Interview Results: Emerging Trends on the Human Factors Issues Regarding Automated Mining Equipment

Danellie Lynas & Tim Horberry

Prepared by:
Minerals Industry Safety and Health Centre, Sustainable Minerals Institute,
University of Queensland

For:
CSIRO Minerals Down Under National Research Flagship
ABOUT THE AUTHORS

Danellie Lynas

Danellie Lynas joined the Minerals Industry Safety and Health Centre (MISHC) as a Research Fellow in February 2010.

Danellie’s background initially is in physiotherapy and more recently in human factors and ergonomics having completed a Masters in Ergonomics in 2005. Since joining MISHC Danellie has been involved in several projects concerning human factor issues related to mining automation and new technologies. She is involved with MISHC’s teaching commitments and also EMESRT (The Earth Moving Equipment Safety Round Table).

Associate Professor Tim Horberry

Tim joined the Minerals Industry Safety and Health Centre (MISHC) in December 2007 as a Principal Research Fellow/Associate Professor (Human Factors). Before this he was Head of Human Factors at the Transport Research Laboratory in the UK. Previously he has worked at both the Monash University Accident Research Centre in Melbourne and the Centre for Human Factors at the University of Queensland.

Dr Horberry’s background is in human factors and safety. At MISHC, Tim is working on several human factors projects concerning mining automation and new technologies. Dr Horberry also plays a major role in promoting the academic profile of MISHC. He is supervising several PhD students, and is involved with MISHC’s teaching and education commitments (especially by helping to increase the human factors component).

Tim has published his research widely, including in two recent books: Understanding Human Error in Mine Safety (2009) and Human Factors for the Design, Operation and Maintenance of Mining Equipment (2010).

CITATION

Cite this report as:

ACKNOWLEDGEMENT

The report authors would like to thank the support of the CSIRO Minerals Down Under National Research Flagship and the cluster partners. In particular, we acknowledge the help and support given by Daniel Franks and David Brereton from the University of Queensland. We also thank all the interviewees for the time they made available for the interviews.
CONTENTS

1. ABSTRACT 4

2. TECHNOLOGY FUTURES PROJECT 5

3. METHOD 6
   3.1. Questionnaire and Interview 6
   3.2. Interview Procedure 6
   3.3. The Participants 6

4. HUMAN FACTORS AND MINING AUTOMATION RESULTS 7
   4.1. Operator and Maintainer Deskilling 7
   4.2. Over-reliance on the Technology by Operators 7
   4.3. Importance of User Trials 7
   4.4. Change Management Processes for Introducing Mining Automation 8
   4.5. Levels of Automation 9
   4.6. Poor Operator Acceptance of New Technologies/Automation after they are introduced 9
   4.7. Human Factors in Maintenance 10
   4.8. Poor Human Factors Design of Equipment Interfaces 10
   4.9. Problems with Integration of Multiple Warnings/Alarms 11
   4.10. Lack of Equipment Standardization 11
   4.11. A New Device being Essentially Irrelevant to the Task 12
   4.12. Inadequate Operator and Maintainer Training and Support 12
   4.13. Organizational Issues 13
   4.14. Miscellaneous Human FactorS Perspectives 13

5. VISIONS OF THE “FUTURE MINE” 14
   5.1. Safety 14
   5.2. Non Automation Issues 15
   5.3. Pathway for Automation 15
   5.4. Human Factors Implications 16

6. CONCLUSIONS 17
1. ABSTRACT

This interim report details the outcomes of interviews conducted with technology developers, mine site and corporate mining personnel, regulators and mining human factors academics/consultants. The purpose of the interviews was to identify the human factors issues that may emerge, or are currently emerging, with automated mining equipment. The interviewees also described their visions for automation technology in a future mine.

