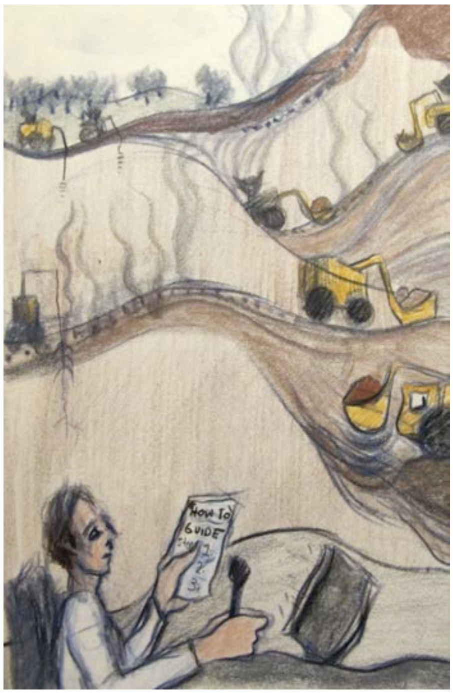
Final Cluster Research Report



Exploring the social dimensions of autonomous and remote operation mining

Applying *Social Licence in Design*

National Research FLAGSHIPS Minerals Down Under
CSIRO
The University of Queensland Australia
Curtin University of Technology
CQUniversity Australia
ANU The Australian National University
University of Technology Sydney

ABOUT THE AUTHORS

Centre for Social Responsibility in Mining

The Centre for Social Responsibility in Mining (CSRM) is a centre within the Sustainable Minerals Institute, The University of Queensland, Australia. CSRM works with companies, communities and governments to respond to the socio-economic and political challenges brought about by resource extraction. The Centre's aim is to help build the capacity of these stakeholders to manage change in more effective ways. CSRM has global reach, with particular experience in Australia and the Asia-Pacific. For more information visit our website at:

http:// www.csrm.uq.edu.au.

For more information: Ms Karen McNab, k.mcnab1@uq.edu.au

Research team:

Mineral Futures Cluster Leader: Professor David Brereton

Technology Futures Project Leader: Dr Daniel Franks

Researchers: Ms Karen McNab, Ms Barbara Onate, Ms Tamar Cohen, Mr Rodger Barnes & Ms Magaly Garcia-Vasquez

Minerals Industry Safety and Health Centre

The Minerals Industry Safety and Health Centre (MISHC) is a centre within the Sustainable Minerals Institute, The University of Queensland, Australia. Through its collaboration with industry partners, MISHC has developed resources that assist with the management of minerals industry safety and health risks.

MISHC is internationally recognised as a world-class centre of excellence and a leading provider of Minerals Industry Risk Management research and education for the global Minerals Industry.

For more information, visit the website at:

http://www.mishc.uq.edu.au

Researchers: Associate Professor Tim Horberry, Ms Danellie Lynas

CITATION

Cite this report as:

McNab, K., Onate, B., Brereton, D., Horberry, T., Lynas, D. and Franks, D.M. 2013. Exploring the social dimensions of autonomous and remote operation mining: Applying Social Licence in Design. Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by the Centre for Social Responsibility in Mining and the Minerals Industry Safety and Health Centre, Sustainable Minerals Institute, The University of Queensland, Brisbane.

ISBN: **978-1-922173-69-0**

ACKNOWLEDGEMENT

This research was undertaken as part of the Mineral Futures Collaboration Cluster, a collaborative program between the Australian CSIRO (Commonwealth Scientific Industrial Research Organisation); The University of Queensland; The University of Technology, Sydney; Curtin University of Technology; Central Queensland University; and The Australian National University. The authors gratefully acknowledge the contribution of each partner and the CSIRO Flagship Collaboration Fund. The Mineral Futures Collaboration Cluster is a part of the Minerals Down Under National Research Flagship. Special thanks are extended to Anna Littleboy and Kieren Moffat from CSIRO for their support for the project and to our collaborators at Pracsys, Michael Chappell and Tessa Jack.

CONTENTS

FIGURES

TABLES

TEXT BOXES

EXECUTIVE SUMMARY

This report summarises the findings of a three-year study investigating the social dimensions of autonomous and remote operations technologies in the Australian mining sector.

Project rationale

These new technologies offer the potential for lower labour and operating costs, improved operational efficiency and a safer, more attractive working environment – all contributing to a more competitive mining industry.

While the broader economic benefits of these technologies could be substantial, there may also be some undesired social impacts associated with the large-scale uptake of autonomous and remote operation technologies.

Responsible mining companies cannot afford to ignore such impacts, especially in light of the strong public commitments they have made around supporting sustainable development and, in an Australian context, to promoting Aboriginal training, employment and business development.

Commonwealth and state governments also have a strong interest in ensuring that the social aspects of this technological change are properly managed in order to fulfil their responsibilities for reducing Aboriginal disadvantage, promoting regional development and providing education and training.

To date, however, the focus of research and planning around remote operation and automation has been on getting the technology right, rather than on the social dimensions.

Project objectives

This three-year project aimed to:

- investigate the social dimensions of autonomous and remote operation technologies in Australian mining
- understand the change in employment arrangements associated with these technologies and identify the effects this could have on different demographic groups such as women, Aboriginal people and on mining communities
- generate a broader discussion about these technologies involving a wide range of stakeholders and considering issues beyond technical capability and productivity advancements
- inform decisions about the further development and application of autonomous and remote operation technologies with the intention of capturing benefits and mitigating potential negative impacts
- assist stakeholders such as education providers, technical service providers, governments, resource communities and traditional owners to prepare for the transition to autonomous and remote operation mining
- help resource companies understand the implications of these technologies for their Social Licence to Operate (SLO).

Project context

This research forms part of a larger body of work focused on developing an applied Constructive Technology Assessment (CTA) framework, *Social Licence in Design*, to aid the early identification of social and environmental implications of new technologies and provide guidance on strategies for mitigating adverse impacts and maximising societal benefit.

The project was part of the Technology Futures stream of the Mineral Futures Collaboration Cluster - a collaborative research program between the Australian CSIRO (Commonwealth Scientific Industrial Research Organisation) and five Australian universities.

This research was conducted by the Centre for Social Responsibility in Mining (CSRM) and the Mining Industry Safety and Health Centre (MISHC) at the Sustainable Minerals Institute at The University of Queensland.

Research findings

New technologies under development will change future mining workforce requirements and the way mine workforces are managed.

- While large-scale automation may lead to reduced growth in mining employment, it is unlikely to result in a net reduction in mining jobs, given current growth trajectories
- Some operations roles, such as driving trucks and trains and manually operating drilling rigs and underground equipment, are likely to disappear over the longer term. In an open pit mine, in-pit roles could be reduced by around one-half. New roles in equipment maintenance, data processing, systems and process analysis, operational control and mine planning are likely to emerge.
- These new roles require different competencies, such as knowledge and skills in mathematics and science, and an aptitude for using information technology.
- Designing an effective human interface may help capture the benefits and address some of the risks of these technologies.
- Automation is expected to improve the safety of mining work. These benefits and how any safety risks are being managed need to be more clearly communicated to stakeholders.
- Workforce acceptance of these new technologies will be important to their successful implementation as people will continue to be part of the mining process
- An increasing number of mining jobs are likely to be concentrated in capital cities.
- The urbanisation of the mining workforce, reduced reliance on long-distance commuting, more flexible shifts, the less physical nature of mining work and a more professional workplace culture, may help to increase workforce participation of women and older workers.

The shift to autonomous and remote operation technologies could disadvantage existing mining regions and communities.

- With fewer on site roles, there are likely to be fewer mine-related jobs in regional areas (both residential and commuter workforces), which is likely to reduce town populations, economic activity in the local and regional area and population-driven social services.

- In the short to medium term, the projected growth of the sector (including in construction activity) may mask any impacts on local and regional economic activity. Conversely, this change could be magnified in a low growth scenario.
- There may be new opportunities for locally-based businesses in the installation and maintenance of autonomous and remote operation equipment. However, many local businesses are unlikely to have the capital and specialist expertise required to take advantage of these opportunities.

Autonomous and remote operation technologies are likely to have a disproportionate impact on Aboriginal Australians.

- In some parts of Australia, employment and business development opportunities in the mining sector have become important sources of regular income and opportunity for Aboriginal people. Increasingly, land use agreements between mining companies and traditional owners include provisions that require the company to provide employment and training opportunities for traditional owners and other Aboriginal people.
- More than half of the Aboriginal mining workforce is currently employed in manual and semi-skilled roles such as truck driving. As indicated, many of these 'entry level' positions are likely to disappear with the roll-out of autonomous and remote operation technologies.
- Aboriginal workers currently employed in these roles may find it difficult to transition to the new jobs that will be created, because they lack the necessary education levels and skill sets. A further barrier is that many of the new jobs are likely to be located in large urban centres, rather than the regions where most Aboriginal employees live.

Recommended actions

A key conclusion of the study is that a more strategic approach is required to develop and roll-out autonomous and remote operation technologies in Australian mining. In particular, it is very important that potential social impacts – and opportunities – are not overlooked in 'the rush to innovate'.

This is not about slowing the pace of technological change; experience has shown that such attempts rarely, if ever, succeed. The challenge, rather, is to ensure that the benefits of innovation are broadly distributed and adverse consequences are minimised.

Preparing for a new workforce

- As a first step, the Commonwealth Government could convene a roundtable of senior industry personnel involved in technology development and workforce planning, representatives of the VET sector and key state government agencies, to exchange non-commercially sensitive information about future workforce requirements in the sector and identify support available from the VET sector. The Minerals Council of Australia could be invited to partner in organising the roundtable.
- The Commonwealth, in conjunction with state governments, could also resource a strategic impact assessment to map and, where practical, quantify the potential impacts of technology-induced workforce changes at the regional level.

- A protocol could be established whereby sensitive information is shared with a trusted third party (e.g. a government agency, CSIRO or a university-based research institute) that is responsible for pooling data to provide an overall picture of likely trends in the sector.

Capturing the safety and efficiency benefits of automation

- Technology developers and mining companies should incorporate an operator-centred approach to the development and deployment of automation technologies. This approach engages the workforce in technology development and helps optimise the operator-equipment interface to achieve effective automation and ensure the technology is safe, usable and acceptable to operators.

Managing the potential change for regions

Actions that companies could take to mitigate these potential adverse impacts on regions include to:

- work with impacted communities to help them diversify their economic and employment base (where this is a practical option)
- engage with education and training providers to build capability for local people to participate in the new mining workforce
- explore other ways in which mining projects might deliver a 'development dividend' for local communities (for example, by funding scholarship schemes, or supporting human capital development in other industries).

Industry and the Commonwealth and state governments could also jointly investigate whether there is scope to locate some remote operation and control facilities in larger centres in or near mining regions, rather than solely in capital cities.

Enhancing the opportunities for Aboriginal people and communities

Steps that companies could take to lessen the impact of changes to the opportunities available for Aboriginal people include to:

- enhance the skills and employability of existing Aboriginal employees through training and work-readiness programs, to increase internal and external mobility
- work with education and training providers to develop culturally appropriate aptitude tests to identify Aboriginal people suited to working in new on-site roles
- explore the potential for enhancing Aboriginal participation in the automated mining workforce through focussing on the needs of Aboriginal people in a human-centred approach to technology development and deployment
- collaborate with government, and other local industries (e.g. retailing, transport, hospitality) to expand the range of non-mining employment opportunities for Aboriginal people
- support schools in Aboriginal communities to build student capability in information technology, complementing existing programs and as a longer term community development strategy

- consider commitments to enhance employability in general, rather than just focusing on providing mining - related jobs and training, in negotiating future land use agreements with traditional owners.

Implications for Social Licence to Operate

The social dimensions of automation identified through this research that are likely to have implications for SLO are the potential changes in:

- the structure of the mining workforce and workforce management practices
- workplace and public health and safety
- mining-related regional development opportunities
- Aboriginal employment and community relations.

Ultimately, the way in which the social dimensions of increasing automation will influence SLO depends on how each change is experienced by different stakeholders in particular mining contexts. It will also depend on how these change processes are managed by mining companies and government. There may also be scope to reconfigure technologies in a way that minimises social risk and enhances social benefits, in turn reducing threats to or strengthening SLO.

1. INTRODUCTION

This report summarises the findings of a three-year study investigating the social dimensions of autonomous and remote operation technologies in Australian mining. The Centre for Social Responsibility in Mining (CSRM) and the Mining Industry Safety and Health Centre (MISHC) at the Sustainable Minerals Institute (SMI) at The University of Queensland conducted this research as part of the Mineral Futures Collaboration Cluster.

1.1. PROJECT CONTEXT

The Mineral Futures Collaboration Cluster is a collaborative research program between the Australian CSIRO (Commonwealth Scientific Industrial Research Organisation) and five Australian universities, which aims to address the future sustainability issues of the Australian minerals industry. [1] This program is part of the Minerals Down Under National Research Flagship (MDU).

MDU is a three-year, $240 million program aimed at ensuring the medium to long term sustainability of the Australian minerals industry through the development of transformative exploration, extraction and processing technologies. 'Intelligent mining' and remote operation are a significant focus of the MDU Flagship.

This project was part of a stream of research that aimed to develop Technology Assessment (TA) tools and methods that can be used to help reduce the social and business risks and improve the sustainability of new technologies developed within the MDU Flagship (Franks et al. 2010). A key output of this work was an applied Constructive Technology Assessment (CTA) framework, *Social Licence in Design*, as outlined in Franks and Cohen (2011) (see Section 1.4). Findings concerning the *Social Licence in Design* framework are reported in Franks *et al* (2013), along with case studies of its application to the use of biomass in iron ore smelting (Weldegiorgis and Franks, 2012) and in-situ leaching.[2]

In this study we extend the application of the *Social Licence in Design* framework by beyond the research and development context to focus on technologies that are already in the process of being rolled out. These technologies are being developed by a range of actors including equipment manufacturers, mining companies, university-based researchers and researchers associated with CSIRO's MDU Flagship.

