Fight or Flight Group 3 Status Paper Emergency Support and Research
Presented by Russell Uhr

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In October 2006, an emergency response seminar was held in Emerald. This seminar was named Fight or Flight (the first 5 Hours). This seminar was organised by the Chief Inspector of Coal Mines (CICM) Queensland in response to ongoing recommendations and issues raised from the Queensland Level 1 Emergency Exercises as well as two explosions at underground coal mines in the USA, namely Sago January 2006 and Darby Mine May 2006. There appeared to be issues relating to emergency evacuation, first response in all of the cases. The intent of the seminar was to identify all of the issues which were perceived to be relevant and formulate a methodology to address and resolve them. The aim is for a standardised emergency response across the mining industry whenever possible

Industry professionals from Queensland, NSW and New Zealand attended this seminar. There were guest speakers from the USA. Full details of the proceedings of the seminar are available from the CICM Queensland. The issues raised at the seminar were documented and fell in to three groups:

1. Self Escape
2. First Response
3. Support and Research

Volunteers were sought from industry to take part in each of the groups. This paper is the status report from Group 3 “Support and Research”.

Group 3 was to address the following issues and the group was split up into smaller working parties to investigate the options and report back at the Group 3 meetings. The purpose was to investigate what, if any, research had already been conducted and what commercial applications were available to solve any of the issues raised. Group 3 was also to investigate matters raised by Groups 1 and 2.

- Protocols for external support (outside s.55) for emergency response and management
- Legal accountabilities for external persons providing assistance
- Use of flame proof (FLP) diesel vehicles in elevated methane atmospheres, legislation changes
- Allowing use of other non-approved item or activity in an emergency
- Define minimum requirements for diesel emergency response vehicle and
- Include options for optimal functionality and using Compressed Air Breathing Apparatus (CABA) while operating
- Post incident tracking system
- Post incident communications repairs
- Communications practices in outside industry, text messages
- Find a robust wireless two-way (and video) communications system
- Determine operational requirements for large diameter borehole drills and availability of apparatus to evacuate persons from underground

- Develop educational tool for mine characteristic modelling
- Standardised support facilities, internet, smart boards, external experts/providers
- Characterise best practice in mine emergency response linking with a mine's first response
- Standardisation of Mine Emergency Management System (MEMS) and identify risks if not endorsed
- Opportunities to improve application of GAG in all or parts of mines
- Process to identify persons with abilities to competently supervise persons while under stressful emergency conditions
- Sub Committee 1 Breathing simulator – resistance and heat

Group 3 was not asked to conduct actual physical research but to identify where there was a requirement for industry to fund research to solve a particular issue. An example of this was a referral from Group 1. This group identified a need for a self contained self rescuer (SCSR) simulator which could be used at all mines to provide the opportunity for all personnel to regularly experience the breathing resistance and temperatures of SCSRs. Simtars has subsequently applied to ACARP for funding for such research.

Some of the referred issues to group 3 had already been investigated as part of the ACARP research programme. It is evident that either the messages are not getting to industry or there is a reticence to adopt them. This in itself merits further investigation.

This update presents information on the current status of the following:

1. The legal responsibilities of personnel responding to a mine emergency.
2. The use of vehicles and other non-approved apparatus in an emergency/special circumstances.
3. The minimum requirements for a diesel escape vehicle.
4. Post incident tracking systems and robust two-way radio systems for use in underground coal mines.
5. Large diameter boreholes for mine evacuations in an emergency.
6. Mine Emergency Management System (MEMS).
7. Use of the GAG in inertisation.
8. SCSR simulator.
9. Emergency management and decision making/communications.

1. The Legal Responsibilities of Personnel Responding to a Mine Emergency.

The *Coal Mine Safety and Health Act 1999* imposes obligations on all persons at a coal mine to ensure that they do not expose themselves or others to situations of unacceptable risk. This applies to all employees, contractors, manufacturers, suppliers, consultants, etc. It is certain that these obligations apply to all persons involved in emergency response at a coal mine site. Due to the nature of an emergency, persons who are not covered by the groups mentioned may be exposed to legal actions following decisions made in an emergency.