The overall results are described in terms of broad themes (eg concerning operator skill levels, or their acceptance of new technologies). Conclusions regarding the human element in future automated mines are drawn, and the parallels with similar work in other domains (eg aviation) where automation has been introduced are presented. The importance of an operator-centred design approach is highlighted.
2. TECHNOLOGY FUTURES PROJECT

The Technology Futures project, being led by the Centre for Social Responsibility in Mining, is one of three streams of research in a broader program of research called the Minerals Futures Collaboration Cluster under CSIRO’s Minerals Downunder Flagship. The Minerals Futures Cluster brings together four University-based research institutions all of which have a strong track record of working in the minerals sector, and CSIRO on addressing the future sustainability challenges of the Australian minerals industry.

The broad aims of CSIRO’s Minerals Downunder Flagship are to unlock Australia’s future mineral wealth through transformational exploration, extraction and processing technologies. The Technology Futures project is a 3-year applied research project to develop technology assessment methods and tools and apply these within the MDU Flagship. More specifically the Technology Futures project fits within the MDU theme; Driving Sustainable Processing through System Innovation. The goal of this MDU theme is to develop “assessment methods and tools to evaluate the impacts of new technologies and the social and environmental cost to Australia.” The Technology Futures Project aims to reduce the risk that emerging MDU Flagship technologies will result in future conflict through the development of technology assessment approaches.
3. METHOD

3.1. QUESTIONNAIRE AND INTERVIEW

This component of the research project involved interviewing stakeholders to obtain an understanding of what automation technology is already out in the market, what the developing trends are, what products they have been exposed to currently and previously, and their perceptions of limitations and drivers of the uptake of that technology.

To cover these issues, a questionnaire was developed that focused in particular on the human factors issues surrounding automated mining equipment. As this work was part of a larger project, the questionnaire also included questions aimed at understanding the social implications of mine equipment automation.

3.2. INTERVIEW PROCEDURE

Relevant approval was sought and received from the University of Queensland Ethics Committee in accordance with the National Health and Medical Research Council’s guidelines. Participation in the study was voluntary and interviewees were free to withdraw at any time without penalty from either their employer or the researchers. Interview information has been treated as confidential to the researchers of the study and all data collected stored in a de-identified format for analysis. Interviewees will not be personally identified in subsequent reports or publications with their written approval. Many interviews were taped with two researchers in attendance.

Researchers realized that industry-based interviewees may not be in a position to provide a significant period of time and provision was made for briefer semi-structured (non tape recorded) interviews, as deemed appropriate, for the successful collection of the required information. Some interviews were conducted by phone and some questionnaires were completed by email, but all followed the same procedure and asked the same questions.

3.3. THE PARTICIPANTS

Interviewees were selected from a broad stakeholder base in an attempt to gain as wide an understanding of automation technology as possible. In total, the study interviewed 17 stakeholders ranging from technologists and developers through to regulators and mine personnel of varying levels of seniority and including technology end-users.
4. HUMAN FACTORS AND MINING AUTOMATION RESULTS

Analysis of the interview results is presented below. To allow a logical structure, the uncovered issues were placed in broad categories related to different human factors concerns.

4.1. OPERATOR AND MAINTAINER DESKILLING

Potential deskilling of the labour force was perceived by the majority of the interviewees to be a real problem. This was thought to be of particular importance when dealing with new/unexpected conditions and the operator need to use knowledge-based behaviour to decide on a course of action.

A common theme with interviewees was concern regarding job security and fears that automation would replace and/or change job roles. Concerns were also raised as to the possible development of a skills gap between knowledge and ability (eg. a qualified technician may be employed but the operation may require an operator with higher order skills).

Another theme that arose was that miners are generally conservative by nature and have a belief that they are “unbreakable’. However, there was additionally an assumption that there was some pressure on them to “have to do something” regarding automation.

The time frame for automation introduction was also a common theme with most interviewees of the opinion that it will take many years to implement full automation successfully and safely.

4.2. OVER-RELIANCE ON THE TECHNOLOGY BY OPERATORS

Technologies were being used in ways not thought of by the developer. Also, there was an unexpected reliance on technology; often for tasks where automation was not intended by the developer to be used.

