing ore types and deposits.
A particular focus is the characterisation of new ore resources, predicting beneficiation performance and optimising sinter, pellets and lump in blast furnaces and other downstream processes.

Ore characterisation and predicting processing performance

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

Work on the automation of ore characterisation has continued, including 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 for 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', has been 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 replace resources that are being depleted and to meet market demand, particularly from China. The need to develop more effective beneficiation strategies to remove 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 under investigation, including:

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

The international demand for iron ore 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 therefore continuing with a number of Queensland, Western Australian and South Australian ores. A key focus of the research has been on the reduction of grinding costs for liberating the magnetite from the gangue minerals and control of impurity levels in the final magnetite concentrate, e.g. using combined magnetic separation and reverse flotation.

Iron ore sintering and blast furnace burden characterisation

The sintering research conducted at QCAT continues to play a pivotal role in proving up new Australian iron ore resources for export. At the fundamental level, ongoing 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 and their impact on sintering performance are being investigated, with a focus on the interaction of size distribution and ore mineralogy. This is crucial as Australian iron ores become more diverse.

The CSIRO state-of-the-art pilot-scale sinter rig (~80–100 kg samples) continues to be used routinely for investigating 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 developed.

In the blast furnace burden characterisation area, the recently upgraded CSIRO softening and melting furnace is now in routine operation with improved data logging, better atmosphere control and the ability to measure waste gas concentrations, including CO, CO_2, O_2 and H_2.

Iron ore pelletising

The CSIRO pilot-scale iron ore pelletising facility is currently being upgraded to enable simulation of grate-kiln-cooler pelletising machines in addition to straight-grate machines. A rotary kiln has been ordered for this purpose and is scheduled to be installed during the coming year. The new facility will be used for optimising balling, drying and induration of iron ore pellets, particularly for magnetite ores.

Significant international interest in the laboratory-scale, infra-red image furnace at QCAT continues. It is being used for investigating and understanding oxidation/reduction 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.

Non-ferrous minerals processing

Plant optimisation

Research for the non-ferrous mining industry on SAG mill optimisation and fine (<38 micron) and ultrafine (<10 micron) grinding is continuing. Work on a three-year extension of the AMIRA SAG mill project to monitor mill performance using surface vibrations progresses. A ruggedised prototype monitor with an inertial power supply for continuous operation continues to operate successfully at the Rio Tinto Northparkes mine in NSW. The

monitor can track the toe and shoulder positions of the charge, mill load and charge size inside the mill as well as other operating parameters.

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

Standards development

Our researchers continue to play a leading role in the development of International Standards Organisation (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. Work on the development of improved ISO methods for physical testing of blast furnace and direct reduction feedstocks for iron and steel making is continuing.

Coal processing

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

Supported by ACARP and the coal producers themselves, the group is developing components for the conceptual intelligent plant system. New hardware and software developments will allow a processing plant to compare its current operational performance, in real-time, 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.

COLLABORATION

BHP Billiton Carbon Steel Materials

In May 2009 BHP Billiton and CSIRO signed an agreement aimed at increasing collaboration between the two organisations. As part of the agreement, BHP Billiton's Carbon Steel Materials group involved in iron ore, manganese and coke-making research was relocated to QCAT in July 2009. The agreement also stipulated an annual symposium for discussing research outcomes and exploring future research directions

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 demonstration of the benefits of using high pressure grinding rolls (HPGR) with the overall objective being to quantify energy efficiency for a three HPGR flow sheet in comparison with a conventional milling circuit.

RioTintoAlcan

Rio Tinto Alcan Queensland Research and Development Centre

As part of a long-term commitment to bauxite mining and alumina production in Australia, Rio Tinto Alcan (RTA) relocated a significant part of its bauxite and alumina R&D to Australia in 2002. The Queensland R&D Centre (QRDC) building was officially opened on the QCAT campus in 2005. The centre has since been steadily developing capability and extending its R&D program.

The centre has developed world class R&D capabilities in alumina refining (Bayer process) technology development. In doing so, it put Brisbane and the QCAT campus on the alumina industry world map.

The Global General Manager of RTA B&A R&D has an office and regular presence at QRDC, defining QRDC and QCAT as central technology site for Rio Tinto Alcan and the Australian alumina industry.

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 per cent ownership), the Yarwun refinery (100% ownership) and Queensland Alumina refinery (80% ownership) both located in Gladstone, Queensland.