While rescue team members are included in the CMSH Act and the Mines Rescue Agreement, persons who assist in an emergency, such as unpaid experts assisting an Incident Management Team (IMT), could be held liable in law for any decision, advice or technical analysis given to IMT.
In the larger context, Emergency Responder or "Good Samaritan" arrangements cover these liabilities for persons operating in broad community response situations. In general, providing these persons act in good faith and with due consideration of risk, they are not likely to be prosecuted in the event of an untoward event as a result of their decisions or advice.

It is considered imperative that similar arrangements are endorsed for persons involved in mine site emergency response. The committee recommend that current mining legislation be amended to provide for these classes of persons to be exempt, under conditions of good faith and sound risk management principles, from prosecution following any unexpected result in an emergency.

This can be done by additions to the current CMSH Act, based on recommendations from the Committee being accepted by other industry stakeholders including the Mines Inspectorate, the unions and the mine operators.

2. The Use of Vehicles and Other Non-Approved Apparatus in "Special Circumstances."

It is recommended that a submission be prepared for consideration by the Legislation Amendment Review Committee seeking the introduction of a new s30 (4) into the Coal Mine Safety and Health Act 1999.

This new section to give the SSE the right to seek relief from section s30 (3) of the Coal Mine Safety and Health Act 1999 under Special Circumstances involving the saving or preservation of lives or in circumstances where no persons are underground.

The purpose of this new section will be to allow the use of vehicles (flameproof or otherwise) to evacuate personnel through atmospheres containing greater than 1.25% methane, deploy non-certified surveillance, monitoring or communication technologies and allow the use of remote, robotic or autonomous reconnaissance technologies in cases where no persons are underground at the time and no lives are to be put at risk by such deployments.

3. The Minimum Requirements for a Diesel Escape Vehicle.

Simtars, under the auspices of the Queensland Mines Rescue Service and ACARP, investigated development of a mines rescue/escape vehicle. This involved investigating the operation of underground coal mine personnel transport vehicles in non-standard mine atmospheres.

The first stage of the project (ACARP C12002) resulted in a design specification for a vehicle to assist in the aftermath of an underground coal mine emergency. The second stage of the project (ACARP C12002 extension) involved testing diesel engines in a variety of atmospheres, consisting of up to 4% methane and low oxygen concentrations produced by the introduction of extra carbon dioxide and nitrogen. This second stage proved the feasibility of using normal diesel engines in such atmospheres.

The principle objective of the third stage (ACARP C14024 Mines Rescue Vehicle Demonstration Phase) was to utilise the information gained in stage one and two of this project to modify an existing mine personnel transport vehicle. The vehicle incorporated modifications in the form of extra features including a high-speed methane analyser and a sonic navigation device.

Phase 4 of the investigation (ACARP C15029) was completed in June 2007. The objectives were to test the range of engines currently used in personnel transport vehicles in underground coal mines in high levels of methane by:

1. Determining torque and power characteristics at various methane / air concentrations covering the explosible range to the practical limit
2. Determining controllability in terms of throttle response and ability to shut down the engine.
3. Investigating the controllability in respect of well worn and reconditioned engines
4. Determining impacts of this testing on relevant engine temperatures.

A fifth stage of the project has been proposed (ACARP 05/0045) a scoping study for a mines rescue vehicle. This involves the accumulation of data, mine-site identification of diesel transport vehicles maintenance programs, issues arising from the vehicle maintenance, to view and obtain data on the vehicle history of use and maintenance issues while in service

It is also intended to audit and obtain data from the Original Equipment Manufacturers (OEMs)' and overhaul workshops of the diesel transport vehicles regarding vehicle conditions when received as either "trade-ins" or for overhaul and refurbishment.

The scope of the project extension will include obtaining and documenting both mechanical and electrical maintenance issues which affect the "flameproofness" of the diesel transport vehicles.

Given the outcomes from the four phases completed and discussions around the hazards associated with using such a vehicle, it is recommended that the following be adopted as the minimum requirement for a diesel escape vehicle.

1. The vehicle should be flameproof
2. Emergency shut down device linked to the air intake
3. On board air supply for driver and occupants

4. Infra red methane analyser
5. Sonic navigation system with links to mine site positioning devices and updated mine plan to assist in evacuation
6. Intake flame arrestor device.

It is intended that the vehicle should be able to operate independent of any mine site communication device.

4. Post Incident Tracking Systems and Robust Two-Way Radio Systems for use in Underground Coal Mines.

A range of technologies are currently available or under development for personnel tracking and communications. These technologies are summarised in Table 1.