1.2. RESEARCH OBJECTIVES

This project sought to:

- investigate the social dimensions of autonomous and remote operation technologies in Australian mining
- understand the change in employment arrangements associated with these technologies and identify the effects this could have on different demographic groups such as women, Aboriginal people and on mining communities

[1] The five universities participating in the Mineral Futures Collaboration Cluster were: The University of Queensland; The University of Technology; Curtin University of Technology; Central Queensland University; and The Australian National University.

[2] CSIRO is also separately developing an integrated research framework to bring together the technical and social sciences to assess the combined environmental and social impacts of mining technologies (Lacey and Moffat, 2012).

- generate a broader discussion about these technologies involving a wide range of stakeholders and considering issues beyond technical capability and productivity advancements
- inform decisions about the further development and application of autonomous and remote operation technologies with the intention of capturing benefits and mitigating potential negative impacts
- assist stakeholders such as education providers, technical service providers, governments, resource communities and traditional owners to prepare for the transition to autonomous and remote operation mining
- help resource companies understand the implications of these technologies for their Social Licence to Operate (SLO) (addressed in Section 1.3).

1.3. PROJECT RATIONALE

Autonomous and remote operation technologies allow for the replacement of human involvement – to varying degrees - in some aspects of the mining process, with the potential to deliver major gains in productivity through improved efficiency and integration. These gains could help maintain the competitiveness of Australian mining in the face of several challenges such as: declining ore grades; increasingly remote reserves; a high Australian dollar; and a labour shortage.

Current technology designs include fully autonomous haul trucks and centralised control centres in capital cities, far removed from where mining is conducted. Other technological advances under development include remote control blast-hole drills, tele-remote rock breakers, driverless ore trains, and tele-remote ship loaders.

In addition to the broader potential economic benefits of these technologies, there is also likely to be a range of social impacts both beneficial and otherwise. These impacts could stem from changes in the type and location of mining-related employment and development opportunities, and could be significant for women and Aboriginal Australians.

Resource companies and governments alike have a strong interest in understanding and managing the potential social impacts of this technological change.

- Responsible mining companies cannot afford to ignore the potential social impacts, especially in light of the strong public commitments they have made around supporting sustainable development at the local and regional level.[3]
- A growing number of mining companies have obligations under land use agreements that will need to be met into the future. These obligations increasingly involve commitments to promote Aboriginal training, employment and business development, the nature of which may change with greater automation.
- Commonwealth and state governments have a strong interest in reducing Aboriginal disadvantage and promoting sustainable regional development, as bi-partisan priorities.
- As a provider of education and training, governments have an important role to play in helping to equip current and future workforces to access the new employment opportunities that may be created.

[3] For example, signatories to the Sustainable Development Framework of the International Council on Mining and Metals (ICMM) have agreed to *contribute to the social, economic and institutional development of the communities in which we operate* (Principle 9). Member companies of the Minerals Council of Australia (MCA) have made a similar commitment.

For mining companies, how these technological changes and the associated social impacts are managed could also have implications for their SLO (Franks and Cohen 2011). This concept refers to an intangible and unwritten, tacit, social contract with society, or a social group, which enables an extraction or processing operation to enter a community, start, and continue operations (Thomson and Boutilier, 2011). It represents an acknowledgment that compliance with statutory regulations is often insufficient to meet societal expectations (Bridge, 2004). Relationships with all stakeholder groups can contribute to strengthening or weakening a company's SLO. Stakeholders' perceptions of, involvement in and experience of this technological change will be critical to their ongoing relationship with industry.

Two years ago, there was little public attention being given to the social aspects of these new technologies. Public discussion was predominantly the domain of technologists and focussed on emerging technical advances. More recently, a broader range of stakeholders have engaged in the topic, including education and training providers, the mining workforce (through the Construction, Forestry, Mining and Energy Union - CFMEU), economists, investment banks and commentators in the mainstream media (ABC, 2012; Mining IQ, 2012). Some within industry have now also publicly acknowledged the social dimensions of this technological change. In December 2012, at the Mining Magazine Industry Leaders' Roundtable (The future of mining), GE Global Mining Chief Executive Officer, Geoff Knox said:

> "*There is a social issue behind all this (automation)…These companies need to maintain their social licence to operate, and that involves employing people in regions that need the employment*" (Lovejoy, 2012).

This project contributes to broadening the discussion to include consideration of the social dimensions and the perspectives of a broader range of stakeholders, through the application of *Social Licence in Design* (see Section 1.4).

1.4. OUR APPROACH

The *Social Licence in Design* framework developed by Franks and Cohen (2011) informed our approach to this research.

Social Licence in Design brings together the concepts of SLO and CTA to incorporate the consideration of social performance issues in technology development (Franks and Cohen, 2011). It is a process ideally facilitated by technically literate social scientists. For the purpose of this research, CTA is a type of Technology Assessment that seeks to influence the technology design process by factoring in stakeholder values and perspectives through a dialogue with technology developers and broader stakeholders, as appropriate for the stage of technology development (see Franks and Cohen, 2011).

Social Licence in Design recognises that new technologies can bring about significant social changes in domains such as: personal and public health and safety; work practices; the knowledge and skills required for work; working conditions; the type, number and location of jobs; workplace culture; and the economic returns to communities. These changes can trigger adverse social impacts and governmental and community responses which may constrain uptake of the technology and increase implementation costs. Lacey and Moffat (2012) also acknowledge the importance of societal acceptance of technologies in the mining and minerals industry.

A key assumption of *Social Licence in Design* is that the social acceptability of new technologies can be enhanced by factoring in the perspectives and values of potential stakeholders and decision makers at the design and roll-out stages. Depending on the circumstances, this may involve reconfiguring the technology itself, implementing mitigation measures to deal with unwanted impacts, or some combination of the two (Franks and Cohen, 2012).

The technologies which are the focus of this study are at an advanced stage of development and, to varying degrees, are already under trial and in operation across several Australian mine sites. Nonetheless, the *Social Licence in Design* process is still valuable because development of these technologies is continuing. Configuring these technologies for individual mine sites is an involved process that needs to account for the different socio-political contexts, workforce management and legislative arrangements into which these innovations will be embedded; *Social Licence in Design* can help to inform this process.

Several actors are involved in the development of these technologies, including research and development organisations and mining equipment and mining companies. These groups have been understandably cautious, for reasons of commercial sensitivity and uncertainty, about sharing information about these technologies and their plans for their further development and implementation. *Social Licence in Design* provides a process that that can be used to facilitate a discussion among a broader array of stakeholders.

This work constitutes a critical first step in enabling a more informed public dialogue about the social implications of autonomous and remote operation technologies. Due to the limited involvement of industry and technology developers at this stage, and in keeping with the nature of *Social Licence in Design* as an ongoing and iterative process, more detailed assessments would be required to develop a more granular understanding of the potential social impacts of automation in particular mining contexts.

1.5. SCOPE OF THE RESEARCH

This work focuses on autonomous and remote operation technologies in surface mining of bulk commodities, in particular - iron ore. This form of mining (including coal) accounts for the majority of mining employment in Australia (based on 2010 projections). It also represents one of the major areas for potential growth in the uptake of autonomous and remote operations technologies (Skills Info, 2012).

The Pilbara region (Western Australia) is used as an exemplary case study throughout the research. This is because of the significant development in automation and the importance of mining employment for Aboriginal communities in this region.

Throughout the study, examples have also been drawn from underground mining as well as other regional and country contexts. These examples serve a comparative purpose and aid our understanding of the application of these technologies in other industrial and mining contexts.

This study considers autonomous and remote operation technologies from a systems perspective, rather than as individual technologies. Together, these technologies are driving sophisticated integration of mining systems and major efficiencies in production, with the potential to fundamentally change the mining process.

These technologies also have a similar, and compounding, influence on the mine workforce and the communities in which mines operate. Together, these technological trends create new activities in the workplace, require higher order skills, remove particular roles (absolutely or from a particular location) and create new ones, potentially generating significant change in the mining workforce.

The design and findings of this research have been limited by a lack of access to industry personnel and data as well as to mine sites and remote operations centres employing autonomous and remote operation technologies. However, this project helps demonstrate the potential value of *Social Licence in Design* and scope the potential social dimensions of increasing automation in Australian mining. It also provides recommendations for the management of potential impacts and discusses the implications for mining companies' Social Licence to Operate.

1.6. OUTLINE OF THIS REPORT

This report summarises the key outcomes of this research and is structured according to the following sections:

- Section 1: Introduction
- Section 2: Methodology
- Section 3: Autonomous and remote operation technologies in Australian mining
- Section 4: Research findings
- Section 5: Recommendations
- Section 6: Implications for Social Licence to Operate.

BOX 1: OTHER RELEVANT REPORTS

The research conducted throughout this project is documented in several interim papers and reports. These documents provide more detailed background to the findings outlined in this report:

- Economic impact of automated mining operations (Jack and Chappell, 2013)
- Autonomous and remote operations technologies in Australian mining: harnessing the societal benefits for Australia – Roundtable report (McNab, 2013)
- Autonomous and remote operation technologies in Australian mining (McNab and Garcia-Vasquez, 2011)
- Automation Design, Skills, Capabilities and Training: Development of a Human Factors Framework (Horberry and Lynas, 2012a)
- Tracking Emerging Technologies: An Automated Mining Equipment Database (Lynas and Horberry, 2012)
- Literature review: emerging human factors trends regarding automated mining equipment (Lynas and Horberry, 2011a)
- Interview results: emerging trends on the human factors issues regarding automated mining equipment (Lynas and Horberry, 2011b).

2. METHODOLOGY

The *Social Licence in Design* framework (see Figure 1) is designed to be informed by a range of research methodologies, as appropriate to the technology under consideration (Franks and Cohen, 2012).

The individual research activities undertaken for the study are outlined in Sections 2.1 to 2.6 below. Each activity was supported by desktop research and attendance at specialist conferences over a period of three years.

This research also incorporated a human factors approach to consider how autonomous and remote operation technologies can be designed to optimise the human interface, to aid the abatement of negative impacts and enhance opportunities relating to human capital and workforce participation.

What type of assessment?	What is the technology?	Where will it be implemented?	Who will it affect?	How will it affect them?	What is the magnitude?	What can be done?
Scope technology assessment • Resources • Degree of reflexivity • Stage of technology development • Level of assessment • Desire for public involvement	**Scope technology design characteristics** • Drivers and constraints • Options/ alternatives • Current picture of the technology under development	**Scope and profile: anticipated social and geographical context** • Identify the target resource or industrial application and understand the features	**Scope and profile stakeholders** • Determine values, concerns and expectations through methods, such as interviews, focus groups, etc.	**Forecasting risks and opportunities** • Imagine possible and not impossible outcomes • Propose controls (design out, mitigate, enhance, offset, constraints on implementation, risk communication • Identify knowledge gaps and confidence	**What is the magnitude?** • With reference to each stakeholder	**Review controls (management options)** • Design out, mitigate, enhance, offset, constraints on implementation, risk communication

Figure 1: Social Licence in Design – potential issues for consideration during Constructive Technology Assessment (Franks and Cohen, 2012).

2.1. INTERVIEWS

Interviews were conducted with 17 stakeholders including technology developers, mine site and corporate mining personnel, regulators and human factors researchers. The interviews explored: 1) emerging human factors issues with automation technologies; 2) visions for the future of automation; and 3) the potential social impacts of automation.

For more information see Lynas and Horberry (2011b).

2.2. AUTOMATION TECHNOLOGIES DATABASE

A database was established to provide a broad overview of existing and emerging (near market) mining automation technologies.

Sources used to create the database included: personal interviews (see above); attendance at relevant industry and technical conferences; podcasts by leading mining personnel; desktop reviews of relevant articles and mining company publications; original equipment manufacturer product lists and websites; and reviews of mining equipment supplier guides. The database was compiled using only publicly available information and does not include technologies about which information is restricted or that were in the research and development stage at the time the database was created.

For more information, see Lynas and Horberry (2012).

2.3. WORKPLACE OBSERVATIONS

A field trip was undertaken to a pilot remote control centre in Australia to:

- understand the scope of work involved in the development of the remote control centre
- discuss a draft human factors assessment process
- observe the operational and maintenance tasks being automated
- observe the pilot control centre and review human-machine interfaces, skills requirements and communication procedures
- discuss the pros and cons of automated equipment with operators (Horberry *et al*, 2011b).

2.4. MULTI-STAKEHOLDER ROUNDTABLE

A multi-stakeholder roundtable, titled *Autonomous and remote operation technologies: harnessing the societal benefits for Australia* was held in in Sydney on 24 November 2011. The objectives of the roundtable were to:

- promote dialogue about autonomous and remote operations technologies in Australian mining and their potential social impacts across multiple stakeholders
- identify potential social change processes and concrete actions to maximise the overall social benefit of these new technologies
- inform the development of a briefing paper targeted at state and federal governments and industry.

The roundtable brought together 23 invited participants from across government, industry and the research community, including social scientists, education and training specialists, community, regional development and sustainability professionals and automation experts.

The roundtable involved a series of scene-setting presentations, each followed by group discussion and two working group sessions.