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

QRDC's program of work seeks to improve performance in our global alumina operations, and has played a part in several significant improvements in the Alumina business in recent years, particularly in the areas of product quality, residue management and refinery emissions.

Through 2008-2009 Rio Tinto Alcan has continued its long history of collaboration with Australian research organisations. Rio Tinto Alcan's commitment to Parker CRC for Integrated Hydrometallurgy Solutions is a key partnership, as well as a number of collaborative research initiatives involving CSIRO or CRCs with CSIRO participation, including several AMIRA projects. Projects continue to be developed and initiated on an annual basis.

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

Advanced materials engineering

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

Manufacturing with light metals

Light metals fatigue

Recent research on the fatigue properties of castings has focussed 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 diecastings is being developed within the CSIRO Light Metals National Research Flagship.Work at QCAT and CSIRO's Clayton campus has shown it can deliver improvements in strength, ductility and fatigue life. Experiments have demonstrated which casting and heat treatment conditions lead to improvements in fatigue life, and which do not. 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 percent of rare-earth (lanthanide) elements, has proven to give light castings excellent properties at the temperatures typically found in car engines. QCAT is working towards optimising manufacturing processes for economical production of this alloy, suitable for automotive engine components. This process optimisation is also being applied to a magnesium alloy with excellent extrusion properties and a grain-refining master alloy.

Steel coating improvements

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

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 is working 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 A$335,000 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 mine design needs 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 through a 900 mm diameter steel-lined hole, bored 80 m from the surface through soil and rock to the mine. When the

Teakle Composites

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

In 2008-9 the company's achievements included::

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

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

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 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 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 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 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.

Tubes of a CSIRO-designed carbon-epoxy composite, a material that does not interfere with the measurements and therefore requires no boron, no machining and no coatings, created a 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 lead to improvements in health and safety.

Low emissions coal

The coal and power industries face the challenge of reducing greenhouse gas emissions while continuing to meet the growing energy and resource demands of our society. Low emissions coal technologies aim to reduce emissions and improve efficiencies right through the coal cycle. R&D at QCAT addresses issues across the coal lifecycle, 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 Queensland 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 nations 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 percent, or on drainage gas with methane concentrations lower than 25%. A 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 2008-09 a 25kWe prototype demonstration unit was successfully constructed and commissioned. Experiments carried out at CSIRO QCAT laboratories have demonstrated the VAMCAT technology. 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 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 case study is 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. During 2008-09, the project team have completed all the studies. The draft final report is now under review.

Coal mine methane capture maximisation

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

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

Low emissions electricity

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, these next generation power technologies, with the capability to capture carbon dioxide, will be required in Australia to meet increasing power demands with increased efficiencies, significantly reduced emissions 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 it adapts to a changing marketplace, and helping the Australian electricity industry reduce the risks of selecting and implementing advanced power generation technologies. Our research also contributes to the expertise required to evaluate fuel and energy strategies for sustainable energy conversion technologies in this country.

Coal gasification

CSIRO operates an advanced gasification research facility at QCAT. The facility is used to investigate 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, as well as contributing to 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 the implementation of the gasification research work. Established in partnership with the Australian coal and power industries and a number of research collaborators this works formed part of the program of the CRC for Coal in Sustainable Development.

This CRC has now concluded and CSIRO is continuing its gasification research through a number of collaborative programs with Australian and international research, government and industry partners.

Syngas processing and gas separation technologies

Until its conclusion in July 2009, CSIRO was the major research contributor to the Centre for Low Emission Technology (cLET). cLET's research focus was on the gas cleaning, processing and separation technologies that will be the key enabling technologies for the development of commercially feasible, coal gasification-based power generation systems that incorporate large scale CO_2 capture and storage.

This program is using state-of-the-art facilities and capabilities developed at QCAT for the development and assessment of hot gas cleaning materials, as well as novel catalytic gas processing and membrane separation systems. A syngas simulation facility has been established at QCAT which, in conjunction with the existing gasification research facility, allows 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 coal technology performance issues, energy efficiency and emissions goals for the coal, power and energy industries. CSIRO is working with the Australian coal and power industries, local and international research groups and with state and federal government agencies to develop the necessary capabilities and technical programs to support the development, demonstration and deployment of large scale, low emission coal based power generation technologies. This will be required to meet our growing energy and environmental requirements.