Interviewees commented that it was likely that assumptions would be made about what a piece of equipment could/couldn’t do. There was the possibility for operators to regard it as a “tool only”, or “switch off” from their immediate working environment. Additionally there was the need to balance trust in the technology being implemented whilst not having an operator over-reliant on it.

Concerns were raised about miners trusting the equipment and not seeing is as taking jobs away.

4.3. IMPORTANCE OF USER TRIALS

The importance of user trials to test the behavioural effects of technologies on actual operators was emphasized by most interviewees. It was noted that these should be iterative, such that the findings from the user-trials could be used to modify the technologies.
Concerns were raised about the limitations of existing systems and the need for robust systems to exist before roll out of new technologies would be successful. Often technologies can be innovative and difficult to use which leads to acceptance failures. This is often due to inadequate consideration being given to the human factors component of design, and interviewees were strongly of the opinion that the more sophisticated the system the higher the probability of failure became. The suggested solution to this problem was to “include the human in the loop” – that is “user centred design”, to ensure that the right problem was being solved rather than adding unnecessary complexity to the task by replicating aspects of the task, or by not considering the high mental concentration and dexterity required for some tasks, or by designing equipment and controls that were unsuitable for the environment in which they would be operational.

Other issues related to the changing role of miners and the need for a more multi-skilled labour force to support the optimal uptake and acceptance of new technologies without adverse effects. This was seen to require from developers a good task analysis prior to technology development to ensure how the task was done was translated correctly into the new technology. Interviewees expressed concern that current automation technology is not well thought through or designed properly and often implemented in an ad hoc manner with the expectation people will cope/know how to use it properly. This highlighted a need to rethink/redesign any implementation plan that was currently in place to include and address the skills shortage and testing to ensure workforce skill levels are adequate.

4.4. CHANGE MANAGEMENT PROCESSES FOR INTRODUCING MINING AUTOMATION

The process of managing how new, automated technologies is introduced into mines is of key importance (especially for human element considerations). For example, mixing manually controlled and automated vehicles on the same mine roadways is currently not acceptable. Existing mines might need to rely more on assistive technology (such as collision detection systems), whereas new mines could potentially operate with only automated vehicles.

Interviewees expressed the need for “top-down” management change. By nature mining is viewed as a conservative industry and the benefits of being the “first to market” often not a compelling argument to automate - with companies not wanting to be first, and happy to be second (having allowed another company to absorb much of the research and development costs associated with testing and implementation of new technologies). Mining is a high risk area and often the players are seen as not liking systems change.

Management “buy in” was seen by many interviewees as essential for new technology uptake, and key drivers for management were seen to be those most heavily focussed on decreasing front line liabilities – that is the need to see benefits in safety/efficiency/financial incentives, less workforce requirements, less industrial disruption, geopolitical issues. “Buy-in” limitations were felt to include the cost of research and development in contrast to unknown commercial benefits (eg. companies like Rio lead technology advances – whereas universities are not the leaders in technological development), and also the consideration of intellectual property protection. Concerns were also expressed about technology limitations/“unknowns” such as component software/design costs. Key drivers for new technologies were seen as cost, reliability and plant performance consistency, decreased human workforce (more for simpler tasks) and internal budget constraints. It was considered that generally the management view
of safety management operations remained productivity focused. Interviewees also commented on the need for the economy to drive uptake of new technologies – a large volume of sales was needed otherwise technology companies would hold back with products.

Those interviewed who worked with technology development indicated there was too much focus on technologies and not enough on human factor implications of the technology – suggesting more a gradual introduction of automation with backup offering a more reliable solution if and when problems occur. They felt the most likely scenario would be semi – automation leading to gradual introduction to fuller automation/remote monitoring and possibly with separate operations – as mentioned previously green sites were seen as more suitable to fully automated processes, but would these sites would still require people on site with the ability to provide fault detection systems/training required.

4.5. LEVELS OF AUTOMATION

Many of the interviewees recognized that there were different human factors challenges for different levels of automation. One important concept emerging was the notion of sliding autonomy. The level of automation depends on the task from full automation to full manual control. Human factors issues in the changeover between levels (e.g. human out of the control loop, situation awareness limitations).