In the first working group session, participants discussed four scenarios that varied in terms of the potential rate of technology uptake and the regional or urban development context (see below). In the second working group session, participants discussed how the potential social change that had been identified could be managed to avoid negative and enhance positive impacts on:

- regional and remote mining communities
- Indigenous participation in the mining sector
- the mining workforce
- human capital requirements (education and training).

For further information, see McNab (2013).

2.5. SCENARIOS

Considering multiple alternative futures (or scenarios) is recommended for informing decision making in a way that acknowledges the uncertainty of a long-range future (10+ years) (Duinker and Greig, 2006). For this project, four scenarios were developed to describe different possibilities for the future of Australian mining: *Brave new mine*; *Smart regions*; *Regions adapt*; and *Urban drift*.

Each scenario represented a different combination of the rate of technology uptake (transformational or incremental) and the focus of development (regional or urban). A description of the four scenarios is provided in Table 1.

The scenarios were developed by the project team with roundtable participants providing feedback. The scenarios were used to help generate discussion at the roundtable and to inform the economic impact assessment (see Section 2.6).

At the roundtable, each working group was asked to consider four questions in relation to the scenarios:

- How plausible are the different possible futures?
- Are there other factors that should be included (in mapping out possible futures)?
- What should we be working towards? Is there a desired future or a combination of desirable aspects across the different possibilities?
- What should we be trying to avoid?

2.6. ECONOMIC IMPACT ASSESSMENT

A predictive impact model was developed by Pracsys to assess the direct and indirect employment, economic and social effects of haul truck automation at an exemplar open-cut, iron ore mine in the Pilbara.[4] Assessing these effects on ‘Town A’ and ‘Town B’ in the Pilbara was used to demonstrate some of the social and economic impacts of automation and remote operation on the structure of the mining workforce and on mining communities.

For further information, see Jack and Chappell (2013).

[4] Pracsys attempted to profile the employment figures and workforce structure for all operational open-cut iron ore mines in the Pilbara, Western Australia. Due to the difficulties faced with collecting this data, workforce data for an exemplar mine site provided by the CSRM was used instead.

Table 1: Description of some possible futures for automation in Australian mining

Brave new mine	*In this scenario, autonomous mining is the dominant mode of operation across different commodities and mining regions, with operations centres and mining jobs based in capital cities.* • Australia becomes a global leader in the development, deployment and servicing of autonomous and remote operation technologies globally. • Mining drives broader technology development in Australia delivering national productivity and development benefits. • Capital cities are the main beneficiaries of this growth. • There is economic contraction in the mining regions, due to the loss of on-site jobs.
Smart regions	*In this scenario, autonomous mining is the dominant mode of operation, but with operation centres and support facilities mainly based in mining regions, rather than capital cities.* • Automation drives wider economic diversification and growth in regional economies. • New regional businesses are created to service the industry. • A more diverse, skilled workforce develops in the regions. • Fly-in fly-out (FIFO) camps become a thing of the past.
Regions adapt	*In this scenario, investment appetite, IT capability and the socio-political context limit the uptake of autonomous and remote operations technologies. To the extent that there is take-up of these technologies, regions share in the benefits.* • Most companies remain hesitant about investing in these new technologies. • Where innovation does occur, it is mostly restricted to new mines, with little retro-fitting. • Local governments, with State government support, encourage mining companies to increase their regional presence. • Where companies do introduce new technology, they opt to locate control centres and support functions in the regions. • Some new business opportunities are created and regional businesses move quickly to capitalise on them.
Urban drift	*In this scenario, there is again a limited uptake of the autonomous and remote operations technologies. To the extent that there is take-up of these technologies, it is mainly the capital cities that benefit.* • Companies that decide to implement these technologies opt to locate control centres and support functions in capital cities. • Companies also opt to make more use of FIFO. • There is a gradual reduction in employment opportunities in regions, especially for entry-level and semi-skilled roles. • Regional towns experience gradual population decline and reduced economic activity.

NB. Macro-economic and environmental factors such as ore grades, market growth and commodity prices were considered consistent across all scenarios.

3. AUTONOMOUS AND REMOTE OPERATION TECHNOLOGIES IN AUSTRALIAN MINING

Automation is already changing the nature of mining in Australia. Autonomous and remote operation technologies are in use or being trialled at some Australian mine sites and are planned for use at others (see Box 2). The implementation of autonomous haul trucks and locating centralised remote operations centres in capital cities, far removed from the mining activity, has been one notable development in recent years.

What is automation?

Automation involves the full or partial replacement of humans in the work process (Parasuraman et al, 2000; Thorogood et al, 2009) with the main objective being to control dynamic systems and increase accuracy, thereby improving productivity (Parreira *et al*, 2009). Such gains, as well as quality improvements, have been made across a range of industries such as aviation, manufacturing, food and beverage production, water and waste management, power generation and in the petrochemical, pharmaceutical and metals and mining sectors.

Different levels of automation involve varying degrees of human involvement in the automated process, ranging from humans initiating the process to functions that cannot be overridden by humans (Parasuraman, 1997 in Lynas and Horberry, 2011a).

Automation in the mining industry

Automation has been increasingly used in the mining sector over the past 50 years to enhance efficiency, remove operators from hazardous environments and to improve the accuracy and reliability of data collection and processing (Lever and McAree, 2003).

Driverless technologies were first used throughout Europe and the United States in the 1960s and 1970s (Konyukh, 2002 in Lynas and Horberry, 2011a), including driverless underground trains, which have been in use at Swedish miner LKAB's Kiruna iron ore mine in Sweden since the 1970s (Spooner, 2012). Autonomous underwater vehicles also operate routinely in deep-sea oil and gas operations for routine monitoring and maintenance tasks (Glance, 2012).

Together, remote operation and tele-operation enable operators to be removed from dangerous environments as well as bringing together normally disparate control systems and placing personnel working with those systems in close proximity to one another, enhancing the integration of information.

It is these integrated autonomous systems involving autonomous haul trucks and other autonomous technologies, with remote operations centres based thousands of kilometres away from mine sites that represent a step change in technology that is expected to transform the mining process and mining workforce.

The drivers of automation in mining

These new technologies are promoted as offering lower labour and operating costs, improving operational efficiency and contributing to a safer working environment – all aimed at providing a sustained competitiveness of the Australian mining industry.

These improvements are important at a time when the quality of ore bodies is declining and mines are becoming more remote, deeper and more dangerous. These technologies also help address a labour shortage and the increasing cost of labour in Australia.

Investment bank Goldman Sachs sees that the degrees of automation may influence future investment decisions. UBS estimates that Rio Tinto Iron Ore could “save $72 million a year, reduce its workforce by 600 and reduce its costs per tonne of iron ore by US30 cents”, if 50 per cent of its trucks were automated (Ker, 2012).

In terms of driverless vehicles, it is claimed that removing the variability of human performance increases the efficiency of machine utilisation through reduced idling and consistent driving speeds improving fuel efficiency (Ashley, 1995; Bennick, 2008 and Murphy, 2011). Additionally machine utilisation may be maximised as there is less down-time associated with breaks and shift changes (Bellamy and Pravica, 2011).

The costs associated with physical damage resulting from human error, such as collisions and tyre wear, are also reduced (Ashley, 1995; Caterpillar, 2011; Kral, 2008). Other productivity gains arise from being able to reduce the distance allowed between operating vehicles (Bellamy and Pravica, 2011) and reduced maintenance (Kral, 2008).

Mining automation in Australia today

The extent to which these technologies are being used in Australia varies considerably across mine sites – from minimal (e.g. machinery operated remotely from the surface), to partial (e.g. wash plant maintained by a central control room) to fully autonomous or integrated operations (e.g. trucks, diggers and rail fleets operated autonomously from a remote location off site).

To date, most automation in Australia is currently concentrated on the component or subsystem level providing semi-autonomous operation, and is on a small scale relative to the number of mines, processing plants and export facilities in Australia (Lynas and Horberry, 2011a). Much of the current automation focus is on surface mining operations (Horberry and Lynas, 2012b), and in particular iron ore mines.

BOX 2: EXAMPLES OF AUTONOMOUS AND REMOTE OPERATION IN AUSTRALIAN MINING

- **Rio Tinto's** Mine of the Future™ program was launched in 2008 and includes an ambitious program to fully automate its iron ore operations including remote control blast hole drills, tele-remote controlled rock breakers, driverless haul trucks, driverless trains to carry ore to port, tele-remote controlled ship loaders and integrating the operations of 14 mine sites and two ports as an integrated single large scale processing system (Rio Tinto, 2011a). This technology is critical for supporting RTIO's projected increase in production in the Pilbara of achieving up to 320 Mtpa in the coming years (Cribb, 2008).

  In November 2011, Rio Tinto announced that it would increase the size of its autonomous haul truck fleet to 150 trucks (40% of its fleet) by 2015 (Rio Tinto, 2011d; O'Brien, 2011), including deployment at its Yandicoogina (Junction South East pit) and Nammuldi mines (Rio Tinto, 2012d). This announcement followed the successful, two-year trial at the West Angelas mine where greater efficiency was achieved (Mining Weekly, 2012) and autonomous trucks have moved out of trial into production.

  In 2012, Rio Tinto announced that it would install 41 autonomous trains in the Pilbara. The trains are driverless and are completely operated by software, not even requiring remote operators (Glance, 2012) and are scheduled to be finished in 2014 (Rio Tinto, 2012a).

  Rio Tinto's Operations Centre in Perth involves approximately 450 staff (Chambers, 2012), including controllers, schedulers and technical planning and support staff (Rio Tinto, 2010). From this control room, mining, rail transport, ship loading and critical infrastructure for all of Rio Tinto's iron ore projects in the Pilbara will be controlled, as well as a semi-autonomous tunnelling system in northern New South Wales (ABC, 2012; Science WA, 2012; Rio Tinto, 2012b).

- **Newcrest's** Cadia Valley operations in Orange, New South Wales (NSW) involve both open cut and underground mining of several extremely large but relatively low grade gold and copper ore bodies. Newcrest is establishing a tele-remote control centre, in which up to 300 people could work or train, in the town of Orange - a regional centre in NSW 25 kilometres (km) from the operation and 250km from Sydney (Shields, 2010). The remote operations centre will be capable of controlling and/or monitoring more than one site in Australia, including the Telfer open pit and underground operations in Western Australia, and possibly sites overseas.

- **BHP Billiton** set up its own remote operations centre at its Perth head office in 2012, with a team of 340 people and from late 2013, 12 to 15 automated Caterpillar trucks will operate at its Jimblebar mine (Chambers, 2012). BHP Billiton plans to establish similar facilities for its coal operations in Queensland and at its Escondida copper mine in Chile (Chambers, 2012). BHP Billiton had announced intentions to implement autonomous haul trucks, blast hole drills and remote control shovels in association with its Olympic Dam expansion project prior to this project being put on hold (BHP Billiton, 2011). Beyond the Pilbara, BHP Billiton is also looking at technologies to remove trucks from mines by using in-pit conveyers, crushers and other technologies.

- **Newmont** is engaged in a staged program of automation at Boddington, Western Australia (approximately 130km south east of Perth). Boddington is a large, long life, low grade, open cut gold mine with an operating life of 24 years.

- **Fortescue Metals Group** signed a Memorandum of Understanding with Caterpillar and WesTrac in July 2011 to implement autonomous vehicles at its Solomon iron ore mine in Western Australia. Caterpillar and WesTrac will provide product and technology implementation, consulting and change management services, technicians and support personnel, as well as operate the complete autonomous system once it is implemented. An initial fleet of 12 autonomous trucks will be deployed in 2012 and a fleet of 45 is expected by 2015 (Williams, 2011).

The future of automation in mining

Both CSIRO and mining company, Rio Tinto have articulated their vision of a future mine that involves minimal people on site in operational roles (see Box 3). However, there is much uncertainty in the potential rate and extent of uptake of autonomous and remote operation technologies because of the challenges in integrating these technologies with current mining practices (Mining Magazine, 2012).

Over the next ten years, a gradual shift towards automation at the systems level is expected, as the integration of semi-autonomous subsystems eventually leads to fully autonomous operation cycles such as dig, load, haul and dump (Dudley *et al*, 2010). Full automation is unlikely however, with humans always expected to be part of the process in some way (Goddard, 2011).

Autonomous operations are likely to be suited to new mines as it is difficult to retrofit the technology to existing mine sites. For new mines, the compatibility with specific mine sites will also influence the rate of uptake.

Uptake will also depend on the emergence of other new technologies such as biological and chemical mining and shiftable conveyor belts that would remove trucks from the mine altogether.[5]

Ultimately, the uptake of autonomous and remote operation technologies will depend on individual companies' investment decisions (as well as the business case and level of risk for an individual mine), the broader context of global economic conditions and Australia's evolving competitive advantage in the resources sector (Giurco *et al*, 2009).

BOX 3: VISIONS OF THE FUTURE MINE

In its description of the future mine of 2030, CSIRO (2011) envisages that:

> *"...High power laser and plasma drilling is more common than it was in the 2020s. Logging and measuring while drilling are standard, with feedback to intelligent control systems for drill rigs. Semi-autonomous moles are guided with pin-point accuracy and are used to drill multi-lateral bore holes from a parent borehole. Sampling boreholes themselves are now very small in diameter, and down-hole probes measure elemental and mineralogical compositions in real time. Remotely controlled semi-autonomous rigs are able to move around in mines or in the field. Many mines are controlled from major centres. Operations are fully automated, highly selective and host minimal local support staff. Geologically 'intelligent' autonomous mining systems are capable of mining ore selected for grade, and are able to sort ore as it is mined. Deep ore mining systems keep people isolated from the hazardous activities of drilling, explosive placement, access construction and ore haulage..."*

CSIRO, 2011

In 2008, **Rio Tinto** released its own vision for the future mine under its *Mine of the* Future™ program. Rio Tinto envisages the future mine as one where:

> *"...humans will no longer need to be hands on as all this equipment will be autonomous - able to make decisions on what to do based on their environment and interaction with other machines. Operators will oversee the equipment from the remote operation control room."*

Rio Tinto, 2008

[5] Vale is planning to install shiftable conveyor belts to move ore from the mine to the processing plant at its Carajas Serra Sul S11D mine in Brazil. This would create a completely truck-less iron-ore mine (Latimer, C, 2012a).