Centre for Low Emission Technology – Final Report

The Centre for Low Emission Technology (cLET) completed its research into the 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.

The Centre officially closed on 31 July 2009. It was an unincorporated joint venture between the Queensland Government through the Department of Employment, Economic Development and Innovation, CSIRO's Energy Technology and Energy Transformed Flagship, Stanwell Corporation, Tarong Energy, the Australian Coal Association Research Program, and the University of Queensland. Focussing on coal gasification and advanced gas cleaning, processing and separation 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 developed a proposal to build a 5 MWt pilot scale gasifier in Australia. The aim was 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. 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 with a commercial vendor were negotiated to enable an outline design and costing for the plant to be obtained. A scoping study to estimate the cost of a seven year program to build and operate the plant was completed, and delivered to the partners as a non-confidential report.

Syngas generator

This project was revised in 2007 to deliver a facility to simulate syngas from coal gasification. The syngas simulation facility was completed in March 2009, and used to provide syngas for testing catalysts and gas separation membranes.

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 used to test gas cleanup concepts developed for cLET.

Water gas shift catalysts

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. The performance of commercially-available catalysts for coal derived syngas streams that contain higher CO, CO_2 and H_2S concentrations in the feed and product streams was established, and shown to be satisfactory.

High temperature catalytic membrane reactor

The aim of the project is to develop a separator module that combines the shift reaction and hydrogen separation in one integrated unit, thereby simplifying syngas processing and hydrogen production and recovery relative to current technology which uses separate process steps. Tubular and planar designs for catalytic membrane reactors and a shift catalyst with the capability to operate at high temperature have been developed.

Molecular sieve silica membrane systems

A ceramic separator was developed to separate hydrogen from shifted syngas, and shown to be suitable for syngas. Membrane separation offers the potential to 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 through the development of thin film metal membranes that avoid or eliminate the use of Palladium, an expensive and scarce precious metal resource. Novel alloys, membrane fabrication methods and separator designs to apply the concept were developed and proven on simulated syngas.

Stakeholder perspectives to low emission technologies

An informed and positive constituency of stakeholders is crucial to successful technology transfer. cLET undertook an extensive program of engagement with the key stakeholder groups regarding low emissions coal technologies, to ensure support for low emission technologies with carbon capture and storage as a climate change mitigation option.

Social Science Research Team

A key issue of technology uptake is how the technology, and the risks associated with it, are perceived. If society perceives the risks to be too great it can delay, or stop, the adoption of new technologies.

An understanding of stakeholder perspectives can help address any issues and concerns stakeholders may have. This knowledge can be used to inform the development of the technology and potentially improve the outcomes and relevance to society.

The Social Science Research Team in CSIRO Exploration and Mining was initially developed to understand the drivers and barriers to the uptake of carbon capture and storage technology. The team has since expanded this initial focus and currently has projects in four of CSIRO's National Research Flagships.

A highlight for the year was securing a $4 million dollar grant from the newly established Global Carbon Capture and Storage Institute. The grant is to focus the work of the international social research group, which is now formally recognised as a network under the International Energy Agency Greenhouse Gas R&D Programme.

Energy Transformed Flagship

Societal acceptance of energy technologies

The mix between energy and society remains a major research focus through the use of large group workshops. Workshops were hosted in Melbourne, Perth and Adelaide. The earlier workshop results of Brisbane and Perth were presented at the 9th International Conference on Greenhouse Gas Control Technologies conference in Washington in November 2008 and were well received. There is growing interest internationally to replicate the study, hopefully through Global Carbon Capture and Storage Institute funding. This work has resulted in an invitation to be on the Programme Committee for public acceptance, communication and capacity building for the 10th Conference in Amsterdam.

A natural extension of this work is to understand how the public and other stakeholders perceive geothermal technology and its future in Australia's energy mix. The team is working to further develop relationships and understanding around this industry.

Energymark

Energymark works through small community based networks, holding meetings to discuss energy and climate change. Balanced information is provided by CSIRO to support the discussions.

The Newcastle trial, co-funded by Newcastle City Council, was a resounding success with interim results showing that households who participated in the eight month process reduced their household carbon footprint on average by 30%. The results are also showing a number of other significant changes in knowledge, attitudes and behaviours.