Concerns were raised by interviewees regarding limitations in the communication infrastructure associated with automation processes. The concerns largely related to the need to remove the latency from the system so that operation was in real time. Interviewees also commented that automation was not “fail safe” and therefore a redundancy mechanism needed to be in place. They felt there was a rush to implement technology without ensuring the systems were assisted by people with the expertise to adequately manage the system, thus creating technology gaps, and there was little consideration at present for mobile operators who could provide support to operators immediately. Interviewees indicated a stronger link needed to be developed between users and suppliers.

4.6. POOR OPERATOR ACCEPTANCE OF NEW TECHNOLOGIES/AUTOMATION AFTER THEY ARE INTRODUCED

Interviewees recognized a skilled and informed workforce is needed to work with the new technologies automation or teleremote equipment will bring.

New technology acceptance was a concern amongst all interviewees, with issues such as maintenance costs, the availability of appropriate maintenance when required, the emergence of situations such as turning off of alarms, malfunctioning equipment and destroying/mistreating equipment all being discussed. Positive and supportive management was seen by all interviewees as essential for uptake of new technology introduction, and many highlighted the need to gain operator acceptance of the equipment and implementation of a system where the operator’s decision making powers and responsibilities were recognized and used rather than creating a system where it seemed technology was removing operator control.
4.7. HUMAN FACTORS IN MAINTENANCE

The main Human Factors in maintenance issues with automation were thought to be both the 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/interfacing with somebody controlling remotely.

It was thought that lack of skilling was relevant for both operators and maintenance workers on sites as experts could be located elsewhere to provide higher level cognitive/fault finding when things went wrong. Concerns were raised regarding lack of adequate maintenance and servicing of the equipment and installations. Interviewees considered fault finding tasks and access gained to equipment for maintenance would remain and therefore significant design aspects could not be overlooked in favour of automation/equipment control issues.

Interviewees believed there was currently a lack of expertise available to teach and guide the mining industry on how to operate, maintain, use and get the most out of the technology. They also commented that any ongoing technical failures with equipment /maintenance issues would result in industry /miners losing faith in equipment use.

It was generally considered that the next generation of mining personnel would be much more familiar with technologies (more interface friendly). The current approach was thought to be very “mechanical” in thinking, and possibly creating a “roadblock” with new ideas needed. Interviewees commented that future maintenance operators would most likely be younger and with mechanical knowledge (possibly fitters and turners) but also would have inherently more knowledge of technology/computer use. It was envisaged that off site “smart assistance technology” would be available.

4.8. POOR HUMAN FACTORS DESIGN OF EQUIPMENT INTERFACES

Generally it was recognised that human machine interfaces for mining automation should be developed according to best practice user-centred design methods and findings.

This was seen as being of particular importance when operators may be potentially controlling multiple vehicles rather than one. This situation presents unique Human Factors challenges in which the role of the operator changes from being the active controller to being a passive observer much of the time and only being an active controller at key points (e.g. during dumping for haul trucks). Interviewees indicated the main driver responsible for this was the mining companies. Whilst routine parts would be automated (e.g. during haul - where the operator only maintained supervisory control) other components such as loading were more demanding and most likely needed to be manually controlled.

It was agreed by most of the interviewees that the equipment needed to be generic to allow various existing systems to connect/merge with the initially implemented mine system. It was considered that unless the equipment was well designed will there would be assumptions about what it could or could not do and users may regard it as a “tool only” or “switch it off. It was considered that human error can’t be overcome, but only minimized/managed through ergonomically designed interfaces and concerns were raised that some technologies may create an increased reliance on the device while the basic hazard remains. Interviewees were
INTERVIEW RESULTS: EMERGING TRENDS ON THE HUMAN FACTOR ISSUES REGARDING AUTOMATED MINING EQUIPMENT

Concerned about a lack of real understanding and technical support for management of technologies during the life cycle of the system and plant decommissioning.