4. RESEARCH FINDINGS

This section outlines the range of potential social change processes that could arise with the uptake of autonomous and remote operation mining equipment (Section 4.1). The potential change in mining employment - in terms of the number, nature and location of mining jobs - is discussed in more detail in Section 4.2. The potential flow on effects this change in employment could have for regional development are outlined in Section 4.3 and the implications for mining-related Aboriginal employment and economic development are outlined in Section 4.4.

4.1. POTENTIAL SOCIAL CHANGE

Figure 2 identifies the range of social change processes that may arise with the implementation of autonomous and remote operation technologies – where specific functions are fully automated and operator roles are moved off-site to a remote operations centre. Change processes are described in a generic way to allow for uncertainty and, in particular, different mining contexts and automation programs.

The nature and impact of these change processes will depend on the location of a remote operations centre (whether it is in a capital city or a regional centre in a mining region) the nature of the regional economy where mining takes place, existing mine workforce management practices and mine-community relationships.

Social change processes associated with automation are grouped in the following categories: employment, workplace health and safety, knowledge and skills, mining communities, (local) supply chains and government.

For ease of presentation, all change processes are presented at the same ‘order’ or ‘level’ (no hierarchy is applied). However, change processes relating to workplace health and safety, knowledge and skills, mining communities, and governance all largely flow from a change in the nature and location of work. Relationships between flow on change processes are not shown, due to the level of uncertainty and the influence of different mine-community contexts on these processes.

POTENTIAL SOCIAL IMPLICATIONS OF AUTONOMOUS AND REMOTE OPERATION TECHNOLOGIES IN AUSTRALIAN MINING

- **HEALTH AND SAFETY**
  - Reduced on-site risks
    - Reduced human exposure to landslides and geotechnical risks
    - Reduced human exposure to equipment operation e.g. loading
    - Reduced incidents/accidents caused by human fatigue
  - New risks - working with automated vehicles
    - Reduced on-site control
    - Breakdown in communication between site and remote control centre
    - Failure of automatic shut-down/back-up control
  - New risks - working in remote operation centres
    - Skills degradation, automation-induced complacency, over-reliance on automated equipment
    - New sources of stress including information overload, boredom and working long hours in -based work
- **EMPLOYMENT**
  - Change in employment conditions
    - Potential reduction in operator salaries due to lower risk and location of work in remote operations centres (based in capitals)
    - Reduced need for FIFO/DIDO workforces
    - Less physical nature of work
    - Greater flexibility in shift rosters
  - Change in location of work
    - Increase in urban-based roles in remote operations centres
    - Reduction in number of on-site roles per site
  - Change in nature of work
    - Increase in work requiring higher-order skills (mathematics, mechatronics, systems approaches and data management)
    - Reduction of in-pit and operator roles
  - Change in size of workforce
    - Reduction in in-pit and operator roles
  - Change in culture and workplace relations
    - Workforce support for or opposition to automation
    - Transition to a predominantly professional workforce culture, working individually, away from site in information-based roles
    - Workforce response to management of transition to automation
  - Change in workforce participation levels
    - Reduction in roles typically occupied by Aboriginal people
    - Increase in participation of women and older workers (due to change in location, nature, conditions and culture of work)
  - Change in flow on employment opportunities
    - New employment opportunities in automation and remote operations centre support
    - Reduced opportunities in servicing remote mine workforces
- **KNOWLEDGE AND SKILLS**
  - Change in skills base of workforce and service providers
    - Increase in higher-order skills including mathematics, mechatronics, systems approaches and data management
  - Change in education and training needs
    - Emergence of new core competencies and qualifications reflecting the need for higher-order skills
    - Change in curricula and supporting resources at the primary, secondary and tertiary levels and in professional development
- **MINING COMMUNITIES**
  - Change in demographics of mining towns
    - Reduction in mining town population, if fewer economic opportunities associated with mining exist
  - Change in social services
    - Reduction in government funding for social services and infrastructure if population decreases and/or mine workforces are not locally based
    - Potential application of automation and remote operation communications and technical capability to health, education and other services in remote areas
  - Change in focus of mining company social investment and community relations
    - Change in nature of employment commitments under Indigenous Land Use Agreements
    - Redirection of community relations funds to urban areas where workforce and remote operations centres are located
    - Reduction in social investment aimed at enhancing liveability of regional areas for mine workforce
    - Increase in need for social investment to maintain Social Licence to Operate if fewer economic opportunities exist for local communities
- **LOCAL SUPPLY CHAIN**
  - Change in mining goods and services
    - Business opportunities in the development, servicing and maintenance of automated and remote operation equipment
    - Reduced opportunities in servicing on-site mine workforce and traditional mining equipment
  - Change in flow on business opportunities
    - Reduced goods and services required to support mine workforce in remote and regional areas
- **GOVERNMENT**
  - Change in supporting institutions
    - Adaptation of safety regulation to accommodate automation and remote operation and impact assessment regulation in relation to a change in workforce management practices

Figure 2: Possible social change processes arising from autonomous and remote operations

4.2. EMPLOYMENT

The implementation of autonomous and remote operation technologies will change the future workforce requirements of the mining industry and the way in which mining workforces are managed.

The potential change in mining employment can be discussed in relation to the size of the future workforce, the nature of work involved and the location of the mining workforce.

4.2.1. Size of the future mining workforce

Autonomous technologies seem likely to reduce additional jobs created through mining industry growth, rather than leading to a net reduction in mining employment.[6]

Automation will reduce the number of operational employees required for functions targeted for automation such as drilling, blasting, train driving and truck driving. While new roles will be created in the development, observation, servicing and maintenance of autonomous and remotely controlled equipment, other traditional roles will remain (including roles relating to site rehabilitation, road building and other site works). There is little information in the public domain about what these new roles will be and in what numbers they will be required. Therefore it is difficult to understand the true nature of the potential effect of automation on the size of the mining workforce.

Conversations with industry representatives indicate that the introduction of a fully autonomous haul truck fleet would reduce the workforce of a typical open-cut, iron ore mine by approximately 30 to 40 per cent (as a result of a 50 per cent reduction of in-pit roles).[7] However, a reduction in the number of operators may not necessarily reduce the absolute size of the mining workforce, based on projections made in 2010 and 2012. This is particularly the case for operational roles in the metal ore and coal mining sectors.

In 2012, the metal ore and coal mining sectors employed the majority of the Australian mining workforce (SkillsInfo, 2012). Continued growth is projected for these sectors, although the largest increase in jobs in the mining sector over the next five years is expected to occur in oil and gas extraction (SkillsInfo, 2012).

Based on 2010 estimates, an additional 10 400 and 8 900 jobs were required in the metal ore and coal mining sectors by 2014-15 (SkillsInfo, 2010). The majority of this projected employment growth was for machinery operators and drivers (an additional 21,372 by 2015, from 2008) and technicians and tradespeople (an additional 15,080 by 2015, from 2008) (National Resources Sector Taskforce, 2010).

In 2011, the Western Australian resources sector overall was predicted to be short 36,000 tradespeople, particularly electricians, by 2015 (Australian Government, 2010).While employment growth projections in the Pilbara have been lowered, this is largely because of a ramping down of construction workers. In the Pilbara, an additional 13,600 operational staff are still expected to be required by 2018 (Chamber of Mines and Energy of Western Australia - CMEWA, 2012).

---

[6] This is based on projections for the Australian mining sector made at a time when high levels of future growth were predicted.

[7] A reduction of operator roles by 50 per cent following the introduction of autonomous trucks is also supported by BHP Billiton executive Marcus Randolph in the mining media (Latimer, 2012b). However at Northparkes, not one job is reported to have been lost to autonomous equipment (Duffy, 2012d).

New jobs may also emerge in the Australian mining and technology services and equipment sector. BAEconomics claim this sector already has a dominant presence in the global market for supply and development of technology goods and services in the minerals industry, with the labour force in this sector doubling from 17,300 in 2000-01 to 31,300 in 2008-09 (Fisher and Schnittger, 2012). However, there is no guarantee the new jobs emerging in technology goods and services will be based in Australia, if Australia does not foster growth and excellence in this sector. In 2012, Rio Tinto launched a partnership with iGATE Patni in Pune, India, opening the Rio Tinto Innovation Centre which will support growth and development of its Mine of the Future™ program (Rio Tinto, 2012c).

The modelling conducted for this project estimates that the introduction of autonomous haul trucks at a typical open-cut iron-ore mine could result in direct employment loss of 113 to 226 jobs (in Town A) and 68 to 136 jobs (in Town B), depending on the extent to which automation is implemented and whether remote operations centres are located in Perth or a regional centre (Jack and Chappell, 2013).

4.2.2. The changing nature of mining employment

The nature of work in the mining sector will change with the introduction of autonomous and remote operation technologies, particularly for the current pool of operators. New roles in equipment maintenance, data processing, systems and process analysis, operational control and mine planning are likely to emerge with more operational roles being undertaken from consoles in remote operations centres. These new roles are likely to require higher-order skills and different competencies, including mathematics and science and an aptitude for using information technology. Demand for professionals such as technicians, mechatronics and communications engineers is also likely to increase.

Industry and other stakeholders such as technology developers and education and training providers are aware of the likely need for these skills generally. However, the full profile of an automated mine workforce is not yet available in the public domain. Although the role of the 'Automation Technician' has been scoped by MISC and the training requirements identified for this role (Dudley et al, 2010), other roles on site and in remote control centres need to be defined to identify the full suite of skills and comprehensive education and training requirements.

There has been some progress in the development of education programs to support automation. Schneider Electric has formed six partnerships with tertiary education institutions in Australia, aiming to address knowledge gaps in mining, oil and gas, including the skills required for mining and process automation (Gomez, 2012). However, education and training providers recognise that there is a lag in the development of education and training programs designed to meet the future workforce needs more broadly.

Transitioning the existing workforce to these new roles will not be easy. Other industries (such as the car industry) which have endeavoured to retrain traditional operators to work in automated environments have experienced poor retention, despite significant investments in training and change management.

4.2.3. A new human-equipment interface

The transition from equipment operators to console operators will involve the development of a new human-equipment interface. It is in the design of this interface where there is potential to capture the safety and efficiency gains offered by autonomous and remote operation technologies. In the transition to automated equipment, issues or new risks that can arise include:

- poor operator acceptance of new technologies
- operator and maintainer deskilling - this is of particular importance when dealing with new/unexpected conditions linked to the new technology
- problems integrating multiple warnings and data sources from the automated equipment
- over-reliance on technology, and placing too much trust in the technology
- high level, diagnosis issues (where no operator is present to be able to explain the problems to the maintenance staff) and lower level sorting out and interfacing with somebody controlling remotely
- operators engaging in more risky behaviour after new technologies have been introduced
- operators becoming outside the system control loop (so, they are sometimes a 'passive' supervisor or the process, rather than an 'active' operator) which may lead to them losing situational awareness/site context and can be a particular problem when they need to directly intervene at times of abnormal operational conditions (Horberry et al, 2011a; Lynas and Horberry, 2011a; Lynas and Horberry, 2011b; Lynas and Horberry, 2011c; Lynas and Horberry, 2011d).

The design and deployment of effective, user-centred technologies requires:

- a participatory approach to technology design, incorporating end user input
- adequate provision of training and support for operators and maintainers
- integration with related organisational processes (including rostering, the organisation of work teams and the level of supervision)
- identification and acknowledgement of operators' decision making powers
- more widespread equipment/technology standardisation - especially in the operator interface
- optimum ergonomic design for mine site conditions
- formal change management processes to introduce new technologies/automation (Horberry et al, 2011a; Lynas and Horberry, 2010).

4.2.4. Workplace health and safety

The safety benefits of autonomous and remote operation mining need to be articulated more clearly by industry.

Automation is expected to improve workplace safety, including through the removal of operators from danger associated with the mining process and machinery (CSIRO, 2008).

The mining industry has one of the highest incident rates of work-related injuries and fatalities in Australia and has made improving safety and health its top priority. In the three years to 2009, vehicle incidents were the most common cause of fatality in the mining industry, accounting for 35 per cent of fatalities (WRMC, 2009). Of the six fatalities (3.5 per 100,000 workers) in the mining industry in 2009-2010, (Safe Work Australia, 2011), three occurred in Western Australia but were not in the iron ore sector (Department of Mines and Petroleum, 2011).

The CFMEU contests the claims of improved safety with automation, citing workshops as the most dangerous places for mine workers and the continued presence of the risks associated with workshops with automation (Australian Broadcasting Commission (ABC), 2011a; Duffy, 2012c).

4.2.5. Workplace culture, employee relations and workforce acceptance

Building workforce acceptance of automation technologies is also an important aspect of successful implementation and maintaining positive employee relations. Engaging the workforce in the development and deployment of new technologies can help to identify and resolve potential issues, contributing to acceptance.

The current mining workforce will need to adapt to more of a professional services culture (away from physical, team-based work and a predominantly male workforce on-site). This shift will warrant a corresponding shift in management approach.