To deliver Energymark in five states the program partnered with Students in Free Enterprise Australia. This enabled the program to be critically evaluated and tested by a range of stakeholders with results consistent with those in the initial trial.

A partnership between Department of Premier and Cabinet South Australia and Local Government South Australia will enable a roll out of the program across a number of South Australian local communities in the coming year.

Plans for the process include tailoring Energymark for small to medium enterprise businesses with a willingness to participate and find ways to reduce their greenhouse gas emissions.

Intelligent grid project

The Intelligent Grid project, currently in its third year, has the objective of identifying the value proposition for distributed energy (DE) in Australia. The social research component of the project has been focusing on interviewing a range of stakeholders from regulators, network providers and generators to identify the potential barriers and enablers for distributed energy, ensuring it can become an early action response to climate change in Australia.

A highlight of this program has been the Maines' Power project, a collaboration between a number of key industry players in Castlemaine, Mount Alexander Sustainability Group, the local council, various state government bodies and CSIRO. Four larger industry players have set a goal to reduce their carbon emissions by 30% by 2010. The work was highlighted in the Garnaut review as an example of businesses voluntarily reducing emissions.

More recently the team worked on a project with Energex to evaluate its demand management trial called Cool Change 2. In this trial a number of Brisbane homes participated in a project where they had their air conditioners remotely cycled. Research identified the decision making process that participants undertook when considering participation.

The Intelligent Grid report is due to be finalised early in the next financial year. Communicating messages of this work will be a focus of the social research team for 2009-2010.

Climate Adaptation Flagship

Climate adaptation and society

The team has been working with the Climate Adaptation National Research Flagship since the beginning of 2008 with two major projects. The first project identified principles of best practice to engage with various groups for climate adaptation planning and capacity building. This project used interviews, literature and workshops to identify key recommendations for stakeholder engagement, as well as noting specific features of climate change that influence engagement outcomes. This project report was published as one of the Climate Flagship's working papers, and has led to the planning of a further Flagship project for 2009/10. This new project builds on the initial findings to create a more detailed assessment of planned engagement activities.

The second project, conducted in collaboration with the Department of Climate Change, was an adaptation benchmarking survey of Australian organisations, which was completed this year and will be repeated in 2010-11. Survey results indicated that although most businesses recognise the challenges posed by climate change, and accept that mitigation and adaptation are important, the nature and extent of adaptation activity was highly variable, with only 59% of surveyed organisations having conducted formal vulnerability assessment, and less than 40% having implemented any specific planning for adapting to future climate changes. Results indicate that there are a number of drivers and barriers to climate adaptation planning. Drivers included a growing awareness of climate change, a sense of vulnerability to climate change impacts, pressure from external stakeholders, and prior experience with long-term planning, while barriers to adaptation planning included a lack of resources (funding, staff expertise and external relationships), a lack of policy clarity and/or government support, scepticism about climate change impacts, and a culture of conservatism within some organisations.

Wealth from Oceans Flagship

Social dimensions of seafloor exploration and mining

In 2008-09, the social dimensions of seafloor exploration and mining (SEM) project continued to integrate the social and environmental sciences to gain a sound understanding of the impact and acceptability of seafloor exploration and mining in Australia. A focus of this research has been identification of the circumstances under which the activity may be undertaken and the boundary conditions for its approval.

The qualitative social research program gauges the reaction, concerns and information needs of key stakeholders for a potential seafloor exploration and mining industry in Australia. This research has included extensive stakeholder consultation through workshops and interviews with regulators, potential industry participants, state and federal government agencies, non-government organisations, investors, and social researchers. The results will inform the design of test case research exploring the environmental impacts of near shore

exploration and mining in Australia and monitoring framework by CSIRO.

A second phase of research explores the values and objectives that the general public use to assess the acceptability of seafloor mining. In collaboration with the Minerals Down Under Flagship (MDU), these values and objectives are considered alongside those associated with onshore mining, providing additional insight into what attributes make up a social licence for onshore and offshore exploration and mining in Australia.

Minerals Down Under Flagship

Minerals Futures

After initial scoping, the social research program within the MDU Flagship has developed strongly with a number of achievements in the past year. A key highlight was the commencement of a three year, $3million collaborative research cluster with five Australian universities. Led by The University of Queensland's Professor David Brereton, the Mineral Futures cluster will investigate three areas:

- Commodity futures: the development of plausible future scenarios, and strategies for transition, for the Australian minerals industry
- Technology Futures: investigating the potential social and environmental impacts of, and community responses to, innovative new technologies being developed through MDU
- Regional Futures: addressing linkages between social and economic impacts of new mining technologies at a regional level emphasising land use change in sensitive environmental settings.