Following the Darby, Sago and Alma mine disasters in the USA in 2006, the Mine Safety and Health Administration called for technology manufacturers to submit for testing various tracking and communication technologies. They received over 80 proposals[1] MSHA reviewed the proposals, first screening for systems that do not rely on a wire back-bone to operate, thereby increasing their chance of remaining functional after a disaster. They then looked at the different types of technology being proposed, e.g. wi-fi mesh network, ultra-wide band, medium frequency, and low frequency, as well as the function of the technology, e.g. miner tracking, through-the-earth, and in-mine communications. From this the candidate technologies were classified into groups to ensure that each major group would be included in the first round of in-mine testing. Additionally, MSHA examined the proposed technologies for evidence that the systems could be commercialized within a reasonable timeframe. Seven communication systems were initially selected for preliminary field tests based on the criteria above as being the most promising for application in underground mines. One of the manufacturers subsequently withdrew from the trials.

Tests of the remaining six technologies where then conducted at CONSOL Energy's McElroy Mine near Moundsville, West Virginia. In general, the testing sought to determine, in-mine line-of-site communication capability, in-mine non-line-of-site communication capability, tracking capability (if part of system), and through-the-earth (TTE) communication capability (if part of system). The results of these tests have been published with a copy the full report available at: http://www.msha.gov/techsupp/McElroyMineTestreport.pdf

A brief summary of the technologies tested follows[1] –

I. <u>Subterranean Wireless Electronic Communications System (SWECS)</u>

SWECS is being developed by Kutta Consulting for the U.S. Army Communications and Electronics Research, Development, and Engineering Center (CERDEC). The system consists of a digital radio, a PDA type of display and a small, portable antenna. The system is designed to provide two-way voice, text, and image transfer through a stationary multi-node network and through the earth. The nodes establish an adhoc mesh network which will provide redundancy in case of individual node failure. Portable units will communicate with the stationary nodes and peer to peer. A key feature of this system is the use of a Software Defined Radio (SDR). The SDR will allow transmission and receiving of signals using several different frequencies.

The SDR allows SWECS to transmit node to node or node to hand-held at a frequency determined to work best underground (or to work with existing systems such as leaky feeder radios), and then switch to a low frequency in order to transmit data through the earth to a matching node on the surface. The node on the surface will need to be above the underground node to within a certain radius, but that distance has yet to be tested. The system can also be configured such that in an emergency, if multiple nodes are disabled, the node to node transmission can be via a lower, earth penetrating frequency that can hop over the disabled nodes, even through a major roof fall, in order to re-establish the network link.

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[1] *Mine Emergency Communications Partnership Phase I, In-Mine Testing*
0-www.cdc.gov.mill1.sjlibrary.org/niosh/mining/mineract/pdfs/phase1testing.pdf

II. Axon Wireless Mesh Networks

The AXON module from Innovative Wireless is a transceiver module that is designed to work with the IEEE 802.15.4 specification. It is deployed as an ad-hoc mesh network. Fixed nodes are stationed throughout the mine while individual personnel will carry hand-held units. It claims to be capable of both wireless data transmission and real-time tracking; voice and text capabilities are planned. The nodes are designed to run both ZigbeeTM and SynaptrixTM, which is an Innovative Wireless proprietary mesh-networking software stack. There are 2.4GHz, 915 MHz, 433MHz and Ultra Wide Band (UWB) modules available. A Graphical User Interface (GUI) is used for a visual tracking display and for remote access to communications between nodes.

III. Rajant BreadCrumb System

The Rajant BreadCrumb System consists of nodes that utilize the IEEE 802.1 lb WiFi networking standard at 2.4 GHz. The nodes are portable and can operate on line power or with battery backup. Several nodes combine to create an ad-hoc mesh network. The network can be deployed as a stand alone wireless network within a mine or may be connected to other networks on the surface with communication links outside the mine such as satellite modem, DSL, cable modem, etc. The function of this system is comparable to a Local Area Network in an office setting, with the advantage of completely wireless communication.

The BreadCrumb system is currently used by the military and police, SWAT, fire fighters, and other first responder agencies in the US. It has also been used to establish communications in areas that have experienced natural disasters.