As an example of the workforce issues that can arise in relation to automation, in September 2012, the Maritime Union of Australian launched legal action to try to force Asciano, Australia's largest port operator, to put its plan to replace employees with automated straddle carriers at Port Botany on hold. This is based on the plan being considered to be in breach of its enterprise bargaining agreement. The introduction of the technology would also result in a loss of 270 traditional operator jobs by 2014. Despite the improved precision, flexibility and safety offered by the system, the president of the international Transport Workers Federation urged customers not to do business with the company until it backs down on the automation plan (Hannan, 2012).

A lack of workforce acceptance also contributed to INCO's abandonment of its automation project at its Sudbury mine in Canada in 1998. Insufficient teamwork across the organisation, including between internal research and development groups with divergent philosophies and a lack of support from head office, have been cited as problems (Mottola and Holmes, 2009 in Parreira et al. 2009).

The CFMEU has already raised questions about automation in relation to autonomous haul trucks and driverless trains, including in its talks with BHP Billiton (ABC, 2012; Duffy, 2012a; Duffy, 2012b; Kirkman, 2011). These questions relate to the motivation for introducing the technology, the likely change in the size of the workforce and the claims of improved safety. Rio Tinto has advocated that the introduction of driverless trains will be gradual with a three-year plan to provide a proper transition to an automated work environment, including the necessary re-training (Wilson Smith, 2012).

Technologists involved in successful automation projects promote a 'ground up' approach for engaging the workforce in the development of new technologies to help ensure their successful implementation.

4.2.6. The location of mining jobs

Automation is likely to drive a change in workforce management - from a combination of fly-in and fly-out (FIFO) and residential employees to an increase in the number and concentration of employees located in capital cities. One mining company in Australia has moved to situate a remote operations centre in a regional town, but most centres have been located or planned in capital cities.

In the economic modelling conducted as part of this project, the location of a remote operations centre was found to have influenced the level of residential employment associated with a mine. For the two scenarios in which a remote operations centre is based in a nearby regional town, there was a net increase in residential employment opportunities (Jack and Chappell, 2013).[8] Situating remote operations centres in capital cities on the other hand, reduced the residential employment associated with mining within a 75 kilometre radius of the selected town (Jack and Chappell, 2013).[9] The net change in residential employment includes operator jobs that are automated (first order jobs) and subordinate and supporting roles (second and third order jobs respectively).

The growth of mining employment in capital cities is likely to facilitate increased workforce participation for those less able to participate in a long distance commuting (for example, women and parents of young children) and those based in capital cities. Conversely, it may reduce the participation of people living in regional areas and who are not mobile. This is likely to have a concentrated effect on Aboriginal Australians (see Section 4.4).

This urbanisation of the Australian mining workforce may also improve opportunities for mining employees and their families in terms of employment, education, housing, and transportation (Jack and Chappell, 2013).

4.2.7. Workforce participation

In addition to the potential urbanisation of the mining workforce and reduced reliance on long-distance commuting, the possibility of shorter shifts, the less physical nature of mining work and a more professional workplace culture, may help to increase workforce participation of underrepresented groups such as women and older workers.

Increased participation in the mining workforce will help spread the benefits of mining. However, these benefits may not extend to Aboriginal people, particularly Aboriginal women, if mining jobs become concentrated in capital cities.

Increasing workforce participation is identified as one of the priority strategies for meeting labour demand in the mining sector (Australian Government, 2011; SkillsInfo, 2012; CMEWA, 2012). Compared to other industries, the mining sector has a lower proportion of its workforce from 15 to 19 year olds (1.5 per cent of the workforce, compared to 6.0 per cent for all other industries) and a lower proportion of its workforce aged over 55 (12 per cent compared to 17.1 per cent for all other industries) (SkillsInfo, 2012).

The mining industry also has a very small proportion of its workers in part-time employment: 98.6 per cent of males in full time roles and 85.7 per cent of females in full time roles compared to 85.7 per cent and 54.3 per cent for all other industries. Mining also has the second lowest share of female employment with females making up 15.5 per cent of the workforce in 2012 (SkillsInfo, 2012). These differences have been attributed to the remoteness of mining sites, the physical demands of the work and a lack of compatibility between the demands of the business such as FIFO and family responsibilities (SkillsInfo, 2010). Autonomous and remote operation technologies may help to address these barriers.

---

[8] In this analysis, a regional town that is currently a base for surrounding mines was used as the location for a remote operations centre. To capture the benefits of autonomous and remote operation technologies, functions operating out of remote control centres would need to be centralised to some degree with one centre servicing multiple mines across a region and beyond. Hence the change in a mining workforce would apply at a regional rather than local level.

[9] Mines over 75 kilometres from a town were assumed to have 100 per cent long-distance commuter workforces.

4.3. REGIONAL DEVELOPMENT

Mining regions and communities are at risk of being disadvantaged by the shift to autonomous and remote operation technologies. A reduction in regionally-based mining employment is likely to have flow on effects for regional employment, populations and household numbers, and subsequently, for expenditure captured in towns and population-dependent community services (such as education, policing and health).

Mines can provide important contributions to regional development in terms of employment, business development opportunities (through the procurement of goods and services from local businesses), the discretionary expenditure of employees and the associated flow on benefits from these transactions (Rolfe *et al*, 2010). Other, secondary development benefits can come from the presence of mine-related infrastructure, community investments and support for local businesses.

With the uptake of autonomous and remote operation technologies, there are likely to be fewer on-site roles and, as a result, less mining jobs in regional areas (both residential and commuter workforces). This assumes that remote operations centres and mining employment are increasingly based in capital cities. This reduction in direct, residential employment has a flow on effect that reduces the residential population of a mining community and as a result less expenditure is captured by local businesses. If large enough, there can also be a reduction in business and economic activity (Jack and Chappell, 2013).

The technical and professional services and workforce support requirements of mining operations will also change with the uptake of autonomous and remote operation technologies. This will change the local supply chains of mining operations, and consequently the development opportunities associated with local procurement by a mining operation. There may be new opportunities for locally-based businesses in the installation and maintenance of autonomous and remote operation equipment. However, many local businesses will lack the capital and specialist expertise required to take advantage of these opportunities. Mining-related technical and professional services may therefore become even more concentrated in capital cities.

Should some mining services companies move away from regional communities, the regional economies in question stand to lose some of the benefits associated with the co-location of businesses in the same type of industry such as: labour pooling; the exchange of ideas, labour and supplies; and the development of related industries (Jack and Chappell, 2013).

It is unclear whether technical service providers are likely to locate themselves in regional areas or to what extent new or existing suppliers are being prepared for the transition to automation. Part of the solution to creating business development opportunities in regional areas associated with automation will include overcoming existing barriers to business development such as remoteness, lack of infrastructure and limited labour availability.

There are some government-funded social services such as education, health and policing for which the amount of funding is determined based on population. Payment or service level increments are often attached to population thresholds therefore these population-driven services can be affected when a town population changes. This can result in reduced service levels or service closure, less employment in these sectors and a further reduction in residential employment.

The economic modelling conducted for this study showed that transferring remote operation centres to Perth (Scenario 1 – Brave New Mine and Scenario 2 – Urban Drift) would reduce residential employment, town population, the number of households, and retail expenditure captured in towns. This contrasts with situating a remote operations centre in a regional town, which would result in a net increase in residential employment, local (or regional) population, the number of households and retail expenditure captured in towns (See Box 4).

BOX 4: MODELLING THE POTENTIAL ECONOMIC IMPACT OF AUTONOMOUS AND REMOTE OPERATION TECHNOLOGIES FOR TWO TOWNS IN THE PILBARA

Direct impacts

The direct economic impact is the net change in mining employment (see Table A). The net change in employment is a combination of operator jobs that will be automated and subordinate and supporting roles that are within a 75 km radius of the town in question. (Mines outside a 75 km radius are assumed to be 100% FIFO and a reduction in this type of employment has a flow on or indirect rather than direct effect on the town).

For the two scenarios in which the remote operations centre is based in a regional town (Smart Regions and Regions Adapt), the introduction of autonomous and remote operation mining generates a net increase in employment ranging from 75 to 151 jobs in Town A and from 92 to 183 jobs in Town B, depending on the level of automation (and given the assumptions outlined in Chappell and Jack, 2012). For the two scenarios in which the remote operations centres are located in Perth, there is a net reduction in local employment, ranging from 113 to 226 jobs in Town A and 68 to 136 jobs in Town B, depending on the level of automation, and given the assumptions outlined in Jack and Chappell (2013).

Table A: Net change in employment

Scenario	Brave New Mine	Smart Regions	Urban Drift	Regions adapt
Level of automation	100%	100%	50%	50%
Town A	-226	151	-113	75
Town B	-136	183	-68	92

Source: Chappell and Jack, 2012

Indirect impacts - expenditure

The flow on or indirect impacts for regional towns include the net change in population, household numbers, expenditure and business opportunities in town and population driven community services. While a net change in residential employment will have implications for population, household numbers, and population driven services, changes in both residential and commuter workforces will have impacts on in-town business and expenditure.

For the two scenarios in which the remote operations centre is based in town (Smart Regions and Regions Adapt), introduction of autonomous and remote operation mining generates a net increase in population ranging from 227 to 454 in Town A and from 273 to 546 in Town B, depending on the level of automation (and given the assumptions outlined in Jack and Chappell, 2013). For the two scenarios in which the remote operations centres are located in Perth (Brave New Mine and Urban Drift), there is a net reduction in population, ranging from 341 to 682 in Town A and 202 to 404 in Town B, depending on the level of automation (and given the assumptions outlined in Jack and Chappell, 2013). The net change in population is reflected in a net change in the number of households (see Table B).

A reduction in the number of households means there is a loss in household expenditure captured in town by local businesses and industries. The loss of expenditure captured in town, if great enough, may reduce business activity in town. The loss of mining business for local industry also has an impact on local business. The net change in town average annual expenditure arising from residents and FIFO employees for Town A and Town B is shown in Table C.

MODELLING THE POTENTIAL ECONOMIC IMPACT OF AUTONOMOUS AND REMOTE OPERATION TECHNOLOGIES FOR TWO TOWNS IN THE PILBARA (CONTINUED)

Table B: Net change in population and households

Scenario		Brave New Mine	Smart Regions	Urban Drift	Regions adapt
Level of automation		100%	100%	50%	50%
Town A	**Population**	-682	454	-341	224
	Households	-226	151	-113	75
Town B	**Population**	-404	546	-202	273
	Households	-136	183	-68	92

Source: Chappell and Jack, 2012

Table C: Net change in town average annual expenditure

	Scenario 1: Brave new mine – Perth	Scenario 2: Smart regions - town	Scenario 3: Urban drift – Perth	Scenario 4: Regions adapt - town
Level of Automation	100%	100%	50%	50%
Town A Residents	-$2,793,210	$1,862,263	-$1,396,605	$931,132
Town B Residents	-$1,675,926	$2,263,320	-$837,963	$1,131,660
Town A FIFO	-$715,664	$249,051	-$357,832	$124,525
Town B FIFO	-$429,398	$386,899	-$214,699	$193,449

Source: Chappell and Jack, 2012

Indirect – population driven services

For the two scenarios in which the remote operations centre is based in town (Smart Regions and Regions Adapt), there is a positive net change in the demand for population driven services. For the two scenarios in which the remote operations centres are located in Perth (Brave New Mine and Urban Drift), there is a negative net change in the demand for population driven services. The change in status of these services (e.g. closure or opening of schools and demand for doctors and police officers) may also have implications for residential employment and economic and social aspects of community life.

Table D: Town A population driven services demand

		Current Supply	Brave New Mine	Smart Regions (Town)	Urban drift	Regions adapt (Town)
Primary Schools	Town A	2	1	2	1	2
	Town B	1	1	1	1	1
Secondary Schools	Town A	1	0	1	0	1
	Town B	0	0	0	0	0
Police	Town A	7	3	4	3	4
	Town B	2	1	3	2	2
Doctors	Town A	3	2	3	2	3
	Town B	1	1	2	1	2

Source: Chappell and Jack, 2012

Note: The conceptual model and assumptions applied in generating these results are outlined in Jack and Chappell (2013).

The Pilbara Industries Community Council (PICC), in its 2010 report, *Planning for resources growth in the Pilbara: revised employment and population projections to 2020*, predicts a population increase to a resident population of 61,086 in 2015 and 62,500 in 2020 on the basis of projected increases in the resource-related workforce (Waller, 2010). These projections are used by the Western Australia Planning Commission (Waller, 2010). Under the Western Australia State Government's 'Pilbara Cities Initiative', Karratha and Port Hedland are planned to be developed into cities with populations of 50,000 supported by Newman as a subregional centre with a population of 15,000 (Pilbara Development Commission, 2011). It is not clear how the transition to large-scale autonomous and remote operations technologies would affect these objectives and projections.

While the modelling conducted for this project helps demonstrate the range and nature of potential social and economic impacts of autonomous and remote operation technologies, the actual nature and scale of potential impacts on regional communities will depend on the diversity of the regional economy in question and its dependence on mining. The extent to which automation will influence regional economies will also depend on the influence of existing workforce management and procurement practices on the regional economies being impacted.

4.4. ABORIGINAL EMPLOYMENT AND ECONOMIC DEVELOPMENT

In some remote parts of Australia, employment and business development opportunities in the mining sector have become important sources of regular income and opportunity for Aboriginal people. Increasingly, land use agreements between mining companies and traditional owners include provisions that require the company to provide employment, training and business development opportunities for traditional owners and other Aboriginal people (Brereton and Parmenter, 2008). In the Pilbara, mining is the major source of Aboriginal employment, representing 20.9% of Aboriginal employment (ABS, 2006). The only other employment options in many remote areas are government agency jobs, including health services and environmental services, hence the importance of mining as a source of employment (Rivers, 2012).