In a related development, Professor Ron Johnston of the Australian Innovation Centre was appointed as a Flagship Fellow in early 2009. Prof Johnston worked collaboratively with University of Technology, Sydney to deliver a position paper and roadmap orienting the activities of the cluster and its foresight component. Also contributing to MDU's foresight work was a large scale survey of 1032 members of the Australasian Institute of Mining and Metallurgy (AusIMM) by the Science into Society Group on the key issues and drivers that will shape the development of the minerals industry. This work was presented at the 2009 Sustainable Development Indicators in the Minerals Industry conference and the report launched at an AusIMM corporate leader's luncheon by Flagship Director Dr Peter Lilly. The Flagship is also contributing to a global resources sector foresight process by the World Economic Forum which will be concluded in Davos, Switzerland in late 2009.

Furthermore, in 2008-09 a research project was initiated seeking understanding of the 'total value' of mining to Australia, beyond economic metrics. This work will also develop a better understanding of what constitutes the industry's 'social license to operate' and how this may be maintained, analyse the institutions that may support equitable distribution of mineral wealth to regional and remote Australia, and define the role of mining in securing indigenous livelihoods.

Information and communication technology

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

Automation

Autonomous hot metal carrier

Hot metal carriers (HMCs) are 8 tonne forklift-like vehicles that transport molten aluminium in large metal bucket-like containers called 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, part of CSIRO's Light Metals National Research Flagship program, is to develop technologies that will allow an autonomous vehicle to conduct continuous, safe, dependable operations around a worksite 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 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.

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 infrared laser pulse to measure distances to objects.

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

The mapping software developed for these sensors has produced the largest

unassisted Lidar maps published to date, covering a path of over 165 km. The challenge in building such maps without GPS is recognising revisits to the same areas after traversing large loops. The ICT Centre's place recognition algorithms quickly and reliably match revisited areas even when the initial location of the vehicle is not provided to the computer.

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

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

Wireless sensor and actuator networks

Wireless sensor and actuator networks provide the means to observe, understand and control the natural environment to a level that has never previously been possible. Wireless sensor and actuator 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

CSIRO's virtual fencing technology involves cattle wearing smart collars that allow monitoring of location and movement. The collars can be used to restrict the movement of cattle past 'virtual fences' in paddocks or around environmentally sensitive areas. The collars contain a wireless sensor node, based on CSIRO's Fleck™ technology, and other sensors for inertial and GPS measurement, as well as a power supply, radio transceiver and low power microcontroller which stores the GPS data for the virtual fencelines. If a cow approaches a virtual fence the collar emits a warning sound, and if it continues past the fence line the cow receives a tactile stimulus. In trials cattle quickly learn to react to the audio warning and stop before the virtual fence.

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

distribute updated boundary fenceline information to the mobile nodes.

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

Monitoring rainforest regeneration

A network of wireless sensor nodes in Queensland's Springbrook National Park is being used to monitor the recovery of rainforest regenerating from agricultural grassland. Nodes are located in areas of open grassland, regenerating rainforest and old rainforest, where they monitor micro-climate indicators including temperature, humidity, leaf wetness, soil moisture, wind speed and wind direction. The sensor network provides a valuable research platform for the study of land-use change, the effects of invasive species on biodiversity, the ecological functioning of rainforests and the impacts of climate change.

The network will be expanded to 200 nodes over the next three years, and sensor capabilities will be extended to include further information such as light readings, rainfall, fog and water quality indicators.

Listening for frogs

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

A trial network of six sensor nodes was established in the upper catchment area of the Somerset Dam near Brisbane. This area is the critical habitat for three species of endangered frogs, with another two species which existed in the area until recently, now presumed extinct. The sensor nodes recorded frog vocalisations and concurrent temperature and humidity readings for two hours each day over the summer of 2009. Data from the experiment is now being analysed by Seqwater.