Concerns were raised about how to employ people at the automation interface, including the ergonomics of control rooms – distraction/disconnection from working groups, and the need for connectivity in real time (transmitters, radar, remote diagnostic linking ability – smart systems caching the information).

One interviewee asked “How do you fix a break down in a remote part of the mine? (e.g. “in a stope – if equipment is used remotely it can go into places that may be high risk for people to go to - what if it breaks down there – remote or try and pull it out?...often a job left for the stope fairies.....”).

4.9. PROBLEMS WITH INTEGRATION OF MULTIPLE WARNINGS/ALARMS

Several interviewees commented that visual information is the most dominant form of feedback in the mining sector followed by sound; often situations arose where both modalities were essential.

Interviewees were concerned that equipment and controls design may not be suitable for real mining people on site, and issues such as environmental operating conditions which may affect equipment operation and reliability may not be given adequate consideration in the original design.

Operator mental overload or distraction with the introduction of multiple warning and alarm systems and difficulty in coping with repetitive tasks requiring high mental concentration and dexterity were also common themes in interviewee feedback.

4.10. LACK OF EQUIPMENT STANDARDIZATION

A number of interviewees commented that it would be difficult to standardize equipment across mine sites and companies. It was thought inconsistencies would arise if displays were not consistent across different pieces of equipment; errors would be more likely to occur and comment was made regarding the need for design and iterative testing with the relevant operator/maintainer population. The issue of trying to make generic connections to various existing systems/trying to merge various systems was a common theme with interviewees, and some interviewees felt that it was not unwillingness on the part of mining companies to take up the technologies, but these the issues around adequacy of support systems that was slowing implementation.

Other interviewees (particularly technology developers) commented that the more sophisticated the equipment, the higher the probability of failure, and this increased the difficulties associated with standardizing equipment.

Some interviewees expressed concerns that environment conditions differ between mine sites and may not be considered initially in technology development. It was thought this could lead
to inadequate maintenance and servicing of the equipment and installations in more remote areas.

4.11. A NEW DEVICE BEING ESSENTIALLY IRRELEVANT TO THE TASK

Some interviewees expressed concern that devices would be developed that were not required, and essentially provided no task assistance to the operator. These devices could be seen as bringing unexpected problems and safety issues into play.

Other interviewees expressed concern that whilst sophisticated computational frameworks were required to deal with uncertainties of the automation process, this often added to the complexity of the overall system which in turn resulted in a higher probability of failure of the equipment. Concerns were also raised that environmental conditions which could affect equipment operation and equipment reliability may not be considered.

4.12. INADEQUATE OPERATOR AND MAINTAINER TRAINING AND SUPPORT

The main issue emerging was the need to ensure ease of operation and maintenance of equipment, and that risks associated with interacting with the equipment were designed out as far as possible.

Interviewees indicated that with new automated equipment, the associated technologies would require different operator skills and different ways of working compared to current and past practices. Training for new equipment would be challenging in that there was uncertainty around the type of equipment that would be used and, therefore, uncertainty around the knowledge and cognitive skills that would be required to undertake problem solving, such as, fault diagnosis or the correct response in an emergency situation. Training would need to reflect the skills required to undertake the more complex work and skilled people are required to support the systems. It was thought operators would need training in computer software use before comfortable with new technologies – otherwise this may lead to reluctance to work in a computer environment (too much information – mental overload).

Interviewees also expressed concern regarding the level of basic and additional skilling operators and, in particular, maintainers required when considering the uncertainty of the type of equipment of the future automated/teleremote mine. They envisaged up-skilling would be required to manage remote/automated mining but there would remain a need to be able to drive the machine (expert skills/diagnostics). A particular area of concern was the method of delivery of training (“on the job” or virtual reality simulation) and the ongoing maintenance of training levels.

It was believed only 3-4 countries (Australia, US, Canada Chile) could currently support the infrastructure needed for automation. Interviewees commented that other mining countries were held back by either infrastructure or cultural limitations. They considered the technology available in Australia still not mature enough and the people not skilled enough to use it. Another area of concern was that technology implementation is expensive and failures amplify/work against it.
However, it was believed that future mining would attract a generation familiar with technologies, so the industry must look at the skill levels of this generation and capitalize on skills.