The move to autonomous and remote operation mining could threaten these opportunities because Aboriginal employment is concentrated in entry-level jobs (manual and semi-skilled roles) (Brereton and Parmenter, 2008; Tiplady and Barclay, 2007). Across three Australian mine sites studied by CSRM, the proportion of the Aboriginal workforce in roles such as truck driving and plant operators ranged from 40 to 60 per cent and it is these roles that are a major focus of automation.

Aboriginal workers currently employed in these roles may find it difficult to transition to the new jobs that will be created, because of the education and skill requirements. Further, many of the new jobs will be located in large urban centres, rather than the regions where most Aboriginal employees live. At mine sites where CSRM has conducted research, the proportion of the Aboriginal workforce that live regionally ranges from 50 to as high as 90 per cent.

This threat to Aboriginal employment and business opportunity is potentially at odds with industry and government goals to increase workforce participation and business development opportunities in mining for Aboriginal people and the development of Aboriginal communities in mining regions generally.[10]

In addition to the commitments that individual companies have made as part of Indigenous Land Use Agreements under the Native Title Act 1993 (Commonwealth), some companies have made broader commitments to Aboriginal employment and business development through Reconciliation Action Plans, the Australian Employment Covenant and setting voluntary targets. Some initiatives have also been developed at an industry level and in partnership with governments. See Box 5 for some examples of industry and government commitments to promoting Aboriginal employment and business development in the mining sector.

Organisations involved in these initiatives will need to engage with Aboriginal groups to determine how these commitments will continue to be best met, in light of the potential impact of autonomous and remote operation technologies on Aboriginal employment and business development.

BOX 5: EXAMPLES OF COMMITMENTS TO ABORIGINAL EMPLOYMENT AND BUSINESS DEVELOPMENT OPPORTUNITIES IN THE MINING SECTOR

Negotiations under the Australian *Native Title Act 1993* (Commonwealth)

The *Native Title Act 1993* (Commonwealth) provides two avenues to enable land access via agreement-making between developers (including mining companies) and native title holders or claimants: Indigenous Land Use Agreements (ILUAs) (introduced in 1998) and section 31 agreements (made through the right to negotiate process).

To secure access to land and obtain agreement to particular uses, these agreements include commitments to compensation or benefit sharing which can be expressed as, among other things: financial benefits; employment, education and training; business development assistance; community development; infrastructure; social programs; environmental management; and cultural heritage protection (Limerick *et al*, 2012). Commitments by mining companies to provide employment and training opportunities have become a critical aspect of these agreements and are an important source of income and opportunity for Aboriginal people in mining regions. Many Aboriginal groups see these agreements as opportunities to gain recognition as the traditional owners of the land, strengthen and preserve their culture and improve the lives of their people.

Reconciliation Action Plans

Reconciliation Action Plans are plans to create relationships and sustainable opportunities for Aboriginal and Torres Strait Islander Australians that are endorsed by Reconciliation Australia, a non-profit foundation promoting reconciliation between Aboriginal and Torres Strait Islander peoples and the broader Australian community (Reconciliation Australia, 2012).

Rio Tinto's Reconciliation Action Plan 2011 includes targets for its Iron Ore business of a net increase in Aboriginal employment numbers of 100 by December 2011 and a long-term target of 20 per cent Aboriginal employment by 2015. There is also a local Pilbara target of 14 per cent Aboriginal employment for Iron Ore Pilbara residential jobs (Rio Tinto, 2011b). There is also a target to exceed 2010 Aboriginal business spend target of $180 million.

BHP Billiton's Reconciliation Action Plan (FY 2013-2015) commits to increasing the number of Aboriginal employees at its operations and to including Aboriginal businesses in Local Procurement Plans (BHP Billiton, 2012).

Australian Employment Covenant

The Australian Employment Covenant is a national, industry led initiative aiming to secure commitments to sustainable jobs for Indigenous Australians.

FMG has also made commitments to Aboriginal employment through its support for the Australian Employment Covenant (FMG, 2011). Other AEC employers from the mining sector include Rio Tinto and Ivanhoe Australia (Australian Employment Covenant, 2011).

Industry-level commitments

The Memorandum of Understanding (MoU) on Indigenous Employment and Enterprise Development is an agreement between the Australian Government and the Minerals Council of Australia (MCA) that aims to facilitate employment and economic development opportunities for Aboriginal people at the local level.

The Queensland Resources Council has also signed a MoU with the Australian Government and Queensland Governments to create sustainable economic development and employment opportunities for Indigenous families and communities in Queensland. This was effective from August 2011 to 2013. The North West Queensland Indigenous Resources Industry Initiative (NWQIRII) and the Bowen Basin Indigenous Participation Partnership are initiatives aimed at increasing Indigenous participation in the resources sector and are funded under this MoU.

5. RECOMMENDATIONS

Potential social impacts – and opportunities – could to be overlooked in "the rush to innovate". A more strategic approach to the further development and implementation of autonomous and remote operation technologies in Australian mining is required. This is not about slowing the pace of technological change, as experience has shown that such attempts rarely, if ever, succeed. The challenge, rather, is to ensure that the benefits of innovation are realised and broadly distributed and that adverse consequences are minimised, enhancing the sustainability of these technologies.

Governments, mining companies and technology developers all have a role to play in identifying and addressing the potential social impacts of autonomous and remote operation technologies in Australian mining. These actions are summarised in Table 2 and discussed in more detail below.

Recommendations relating to the application of *Social Licence in Design* as a CTA process are addressed in Franks *et al* (2013).

Preparing for a new workforce

To date, companies at the forefront of developing new technologies appear to have been reluctant to publicise the details about the profile, size and location of the future mining workforce under different automation scenarios**.** This reticence presumably reflects a desire to protect proprietary information and secure a competitive edge. However, beyond a certain point such behaviour becomes counter-productive as it takes time to build a pipeline of people with the necessary skills and other organisations need to be involved in this process. In particular, engagement with the vocational education and training (VET) sector about future workforce needs and the new skills and competencies that will be required, is critical to build a pipeline of people to work with new technologies and fill new roles.

<u>Suggested actions</u>

- As a first step, Commonwealth Government departments with responsibility for industry, trade and regional development, could convene a roundtable of senior industry personnel involved in technology development and workforce planning, representatives of the VET sector and key state government agencies, to exchange non-commercially sensitive information about future workforce requirements in the sector and identify the support required to build the future workforce. The Minerals Council of Australia could be invited to partner in the organisation of the roundtable. This forum could be used to:
    - identify the profile of the automated mine workforce
    - identify the skills and training requirements of an automated mining workforce
    - develop an industry-wide strategy to meet the education and training needs for automation
    - identify responsibilities and appropriate support mechanisms, including options for re-training and re-deployment, to assist the existing workforce in the transition to a more highly automated mining industry.
- As a priority, training organisations could develop training and recruitment strategies to help capture the opportunity that emerging technologies present for increasing female representation and participation by other underrepresented groups, such as older workers in the mining workforce.

- A protocol could be established for sensitive information to be shared with a trusted third party (e.g. CSIRO or a University-based research institute) that is responsible for pooling data to provide an overall picture of likely trends in the sector.

Table 2: Actions to address the potential social impacts of autonomous and remote operation

For governments	• The Commonwealth Government could convene a roundtable involving industry, representatives of the Vocational Education and Training (VET) sector and key state government agencies to exchange non-commercially sensitive information about future workforce requirements in the sector and identify support available from the VET sector. The Minerals Council of Australia could be invited to partner in the organisation of the roundtable. • The Commonwealth Government, in conjunction with state governments, could resource a strategic impact assessment to map and, where practical, quantify the potential impacts of technology-induced workforce and supply chain changes at the regional level. • Both levels of government could work to develop strategies to help capture the opportunity that emerging technologies present for increasing the participation of women and older workers in the mining workforce. • In collaboration with industry, state governments could investigate the potential for locating remote operation facilities in regional centres.
For mining companies	• Adopt technology development, education, training and employment strategies to enhance the employability and mobility (internal and external) of Aboriginal employees for on-site roles associated with automation as well as non-mining employment opportunities for Aboriginal people. • Continue to contribute to the economic development of regional mining areas through direct employment and support for broader economic development initiatives. Target such initiatives at helping people and business adapt to the implementation of autonomous and remote operation technologies. • Investigate the potential to locate remote operation centres in regional towns as opposed to capital cities. • Adopt an operator-centred approach to technology development and deployment (see Box 6). • Consider the social factors and involve social scientists in Constructive Technology Assessment processes during the development of new technologies, and stipulate these requirements when commissioning such work.[11]
For technology developers	• Specifically address the needs of Aboriginal employees in the application of an operator-centred approach to technology development and deployment. • Acknowledge the role of technology developers in contributing to the Social Licence of mining companies. • Consider the social factors and involve social scientists in Technology Assessment processes during technology development, and build the capacity of technologists to consider social factors and to adapt their designs accordingly. • Adopt an operator-centred approach to technology development and deployment (See Box 6).

[11] This point obviously also applies to companies undertaking significant technology innovation in other sectors; however, the focus of this study is specifically on the mining industry.

Capturing the safety and efficiency benefits of automation

Incorporating consideration of human factors and workforce engagement into the development and deployment of automation technologies will contribute to the safety, effectiveness and acceptance of these new technologies. Currently, there is not a strong culture of this type of approach in the mining industry (Lynas and Horberry, 2011d; Horberry et al, 2011a).

Suggested actions

- Technology developers and mining companies could incorporate an operator-centred approach to the development and deployment of automation technologies, such as the process advocated by human factors experts in Box 6. This approach engages the workforce in technology development and helps optimise the operator-equipment interface to achieve effective automation and ensure the technology is safe, usable and acceptable to operators.

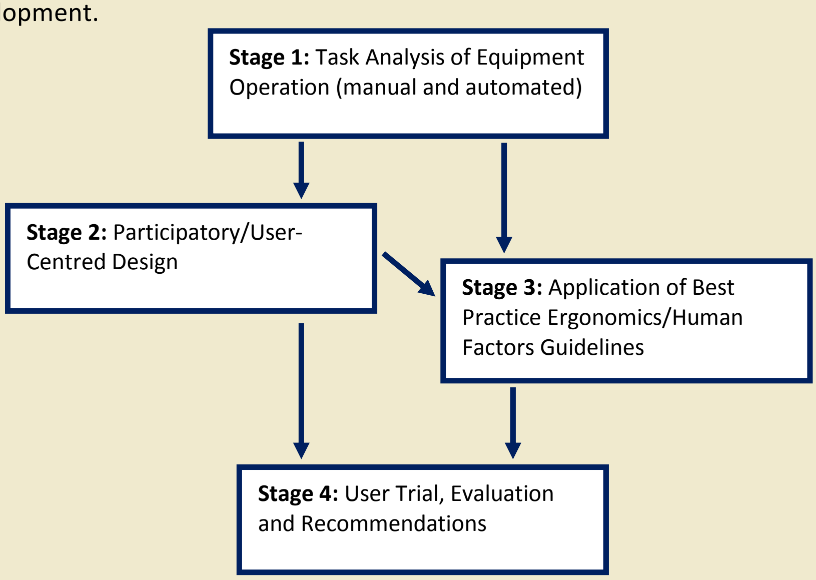
BOX 6: A HUMAN FACTORS APPROACH TO DEVELOPING EFFECTIVE USER-CENTRED MINING TECHNOLOGIES

Stage 1: Task analysis of equipment operation (manual and automated)
Compile a description showing the overall and sub-elements of the task. This is based on data collected from interviews and observations, document reviews (such as training manuals), and safety data. It should identify 1) tasks required to meet system objectives; 2) user information requirements; 3) actions and user decisions needed; 4) postures and movements; and 5) working conditions. This information informs the development of effective interface design specifications.

Stage 2: Participatory/user-centred design
This is an iterative process of developing (or critiquing) interface specifications based on operator feedback. This aims to assist operators manage key decisions (or leverage points) in a task. This process should begin as early as possible in the technology design process.

Stage 3: Application of best practice ergonomics/human factors standards and guidelines to the prototype interface
This is conducted in conjunction with Stage 2. Relevant guidelines and standards will relate to the leverage points identified in Stage 2.

Stage 4: User trial, evaluation and recommendations
This iterative process may consider evaluations of operator acceptance; how operator skills are maintained; and how operators cope with multiple alarms and display modalities. User trials are best undertaken in the field in operational conditions but can be undertaken as a desktop trial for systems early in its development.



The full process and background are outlined in Horberry *et al* (2011b). It is situated within a broader constructive technology assessment process described in Franks and Cohen (2011).

Managing the potential regional impacts of autonomous and remote operation mining

As documented in this report, over the longer term the roll-out of new technologies is likely to reduce the number and range of mining jobs that will be filled by locally-based employees and change the nature of mining-related local and regional supply chains. This will potentially reduce the 'development dividend' for communities and regions in which mining is conducted and could accelerate the decline of some communities.

Suggested actions

The Commonwealth Government, in collaboration with state governments, could assist by resourcing a strategic impact assessment to map and, where practical, quantify the potential impacts of technology-induced changes to the mining workforce and supply-chain at the regional level. This information could then inform a discussion about the flow on effects for regional populations, businesses and development. Such an approach may have helped in forecasting and proactively addressing the issues associated with the rapid and large-scale uptake of long-distance commuter (fly-in fly-out/drive-in drive-out) workforces.