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

Monitoring water quality

CSIRO has partnered with Seqwater to develop Australia's largest integrated intelligent wireless sensor network for monitoring drinking water. Lake Wivenhoe is the major source of drinking water for south-east Queensland, with a catchment area equivalent to the city of Brisbane, and supplies water to the region's 1.5 million residents. A deployment of over 100 nodes, using CSIRO's Fleck™ smart wireless sensor network technology, are monitoring the environmental conditions on Lake Wivenhoe and the surrounding catchment.

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

Forty five floating nodes have been operating on the lake since November 2008, measuring water temperature at varying depths. A further 25 land-based nodes are currently being installed throughout the surrounding catchment region to measure microclimate; air temperature, humidity, soil moisture, wind speed, and wind direction. The next stage of deployment in will see the addition of a further 30 nodes in the form of collars worn by cows grazing in the catchment area (please refer to our research on autonomous spatial management of animals, previous page). The nodes operate in a meshed network, meaning that they cooperate with each other to set up an ad hoc network to wirelessly transfer data back to a central point for collection and analysis.

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

Aviation and aerospace

Unmanned aerial vehicles

The ICT Centre is pioneering research on robust autonomous helicopter systems which can operate in unknown environments. The unmanned aerial vehicles (UAV) are being used for evaluating new air traffic separation methods and in future will inspect infrastructure such as bridges, cooling towers, powerlines and pipelines.

ARCAA - Smart Skies

ARCAA, the Australian Research Centre for Aerospace Automation, is a joint venture between CSIRO and the Queensland University of Technology to promote civil research into UAVs. In March 2008 the ARCAA Smart Skies project was formed in collaboration with Boeing Research and Technology Australia to explore and develop technologies for automated air traffic management for manned and unmanned aircraft.

The project involves research teams from CSIRO and QUT building on the already strong relationship with Boeing. Several collaborative workshops have been held in Brisbane and Denver and two flight trial campaigns have already been conducted in 2009, with another two planned. The flight trials so far have been to evaluate the automated separation management algorithms in real-world flight tests and have included an autonomous helicopter UAV developed and operated by CSIRO. The integrated hardware and software components of the UAV allow it to communicate with the separation management system located in the United States, and follow new flight paths commanded by the system to avoid collisions with other manned and unmanned aircraft. Future flight trials will test the capability of systems currently under development to sense other aircraft and ground based obstacles to plan flight paths to avoid collisions.

ARCAA - UAV Outback Challenge

The UAV Challenge, Outback Rescue is a competition aimed at university students, high school students and hobbyists with the aim of showing how small UAVs can be used to locate a lost bush walker and drop an aid package to them. The Challenge, an initiative of ARCAA and the Queensland Government, is now in its third year. Teams failed to complete the mission in 2007 and 2008. 25 teams are competing in 2009 for $75,000 in prizes including a $50,000 cash prize for the winner of the Search and Rescue Challenge.

Defence Science and Technology Organisation

Hypersonics

Flights at hypersonic speeds potentially offer significant advantages in performance for 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.

A test vehicle built by Air Vehicle Division staff at DSTO Brisbane was successfully launched during May 2009 as part of DSTO's initial trial for the HIFiRE program. The HIFiRE 0 launch was conducted at the Woomera Test Range in collaboration with US Air Force scientists. The launch vehicle was an unguided 2-stage Terrier-Orion rocket system.

HIFiRE 0 was a risk-reduction flight testing new flight computers and control software. Systems for hardware-in-the loop testing in the laboratory and a system for prelaunch set-up and control of the payload were also tested successfully.

Preliminary analysis of the data confirmed that the test vehicle turned onto the correct heading and elevation for re-entry into the atmosphere as designed. As a result, it is considered that HF0 achieved its mission goals, while also establishing a strong working relationship between DSTO, the US Air Force Research Laboratory, RAAF Aerospace Operations Support Group and RAN Range & Assessing Unit.

Before this launch the HIFiRE program had already achieved significant milestones including the design, integration, assembly and pre-flight testing of the hypersonic test vehicles; the design of complex avionics and flight systems; and computer modelling of the external and internal aerodynamics.

Design and development of test vehicles for the later flights are continuing. Future launches will be a mix of engine tests and aeroscience tests.

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.