Many interviewees commented that inadequate emphasis was placed on human factors issues in the conception of technologies – in particular operator interface design.

Interviewees felt there was a real possibility of a significant skills gap between knowledge and ability (i.e. a technician by training but the task may require an operator with higher order skills). Interviewees envisaged a significant level of support would be required in this area. Appropriate training for maintainers and operators and an awareness of the limitations of their training were two key areas highlighted by most interviewees. Comment was also made that technology may need to service mobile operators – indicating the need to be flexible in providing assistance, and it will need to be delivered in real time to where the operators are located.

Interviewees believed there was an issue with miners trusting the equipment - a need ensure it was not seen as taking jobs away. It was acknowledged that automation could make the task more complex and therefore 3D and virtual training opportunities would be needed. Uptake was seen as being limited by what can be used/what is wanted – (eg. many mine control rooms operators do not have the level of needed for operating more complex equipment so need would be a need to introduce slowly and gauge take up rate).

Concerns were also raised about the lack of adequate maintenance and servicing of the equipment and installations – highlighting the need for significant and positive links between users and suppliers.

4.13. ORGANIZATIONAL ISSUES

As is often found for automation in many domains, introducing new technology often changes the nature of the tasks to be performed. Thus, a careful analysis of the new tasks is a vital early step in ensuring that organizational issues are addressed.

Interviewees recognized issues such as fatigue, shift work (in particular night shifts), autonomous work teams and supervision as areas requiring specific consideration in technology development. Some interviewees expressed the opinion that the drivers for technology development are productivity more so than safety, and therefore not enough attention was being paid to issues of vigilance, monitoring and deskilling of the workforce.

4.14. MISCELLANEOUS HUMAN FACTORS PERSPECTIVES

A raft of other issues was also raise by one or more interviewees. Although they did not easily fit into the above categories, they were still judged to be worth reporting here. In summary,

- The need for qualitative measures, rigorously determined and not simply operator feedback – also a need for defined data (e.g. as available in the aviation industry, defense services, nuclear industry - industries more mature from a human factors
perspective where qualitative data has been collected on issues like fatigue/multiple alarms).

• There is already a recognized industry need for improvements in operator health from certain exposures (dust, noise), but automation leads to new exposures such as sitting and looking at computer screens, confined spaces/lighting issues, fatigue in the control room situation (less stimulus to remain alert, job satisfaction, rotation of tasks) How will these issues be identified and addressed?

• The main concern remains - getting people out of a dangerous environment (e.g. off continuous miner) but maintenance will still need to be done manually. Automation hasn’t decreased the number of people underground, rather has changed their roles, how will this be addressed and will it cause more problems?

• Different cultures may need different types of automation. The often a highly-educated workforce such as the Australian workforce may have quite different user-requirements from, for example, the South African one which may not need as high a level of skills or technology but can learn to be equally productive. How will these issues be addressed?

5. VISIONS OF THE “FUTURE MINE”

As with the human factors interview results presented in Section 2, the interviewees’ visions of a future mine have been placed into a number of broad themes.

5.1. SAFETY

As could be expected most interviewees indicated that a safe mine was of paramount concern in their vision of a “future mine”.

• A safe mine where people can be replaced as much as possible – i.e. getting people out of a dangerous situation. An ideal situation would be production without anyone in a hazardous zone and maintenance without potential for manual tasking – i.e. systems in place to manage equipment without humans harmed in the process. There will always be maintenance issues but understanding the high risk areas and implementing appropriate preventative strategies will increase safety – i.e. wide level good roads; people being kept away on foot from big gear (trucks, loaders); maintenance incorporated into system using skeleton staff (possibly larger) on site to provide maintenance.

• A mine that would leave the environment largely undisturbed using mining techniques that don’t interfere with environment - a “clean” mine.