Actions that companies could take to mitigate adverse impacts for on regional communities include:

- Work with affected communities to help them diversify their economic and employment base (where this is a practical option).
- Engage with education and training providers to build capability for local people to participate in the new mining workforce. This could include operating education and training programs or basing institutions associated with automation and automated technology in larger mining towns).[12]
- Explore other ways in which mining projects may be able to deliver a 'development dividend' for local communities (e.g. by funding scholarship schemes, or supporting human capital development in other industries).
- In collaboration with the Commonwealth and State Governments, investigate the potential to locate centralised remote operations centres in regional centres in or near mining regions. The feasibility of this option will depend on:
    - the diversity and stability of regional town populations and economies
    - the size of the population (critical mass)
    - the ability to encourage people to re-locate to and remain in regions
    - supporting infrastructure, including information and communication technologies
    - the relationship of a remote control centre to the mining operations it controls (ie whether it controls one or more sites and the level of integration between sites).
- Work with existing professional and technical service providers in mining communities, either to help them scale down or transition to a business model compatible with the technical and professional requirement of autonomous and remote operation mining.

Enhancing Aboriginal employment and development

As indicated, in some parts of Australia, mining is now one of the most important sources of employment and business for Aboriginal people, often providing them with the first opportunity to participate in the mainstream workforce and economy. With the increasing uptake of new technologies such as driverless trucks and a potential reduction in the mining workforce based in regional and remote areas, there may be fewer of these opportunities in the future.

[12] Such as the University of Western Australia's consideration of a campus in The Pilbara.

Suggested actions

Steps that companies could take to lessen the impact of these changes include:

- Enhance the skills and employability of existing Aboriginal employees through training and work-readiness programs, to increase internal and external mobility.
- Work with education and training providers to develop culturally appropriate aptitude tests to identify Aboriginal people suited to working in new on-site roles (such as equipment monitoring and maintenance) and in other roles and then providing the necessary training.
- Explore the potential for enhancing Aboriginal participation in the automated mining workforce through focussing on the needs of Aboriginal people in a human-centred approach to technology development and deployment. For example, there may be potential to reduce shift lengths and a greater capacity to work from above ground, both of which are likely to be more culturally appropriate.
- Collaborate with government, and other local industries (e.g. retailing, transport, hospitality) to expand the range of non-mining employment opportunities for Aboriginal people in mining regions.
- As a longer term community development strategy, companies could support schools in Aboriginal communities to build student capability in information technology. This would need to be done in liaison with government and should not duplicate or replace existing programs.
- In negotiating future agreements with traditional owners, companies should also consider including commitments to enhance employability in general, rather than just focusing on providing mining - related jobs and training. Where governments are parties to agreements, they should look to make similar commitments.

6. IMPLICATIONS FOR SOCIAL LICENCE TO OPERATE

The social dimensions of automation identified through this research and which are likely to have implications for SLO are the potential changes in:

- the structure of the mining workforce and workforce management practices
- workplace and public health and safety
- mining-related regional development opportunities
- Aboriginal employment and mine-community relations.

The way in which these social aspects of increasing automation influence SLO will depend on how the change is experienced by different stakeholders in particular mining contexts. It will also depend on how these change processes are managed by mining companies and government. There may also be scope to reconfigure technologies in a way that assists with this aim.

Workforce structure and management

Workers are more likely to accept a reduction in entry-level operational roles if they are offered new, safer and more satisfying roles and alternative employment with adequate training and support. On the other hand, without these support measures in place, a dissatisfied workforce can act to weaken a company's SLO.

In terms of workforce acceptance of the new technologies, participatory change management processes will help the existing mining workforce adapt to the use of new technologies and enable a more worker-centred approach to technology development.

One aspect of a potential change in the structure of the mining workforce that is particularly sensitive is the potential for jobs to be moved off-shore. This sensitivity is likely to be heightened at a time when there is a downturn in other major sources of employment such as the tourism, agriculture and manufacturing sectors. Mining companies will find the most cost effective solution to labour in a global setting and there are economic advantages of this approach. However, governments are able to help maximise the benefit for Australia, by ensuring that Australia continues to be a competitive employment environment.

Health and safety

In addition to the safety performance of these new technologies, helping stakeholders to understand the safety benefits and how potential risks are being addressed will be critical to mining companies' ongoing credibility. There is potential for perceived risks about the likelihood of catastrophic failure of autonomous and remotely controlled equipment to become an issue for industry. Safety standards, legislation and stakeholder engagement or risk communication strategies can help to address this social risk.

Regional development contribution

A change in workforce structure or management, or mine-related supply chains could reduce the regional development contribution of mining, which in turn could have Social Licence implications. Mining does and can make significant contributions to regional communities and their economies and, as mentioned, regional development is an issue that has bipartisan support at both State and Commonwealth levels of government in Australia.

In recent times, there has been significant attention paid to the rapid increase in the industry's use of long-distance commuter workforces, in part because of its implications for regional development - perceived and otherwise. This has culminated in a federal Parliamentary Inquiry. Some State Governments have also prescribed the proportion of a particular mine's workforce that had to be residential, or funded development projects to encourage residential workforces.

Aboriginal employment and business development

A critical aspect of many mines SLO is the ability to maintain positive relationships with the traditional land owners with who land use agreements are made. How mining companies continue to meet their commitments to support Aboriginal employment and business development opportunities will be critical to their SLO. Working with Aboriginal people and traditional owners in the process of developing and deploying automation technologies will help in addressing this.

7. REFERENCES

Ashley, S. 1995. Underground mining from above. *Mechanical Engineering*, vol. 117, no. 5, pp. 78-81.

Australian Broadcasting Commission (ABC). 2012. Union to begin talks with BHP in Pilbara. *ABC* News, 31 July 2012. Available at: http://www.abc.net.au/news/2012-07-31/union-to-begin-talks-with-bhp-in-pilbara/4165866?section=business

ABC. 2011a. Driverless mine trucks spark safety fears, *ABC News*, 7 July 2012. Available at: http://www.abc.net.au/news/2011-07-07/driverless-mine-trucks-spark-safety-fears/2785570

Australian Bureau of Statistics (ABS). 2006. *2006 Census of Population and Housing*. Available at http://www.abs.gov.au/websitedbs/censushome.nsf/home/data?opendocument#from-banner=LN

ABS. 2011. *2011 Census of Population and Housing*. Available at: http://www.abs.gov.au/websitedbs/censushome.nsf/home/data?opendocument#from-banner=LN

Australian Employment Covenant. 2011. *Current Employers Register*. Available at: http://www.fiftythousandjobs.org.au/AEC_JMS/public/employers/current-employers.aspx

Australian Government. 2011. *National Resources Sector Workforce Strategy*. Australian Government response to the National Resources Sector Employment Taskforce Report: Resourcing the Future. Australian Government, Canberra. Available at: http://www.innovation.gov.au/Skills/SkillsTrainingAndWorkforceDevelopment/Documents/AGResponseNRSET.pdf

Australian Government. 2010. *Resourcing the Future*. National Resources Sector Employment Taskforce Report, July 2010. Australian Government, Canberra. Available at: www.deewr.gov.au/nrset

Bellamy, D. and Pravica, L. 2011. Assessing the impact of driverless haul trucks in Australian surface mining. *Resources Policy,* vol. 36, no. 2, pp149 – 158.

Bennink, C. 2008. Trucks and transportation - take steps to cut vehicle fuel costs; a proactive approach can add up to major savings. *Equipment Today*, vol. 44, no. 6.

BHP Billiton. 2011. Mine Autonomy Lead, Job Details, BHP Billiton Olympic Dam Project, Adelaide, viewed 4 July 2011, http://jobs.bhpbilliton.com/jobDetails.asp?sJobIDs=725874&lCategoryID=1007&lBrandID=&lWorkTypeID=&lLocationID=&lPage=3&stp=AW&sLanguage=en

BHP Billiton. 2012. *Reconciliation Action Plan*. Financial Years 2013-15. BHP Billiton, Melbourne. Available at: http://www.bhpbilliton.com/home/aboutus/sustainability/Documents/2012/BHP%20Billiton%20Reconciliation%20Action%20Plan%202013-15.pdf

Brereton, D. and Parmenter, J. 2008. Indigenous employment in the Australian mining industry. *Energy and Natural Resources*, vol. 69, pp. 66-78.

Bridge, G. 2004. Contested terrain: mining and the environment. *Annual Review of Environment and Resources*, vol. 29, pp 205-259.

Caterpillar. 2011. Autonomous mining: improving safety and increasing productivity - CAT® MINESTAR™ SYSTEM. Available at: http://catminestarsystem.com/articles/autonomous-mining-improving-safety-and-increasing-productivity

Chamber of Minerals and Energy of Western Australia (CMEWA). 2011. *State Growth Outlook 2011*. CMEWA. Perth. Available at: http://www.cmewa.com/UserDir/CMEPublications/State%20Growth%20Outlook%20Final%20Advocacy%20publication-v2250.pdf

CMEWA. 2012. *State Growth Outlook 2013*. CMEWA. Perth. Available at: http://www.cmewa.com/Publications/Details/State_Growth_Outlook_2013

Chambers, M. 2012. BHP unveils robot trucks. *The Australian*, 1 November 2012. Available at: http://www.theaustralian.com.au/business/mining-energy/bhp-unveils-robot-trucks/story-e6frg9df-1226507887714

Commonwealth Scientific and Industrial Research Organisation (CSIRO). 2008. Remote-control system boosts safety. *Earthmatters*, issue 17, July /August 2008. CSIRO Exploration & Mining Magazine. Available at: http://www.csiro.au/files/files/plr7.pdf

CSIRO. 2011. *Our vision for the Australian mineral resources sector.* Minerals Down Under National Research Flagship. CSIRO. Available at: http://www.csiro.au/science/2030-vision.html

Cribb, J. 2008. Miners of the future. *Rio Tinto Review*, September 2008, pp. 11-15. Available at: http://www.riotinto.com/documents/ReportsPublications/Review_86_-miners_of_the_future.pdf

Department of Mines and Petroleum. 2011. *Safety Performance in the Western Australian Mineral Industry — Accident and Injury Statistics 2009–10*. Western Australian Government, Perth.

Dudley, J., McAree, R. and Lever, P. 2010. *Bridging the Automation Gap: Why the Australian Resource Industry Should Support an Automation Skills Development Program.* Cooperative Research Centre (CRC) for Mining for the Mining Industry Skills Centre. Brisbane.

Duffy, A. 2012a. Rio Tinto's economists should check their facts: Union. *Australian Mining*, 21 February 2012. Available at: http://www.miningaustralia.com.au/news/rio-tinto-s-economists-should-check-their-facts-un

Duffy, A. 2012b. Unions v Rio: the automation battle. *Australian Mining*, 22 March 2012. Available at: http://www.miningaustralia.com.au/features/unions-vs-rio--the-automation-battle

Duffy, A. 2012c. Building safer sites. *Australian Mining*, 7 September 2012. Available at: http://www.miningaustralia.com.au/features/building-safer-sites

Duffy, A. 2012d. The future of automation. *Australian Mining*, 11 December 2012. Available at: http://www.miningaustralia.com.au/features/the-future-of-automation

Duinker, P.N. and Greig, L.A. 2006. Scenario analysis in environmental impact assessment: Improving explorations of the future. *Environmental Impact Assessment Review*, vol. 27, pp 206-219.

Fisher, B.S. and Schnittger, S. 2012. *Autonomous and remote operation technologies in the mining industry*: *benefits and costs*. Research report 12.1, February 2012. BAEconomics. Canberra. Available at: http://www.baeconomics.com.au/wp-content/uploads/2010/01/Mining-innovation-5Feb12.pdf

Fortescue Metals Group Limited (FMGL). 2011. Fortescue and the Pilbara: Our Commitment to the Community. FMGL. East Perth. Available at: http://www.fmgl.com.au/UserDir/FMGResources/Download/en/Fortescue%20and%20Pilbara%20Cities%20Brochure8.pdf

Franks, D.M., McNab, K, Brereton, D, Cohen, T, Weldegiorgis, F, Horberry, T, Lynas, D, Garcia-Vasquez, M, Oñate Santibáñez, B, Barnes, R and McLellan, B. 2013. Designing Mining Technology for Social Outcomes: Final Report of the Technology Futures Project. Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by the Centre for Social Responsibility in Mining & the Minerals Industry Safety and Health Centre, Sustainable Minerals Institute, The University of Queensland. Brisbane.

Franks, D.M., Cohen, T., McLellan, B. and Brereton, D. 2010. *Technology futures discussion paper: technology assessment and the CSIRO Minerals Down Under National Research Flagship*. Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster by the Centre for Social Responsibility in Mining, Sustainable Minerals Institute, The University of Queensland, Brisbane.

Franks, D.M., and Cohen, T. 2011. *Investigating constructive technology assessment within the Minerals Down Under Flagship: interview results.* Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by the Centre for Social Responsibility in Mining, Sustainable Minerals Institute, The University of Queensland, Brisbane.

Franks, D.M. and Cohen, T. 2012. Social Licence in Design: Constructive technology assessment within a minerals research and development institution. *Technological Forecasting and Social Change*, vol. 79, pp 1229 – 1240.

Giurco, D., Prior, T., Mudd, G., Mason, L. and Behrisch, J. 2009. *Peak minerals in Australia: a review of changing impacts and benefits*. Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by the Institute for Sustainable Futures, University of Technology, Sydney and Department of Civil Engineering , Monash University, Australia.

Glance, D. 2012. The mining sector's automation agenda. *Technology Spectator*, 21 August 2012. Available at: http://www.technologyspectator.com.au/mining-sectors-automation-agenda

Goddard, D. 2011. Mine site automation and communications. *Mine Site Automation and Communication Conference*, 30-31 August 2011, Perth.