Commercial tenants in the 2008–09 year included:

- Applied Mining Technologies Pty Ltd
- CET Group
- GeoTek Solutions
- Teakle Composites
- DSTO
- Rio Tinto Alcan Queensland R&D Centre

Outgoing tenants in 2008–09:

- cLET
- Carbon Energy

QCAT events

Visiting delegations

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

This collaboration takes many forms from hosting international expert speakers and government delegations to national industry and organisation representatives. 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 2008-09 financial year period. A sample of delegations visiting the site included:

Australia
- Australian Youth Aerospace Forum
- BHP Billiton
- Dow Chemical Australia
- Rio Tinto
- Clunies Ross Foundation
- Queensland Resource Council
- Australian Student Mineral Venture
- Pilbara Iron
- Pluton Resources

Botswana
- Botswana Railways and InfraDev

Brazil
- Vale

Canada
- Province of Manitoba's Department of Science, Technology, Energy and Mines.

Chile
- University Arturo Prat
- Industrial Comercial Chile Ltd.
- Sociedad Minera Varry
- Drillco Tools Ltd.
- Codelco

China
- Tiangong Technology Company
- China Coal Research Institute

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

India
- Jaiprakash Associates Limited
- Coal India Limited
- Essel Mining & Industries Limited
- Central Mines Planning & Design Institute Limited

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

Taiwan
- National Taiwan University
- National Tsing Hwa University
- National Chung Hsing University
- National Sun Yat-Sen University

Vietnam
- Vietnam National Coal-Mineral Industries Group

QCAT Innovation and Excellence Day 2008

On Friday 1 August QCAT held its fourth annual Innovation and Excellence Day with a receptive audience of over 70 opinion leaders from industry, Queensland Government and other research organisations. The theme of 'Impact through Innovation' was highlighted as industry partners presented in tandem with CSIRO researchers.

The day provided a range of benefits to stakeholders, from partnerships and collaborations on individual projects to strategic positioning of the entire site with government and industry.

Dr Geoff Garrett, CEO of CSIRO at the time of the event, delivered the opening address and used the opportunity to meet with high level partners from industry and the Queensland Government.

In reply the Hon. Geoff Wilson MP, Queensland Minister for Mines and Energy, emphasised the importance of QCAT's research in assisting the Queensland resource sector to stay ahead of the global field.

Visitors were treated to a morning of presentations followed by an optional site tour, allowing more time for interaction between stakeholders.

Public engagement

QCAT Open and Schools Day

On 27 and 28 March QCAT invited the students and general public to a Schools Day and Public Open Day respectively. These events allowed CSIRO and other QCAT tenants including DSTO and Teakle Composites to engage at a personal level with children and adults from the community.

On the Schools Day more than 300 primary and secondary students took part in a structured day of activities with lectures, science demonstrations and hands-on experiments. Teachers and students were impressed. "It is very obvious that everyone (at QCAT) is passionate and proud of their work," was one comment from a secondary teacher.

The Public Open Day attracted more than a thousand people. It echoed many of the Schools Day events, and added a demonstration of CSIRO's new Virtual

Mining Centre, a series of lectures; and a display of autonomous equipment from the ICT Centre including the 20 tonne autonomous HMC (see page 28). CSIRO Education took part in both days with a variety of hands-on activities.

Visitor feedback results indicated a majority of visitors were happy with the day and were "deeply impressed with the research taking place in their community."

Educational engagement

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

RNA Exhibition

For the ten days of the Royal National Association Show, the Ekka, QCAT assisted CSIRO Education in presenting a range of science activities to an estimated audience of over 40 000. With a diverse audience of children and adults QCAT's presence at the Ekka allowed for public engagement and discussion of the precinct's and CSIRO's research in general.

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QCAT Steering Committee

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

Members of the QCAT Consultative Steering Committee in 2008-09 were:

The Hon Mike Ahern AO
Chair QCAT Consultative Committee

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

Mr Michael Roche
CEO Queensland Resources Council

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

Mr Bob Potter
General Manager Industry Development, Queensland Department of Employment, Economic Development and Innovation

outgoing
Mr Geoff Cooke
Acting Executive Director, Department of Mines & Energy

Ms Leigh Roach
Executive Director, Science Policy and Commercialisation, Queensland Department of Employment, Economic Development and Innovation

outgoing

Mr Ray Kelly
Executive Director, Innovation and Emerging Industries, Queensland Department of Employment, Economic Development and Innovation

Dr Mike McWilliams
QCAT Executive Manager
Chief CSIRO Exploration and Mining

outgoing
Mr Tim McLennan
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