• Need for significant risk analysis and flag areas of human areas of concern, i.e. ideally eliminate/take over repetitive tasks, and other highly hazardous tasks such as gas monitoring etc.
5.2. NON AUTOMATION ISSUES

Whilst many of the responses focussed on automation related issues, interviewees also emphasised the need proactive mine planning and for technology developers to ensure they understood the needs of their customers and were developing technologies that met those needs.

- More communication is required between developers and the mining industry to show the real capability of current technologies that can be used. Developers must spend enough time on mines sites to understand the real needs, issues and challenges in deploying the technologies to ensure customer satisfaction and commitment for further development and improvement.
- Proactive scheduling (higher level – need information) to predict failures before they occur (cognitive skills).

5.3. PATHWAY TO AUTOMATION

Many interviewee responses focussed on how they envisaged automation would be introduced onto the mine site of the future. Some expressed the idea of a quantum leap in sensing, planning and operation of the “future mine” with remote supervision while others indicated that implementation would be gradual and there would not be a “peopleless mine” in the foreseeable future. Many expressed concerns around maintenance issues and the workforce skills and knowledge required to cope with automated technologies. In summary, the emerging responses were:

- Not as much variation in future implementation, but rather a gradual implementation with ability to revert to a level of operator control when things went wrong started to go wrong. Future trends were viewed largely as an operator assisted environment with automation of some equipment – e.g. LHDs, trucks, drills, shovels, possibly dozers (diggers were felt to be too complex for fully automated operation).
- There will be no “peopleless mine” in the near future – as currently too much of a technology gap exists to provide optimal efficiency required for this method of operation.
- There will be a move to a higher level of supervision (less mindless repetitive work, but humans to do what machines don’t do well). This will involve “keeping humans in the loop” – making a judgment about balancing the level of machine control leading to a more efficient process with providing rewarding, fulfilling and safer work for humans.
- A gradual shift to virtual apparatus is envisaged – largely driven by the bigger mining companies, and including Virtual 3D and eventual integration of operation and control leading to more efficient running with lower environmental impact but digging more.
- A quantum leap that provided a greater level of understanding of the physical environment/infrastructure/product (location and characteristics) could then result in invention new ways of mining/extraction/processing which would lead to changes in mine design and production. Interviewees envisaged a system where sensing, planning and operation used telepresence.
- A system where the machine was set to work and operation continued under remote supervision with enough information in the appropriate format to allow the operator to make intelligent decisions, but also allowing the operator control when necessary. Many interviewees envisaged more mobile equipment with fewer operators, that is a
“top – down” view with machines working knowing what to do - e.g. remove a pile of dirt but not whole seam. It was envisaged this would require a very high level of supervisory control (not necessarily at mine site level but most likely remote controlled).

- Maintenance issues were of significant concern with rapidly changing technologies creating uncertainty around what equipment would be in operation, both from a systems and technology perspective. An ideal scenario would be to have systems in place to manage equipment without humans being harmed in the process – i.e. production quotas met but achieved by removing people from hazardous areas, however across all interviewees, maintenance issues were seen as a difficult problem to solve.

- The possibility of the maintenance workforce being located at the mine site with gradual changes towards achieving a situation where the mine operators are mining engineers.

- Educational issues for automation technologists were seen as one of the major concerns with new technologies – currently a significant gap exists between technology and users. Skill levels were of concern, highlighting that technicians can be trained for specific technology applications, but engineers will still be needed to interact with the technicians. Interactive and user friendly technology in synchronisation with normal human behaviour was seen as an ideal outcome. The practicalities of automation were raised - e.g. no electricity means no technology - therefore no production. This is an important factor in remote areas.

5.4. HUMAN FACTORS IMPLICATIONS

A consistent theme across all interviewees was unless human factors are deliberately part of the technology then the technology will fail. They felt there was a need for greater consideration of human factor implications in the development of emerging technologies and most significantly to look at the cognitive aspects and devise programs/equipment that would support and not hinder operation.