Gomez, K. 2012. Schneider Electric forms alliance with Skills Tech Australia. *Process and Control Engineering (PACE) Today*, 30 August 2012. Available at: http://www.pacetoday.com.au/news/schneider-electric-forms-alliance-with-skillstech

Hannan, E. 2012. Maritime Union to take port 'breach' to court. *The Australian*, 10 September 2012. Available at: http://www.theaustralian.com.au/national-affairs/industrial-relations/maritime-union-to-take-port-breach-to-court/story-fn59noo3-1226468549294

Horberry, T., Burgess-Limerick, R. and Steiner, L. 2011a. *Human factors for the design: operation and maintenance of mining equipment*. Boca Raton: CRC Press.

Horberry, T. and Lynas, D. 2012a. *Automation Design, Skills, Capabilities and Training: Development of a Human Factors Framework*. Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by the Minerals Industry Safety and Health Centre, Sustainable Minerals Institute, The University of Queensland, Brisbane.

Horberry, T. and Lynas, D. 2012b. Human interaction with automated mining equipment: the development of an emerging technologies database. *Ergonomics Australia*, vol 8, no 1.

Horberry, T., Lynas, D., Franks, D., Barnes, R. and Brereton, D. 2011b. Brave New Mine – examining the human factors implications of automation and remote operation in mining. *Second International Future Mining Conference*, 22-23 November 2011, Sydney.

Jack, T. and Chappell, M. 2013. Economic impact of automated mining operations. Cluster Research Report 2.10. Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by Pracsys, Perth.

Ker, P. 2012. Rio high in an empty driver seat. *Brisbane Times*, 6 April 2012. Available at: http://www.brisbanetimes.com.au/business/rio-high-in-an-empty-driver-seat-20120405-1wfj5.html

Kirkman, K. 2011. Union blasts remote controlled mining – FMG. *The West Australian,* 14 July. Available at: http://au.news.yahoo.com/thewest/regional/pilbara/a/-/news/9841720/union-blasts-remote-controlled-mining/

Konyukh, V. 2002. Robotics for mining. *Mineral Resources Engineering,* vol. 11, no. 1, pp. 73.

Kral, S. (ed.) 2008. De Beers, Sandvik team up on underground automation. *Mechanical Engineering,* Society for Mining, Metallurgy, and Exploration, Inc., 1 November 2008.

Lacey, J. and Moffat, K. 2012. *A framework for Technology Assessment in the Minerals Down Under Flagship*: *integrating Life Cycle Assessment and Social Analysis of Mining Technologies*. CSIRO, Australia.

Latimer, C. 2012a. World's largest iron ore mine to go truckless. *Australian Mining*, 12 September 2012. Available at: http://www.miningaustralia.com.au/news/world-s-largest-iron-ore-mine-to-go-truckless

Latimer, C. 2012b. BHP going automated, and truckless. *Australian Mining*, 1November 2012. Available at: http://www.miningaustralia.com.au/features/bhp-going-automated-and-truckless

Lever, P.J.A. and McAree, P.R. 2003. *Open-cut automation scoping study*. Australian Coal Industry's Research Program (ACARP) Project C11054, CRC for Mining Technology and Equipment (CMTE). Australia.

Limerick M., Tomlinson K., Taufatofua R., Barnes R. and Brereton D. 2012. *Agreement-making with Indigenous Groups: Oil and Gas Development in Australia*. Centre for Social Responsibility in Mining, The University of Queensland, Brisbane. Available at: https://www.csrm.uq.edu.au/Portals/0/docs/Agreement-making-with-Indigenous-Groups.pdf

Lovejoy, C. 2012. *Industry leaders' round table: The future of mining*. A supplement to Mining Magazine, Mining Magazine, December 2012.

Lynas, D. and Horberry, T. 2010. Exploring the human factors challenges of automated mining aquipment. Conference proceedings, November 2010. Human Factors and Ergonomics Society of Australia.

Lynas, D. and Horberry, T. 2011a. *Literature review: emerging human factors trends regarding automated mining equipment*. CSIRO Cluster Research Report No. 2.3. Prepared for CSIRO Minerals

Down Under Flagship, Mineral Futures Collaboration Cluster, by the Minerals Industry Safety and Health Centre, Sustainable Minerals Institute, The University of Queensland. Brisbane.

Lynas, D. and Horberry, T. 2011b. *Interview results: emerging trends on the human factors issues regarding automated mining equipment*. CSIRO Cluster Research Report No 2.4. Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by the Minerals Industry Safety and Health Centre, Sustainable Minerals Institute, The University of Queensland. Brisbane.

Lynas, D. and Horberry, T. 2011c. A review of Australian human factors research and stakeholder opinions regarding mines of the future. *Ergonomics Australia*, HFESA 2011 Conference Edition, 2011 pp 11:13.

Lynas, D and Horberry, T. 2011d. Human factors issues with automated mining equipment. *Ergonomics Open*, vol. 4, pp 74-80.

Lynas, D. And Horberry, T. 2012. Tracking emerging technologies: an automated mining equipment database. Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster Collaboration, by the Minerals Industry Safety and Health Centre, Sustainable Minerals Institute, The University of Queensland, Brisbane.

McNab, K. 2013. *Autonomous and remote operations technologies in Australian Mining: harnessing the societal benefits for Australia, roundtable report*. Cluster Research Report 2.6. Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by the Centre for Social Responsibility in Mining, Sustainable Minerals Institute, The University of Queensland. Brisbane. (*forthcoming*)

McNab, K. and Vasquez, M. 2011. *Autonomous and remote operation technologies in Australian mining*. Cluster Research Report 2.5. Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by the Centre for Social Responsibility in Mining, Sustainable Minerals Institute, The University of Queensland, Brisbane.

Mining IQ. 2012. Mining automation: challenges and strategies. *Mining IQ*, 13 February 2012. Available at: http://www.miningiq.com/technical-services-and-production/articles/mining-automation-challenges-and-strategies/

Mining Weekly. 2012. Driverless trucks take to Rio roads. *Mining Weekly*, 19 July 2012. Available at: http://www.miningweekly.com/article/driverless-trucks-take-to-rio-roads-2012-07-19

Murphy, M. 2011. Haulage goes autonomous. *Net Resources International*, 28 July. Available at: http://www.mining-technology.com/features/feature125450/

O'Brien, A. 2011. Rio hits top gear with new robot fleet for the Pilbara. *The Australian*, 3 November 2011. Available at: http://www.theaustralian.com.au/business/companies/rio-hits-top-gear-with-new-robot-fleet-for-the-pilbara/story-fn91v9q3-1226183991641

Parasuraman, R. and Riley, V.A. 1997. Humans and automation: Use, misuse, disuse, and abuse. *Human Factors,* vol. 39, pp. 230-253.

Parasuraman, R., Sheridan, T.B. and Wickens, C.D. 2000. A model for types and levels of human interaction with automation. *IEEE transactions on systems, man, and cybernetics - Part A: systems and humans*, vol. 30, no.3, pp. 286-297.

Parreira, J. Mullard, Z., Meech, J. and Garcia-Vasquez, M. 2009. How automation and key performance indicators (KPIs) contribute to sustainable development in the mining industry. *Second International Conference on Multinational Enterprises and Sustainable Development*, Strategies for Sustainable Technologies and Innovation, 4-6 November 2009, Nancy-Mets, France. Available at: http://www.infomine.com/publications/docs/Parreira2009.pdf

Pilbara Development Commission. 2011. *Pilbara: a region in profile 2011.* Western Australian Government, Department of Regional Development Lands, Perth. Available at: http://www.pdc.wa.gov.au/media/75465/pilbara%20a%20region%20in%20%20profile%202011.pdf

Reconciliation Australia. 2012. *Reconciliation Action Plans*. Available at: http://www.reconciliation.org.au/home/reconciliation-action-plans

Rio Tinto. 2008. *Rio Tinto chief executive unveils vision for Mine of the Future™.* Media release, 18 January 2008. Available at: http://www.riotinto.com/media/18435_media_releases_7037.asp

2010. *Rio Tinto launches its operations centre as a key part of its vision for the Mine of the Future™*. Media release, 25 June 2010. Available at: http://www.riotinto.com/media/18435_media_releases_19328.asp

2011a. *Mine of the Future™*. Rio Tinto. Available at: http://www.riotinto.com/ourapproach/17203_mine_of_the_future_17279.asp

2011b. *Reconciliation Action Plan*, Rio Tinto. Available at: http://www.riotinto.com/documents/Rio_Tinto_Reconciliation_Action_Plan.pdf

2011d. *Rio Tinto boosts driverless truck fleet to 150 under Mine of the Future™ programme*. Media release, 2 November 2011. Available at: http://riotinto.msgfocus.com/files/amf_rio_tinto/project_37/111102_Rio_Tinto_boosts_driverless_truck_fleet_to_150_under_Mine_of_the_Future_programme.pdf

2012a. *Rio Tinto invests US$518 million in autonomous trains for Pilbara iron ore rail network in Western Australia*, Media release, 20 February 2012. Available at: http://www.riotinto.com/media/18435_media_releases_21665.asp

2012b. *Rio Tinto expands Mine of the Future™ programme with new technologies in underground tunnelling and mineral recovery*. Media release, 21 February 2012. Available at: http://www.riotinto.com/media/18435_media_releases_21667.asp

2012c. *Rio Tinto and iGATE Patni open world-leading innovation centre in India*, Media release, 27 March 2012. Available at: http://www.riotinto.com/media/18435_media_releases_21900.asp

2012d. *Rio Tinto's driverless trucks achieve a new milestone at Yandicoogina mine under Mine of the Future™ programme*. Media releases, 19 July 2012. Available at: http://www.riotinto.com.au/ENG/media/38_media_releases_1864.asp

Rivers, L. 2012. Remote Aboriginal and Torres Strait Islander employment pathways: a literature review. Working Paper CW008. Cooperative Research Centre for Remote Economic Participation. Kent Town. Available at: http://www.crc-rep.com.au/resource/CW008_RemoteEmploymentPathways.pdf

Rolfe, J., Lawrence, R., Gregg, D., Morrish, F. and Ivanova, G. 2010. *Minerals and energy resources sector in Queensland economic impact study*. Eidos Institute. Brisbane

Safe Work Australia. 2011. *Notified Fatalities Statistical Report 2009-2010.* Safe Work Australia. Available at: http://safeworkaustralia.gov.au/AboutSafeWorkAustralia/WhatWeDo/Publications/Documents/578/NotifiedFatalitiesStatisicalReport2009-10.pdf

Science WA. 2012. Rio Tinto is set to bring 150 driverless trucks to its Yandicoogina mine in WA. *Science WA*, 13 January 2012. Available at: http://www.sciencewa.net.au/topics/technology-a-innovation/item/1180-rio-tinto-launches-driverless-trucks-in-the-pilbara?tmpl=component&print=1

Shields, B. 2010. Newcrest's $30 million Leewood development is...Mine-boggling. *Central Western Daily*, 8 August 2010. Available at: http://www.centralwesterndaily.com.au/news/local/news/general/newcrests-30m-leewood-development-is-mineboggling/1907349.aspx?storypage=1

SkillsInfo. 2010. *Employment outlook for mining,* Prepared for the Australian Government Department of Education, Employment and Workplace Relations. Available at: http://www.skillsinfo.gov.au/NR/rdonlyres/7FA3ECD3-BB3F-4594-A421-DFD623F810A9/0/OutlookMining.pdf

SkillsInfo. 2012. *Mining employment outlook*, Prepared for the Australian Government Department of Education, Employment and Workplace Relations. Available at: http://www.deewr.gov.au/lmip/default.aspx?LMIP/Publications/IndustryReports

Spooner, R. 2012. Are robots the future of the WA mining industry? *WAToday*, 7 February 2012. Available at: http://www.watoday.com.au/technology/sci-tech/are-robots-the-future-of-the-wa-mining-industry-20120206-1r1nd.html

Thomson, I. and Boutilier, R. 2011. The social Licence to operate. In *SME Mining Engineering Handbook* by P Darling (ed.), Society for Mining, Metallurgy and Exploration, Colorado.

Thorogood, J.L., Aldred W.D., Florence, F. and Iversen, F. 2009. Drilling automation: technologies, terminology, and parallels with other industries. In *SPE/IADC Drilling Conference and Exhibition*, Amsterdam.

Tiplady, T. and Barclay, M.A. 2007. *Indigenous Employment in the Australian Minerals Industry,* Centre for Social Responsibility in Mining, Sustainable Minerals Institute, The University of Queensland, Brisbane.

Waller, M. 2010. *Planning for resources growth in the Pilbara: revised employment and population projections to 2020.* Prepared for the Pilbara Industries Community Council (PICC), Chamber of Minerals and Energy Western Australia (CMEWA), Perth. Available at: http://www.cmewa.com/UserDir/CMEResources/100517-MPR-Pilbara%20demographic%20projections-April2010-v121.pdf

Weldegiorgis, F.S. and Franks, D.M. 2012. The social dimensions of charcoal use in steelmaking: analysing technology alternatives. Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by the Centre for Social Responsibility in Mining, Sustainable Minerals Institute, The University of Queensland, Brisbane.

Williams, P. 2011. FMG to use driverless trucks. *The West Australian,* 7 July 2011. Available at: http://global.factiva.com

Wilson Smith, N. 2012. Technology set to change face of mining boom. *7:30 Report*; 21 February 2012. ABC. Available at: http://www.abc.net.au/news/2012-02-21/technology-set-to-change-face-of-mining-boom/3843398

Workplace Relations Minister's Council (WRMC). 2009. *Comparative Performance Monitoring*. 10th ed. Australian Government Department of Education, Employment and Workplace Relations, Canberra.