Interviewees with a more technical indicated that the concept of automation is now “too old” and argued that more significantly we need to ask “how will we get there?” Their view was that large scale automation will fail unless change is incremental, flexible and can be customized, that is, to include areas such as mine mapping & planning, and to provide information on productivity issues for successful implementation. Human factor implications largely depend on the social values applied such as variable acceptance of jobs available, however they felt better uptake will be achieved if enough forewarning is provided.

Another dominant theme emerging concerned not having automation as the sole focus, and they felt whilst it will play a role it is only one element of the whole picture and “tele-assistance” may be more appropriate to consider. Again, as in the above theme interviewees indicated there is a need to “look outside automation box” to include planning, logistics, finance, customer-trainer loop, and tele-collaboration.

Concerns were raised that the human-machine interfaces needs to be suitable for the human capability and physical behaviour, and that is designing the technology to suit the person (and not the other way around) to ideally develop suitable and fit for purpose automation technology that separates persons from the mining hazards.
Many interviewees considered multi-tasking will become more common — therefore those working with future technologies will be required to take on different roles as needed (linkages between key people will become essential). There was the view that the complexity of the equipment meant would most likely not be “trades people” who will require as technical support.

Some of the interviewees thought it would be those with experience in artificial intelligence/technologies who will hold key responsibilities as it is foreseen key experts will be required who understand the mine site and can deliver the service required (possibly via network capabilities). It was thought technologies will need to be customized and site specific to optimize function, and this may/may not be confined to automation skills, but it was mostly thought that it was likely include other skills such as such as finance and management.

Many interviewees were of the opinion that depending on the social values applied, there will be variable acceptance of job availability, however better uptake will be achieved if sufficient forewarning is provided. Maintenance operators were thought most likely to be younger workers with inherently more knowledge of technology/computer use and mechanical knowledge – a possible scenario being fitters and turners working onsite with real time off site “smart” assistance technology available to them.

A fear expressed by interviewees was that “too much automation would mean humans would lose their capability to deal with the environment” (for example the ability to function in extreme temperatures, biological weakness to fight infections/illnesses). In addition there was discussion around the demands of automation and the probability that it required greater intellectual capacity and concentration which in turn may induce mental fatigue or impose other cognitive limitations. The issue was raised that automation may create a gap in knowledge of how things work and how can be repaired/maintained.

6. CONCLUSIONS

The research presented here has focused on the opinions and experiences of a wider range of stakeholders. Each interviewee had experience with various facets of mining automation, and had thought deeply about many of the issues involved.

From a human factors standpoint it is pleasing to note that a range of human element issues were reported. Many of these match the ‘classic’ human factors and automation issues found in similar domains (such as defence, aviation or medical), these include poor operator acceptance of technologies, possible deskilling of operators and over-reliance on the automation. However, issues that were specific to the mining industry were also reported, such as: lack of specialist skills in maintenance of automated mining equipment in remote areas, or cultural differences in response to automation in different mining regions around the world (eg Australia vs South Africa).

Similarly, many interviewees had expansive and deeply thought-through visions for a future mine. Safety, sustainability and a focus on improvements wider than just automation (eg intelligent logistics and planning) were frequently mentioned. From this, some of the issues/scenarios that would be investigated in the next (fieldwork) phase of the project include:
• Haul truck/LHD breakdown, and how this is resolved in a future automated mine.
• Alarms – the potential overload issues for operators controlling several pieces of equipment.
• How the technology/automation is introduced.

This interim report was designed to be read in conjunction with its sister report that was a literature review of human factors and automation (including best practice in other comparable industries). Both of these reports form the bedrock upon which many of these skills and human factors issues will be explored by means of conducting fieldwork at a prototype Integrated Control Centre that is being developed by a major mining company. The expected results will provide insights into the human factors aspects of the application of automation and remote mining technologies on mine sites, including the skills/capabilities required to operate and maintain the technologies. The ultimate objective is to develop a broad ‘technology assessment’ approach to design, deploy and evaluate automated mining technologies, considering user-centred design of these technologies.