IV. Time Domain/Concurrent Technologies Corporation Ultra-Wide Band Radio Communications and Tracking System

The appeal of Ultra Wide Band (UWB) radio is that it is a different technology as compared to other systems being evaluated. Other systems implement communications by using one frequency or another (narrowband), going up and down the frequency spectrum depending on the desired result, i.e., from low frequency for through the earth to high frequency for large data rates. Narrowband signals are continuous sine waves spanning a few MHz while UWB signals are short pulses that contain many GHz of the radio spectrum. The result is high bandwidth but low energy on any one frequency. The energy is spread enough that UWB resides below the noise floor so interference from and to other RF systems is negligible. UWB systems are inherently low power which will help in designing components to meet permissibility requirements.

Time Domain builds radios that use UWB signals as compared to conventional narrowband radio signals. The Time Domain system spans frequencies of 3.1 to 5.5 GHz. This system can be used to build a wireless network similar to an 802.11-based LAN system. A network of stationary nodes would need to be in place in the mine to create a wireless network. Each miner would carry a radio that would act as a communication device as well as a tag for tracking purposes. The radios can communicate peer to peer as well as hand-held to node. Using range information from nodes to hand-helds and known node locations, precise locations of hand-held devices can be found.

V. Transtek Telemag System

The Telemag system is a two-way, real-time prototype communication system that uses very low frequency (<10kHz) signals to transmit through the earth. The system allows individuals to talk between the underground and the surface without a hard wired connection outside the mine. The system has identical surface and underground units that use a loop of wire to induce magnetic waves and penetrate deep into the earth

VI. Geosteering's Minertracker

The Geosteering Minertracker is a tracking system that uses the existing field generators and personal alarm devices (PAD) that were developed for use with Geosteering's TramGuard proximity protection system which has been MSHA approved. Each miner's PAD communicates via UHF to field generators located at various points around the mine. The field generator will then transmit the ID numbers of each PAD that it is in contact with through the earth using very low frequency (<10kHz) signals to surface mounted receivers. Each PAD and field generator will have a unique ID; by knowing which field generator the PAD is in contact with as well as each field generator position, location of the PAD can be determined. Using buttons corresponding to certain messages, information can be sent from the PAD, through the field generator, to the surface. The system will use line power and have a back up battery.

Future Developments

The technologies listed above are currently undergoing further testing, modification and MSHA approval modification and certification. These Phase II tests involve full demonstration programmes on mine-wide basis to determine potential vs actual performance. The results of these full scale demonstrations are scheduled for completion in 2008 with the results eagerly anticipated

It should be said, however, that all of these technologies have shortcomings, limitations or unproven capabilities. Australia is well recognised as being at the leading edge of technology development in this area and its mining industry has a long established history in the implementation of state of the art safety and communication technologies. To further this history, there are a number of exciting developments underway within Australia's R&D and Technology Services sector. The application of energy scavenging technologies coupled with advanced materials, embedded sensors, infrastructure autonomous micro-electro-mechanical systems and growing demands by operators that the installation of these technologies be minimalist, or be part of the normal operations of the mine's production cycle, provides a Design Basis Criteria for the development of the next generation of communication, data transfer and equipment and personnel locating technologies.

5. Large Diameter Boreholes for Mine Evacuations in an Emergency

The use of extraction capsules raised by portable or fixed winders to rescue persons trapped underground in an emergency has been proven in other countries. It is not unreasonable to consider their use in Queensland as an additional tool for certain circumstances.

In the USA, such items are part of the Mining Safety & Health Administration (USA) MSHA response program, and were successfully deployed for the recent and much publicised rescues. South Africa has a similar response capability that has been used successfully in an emergency response.

It is proposed that a capability be set up in Queensland that includes a mobile winder and one or more rescue capsules, to be owned and operated by Queensland Mines Rescue. Such equipment can be modelled on the existing overseas designs.

Of more concern to the committee was the possibility of post-incident construction of medium diameter boreholes into affected mines. Given the minimum 400 mm diameter requirement for successful operations, borehole and shaft construction companies were surveyed in early in 2007 to determine the practicality of putting boreholes into a mine post incident.

No company surveyed could drill such a borehole without the use of drilling fluid, which would be unacceptable, if not impractical. The more logical and practical method would be to have rescue boreholes created at strategic positions in underground mines to allow rescue deployment of the winch and capsule.

With this in mind, the committee recommends that each underground coal mine be required to perform a risk assessment to determine the need and possible location(s) for such rescue boreholes, and also any requirements for additional equipment and facilities to be available for identified emergency situations. This may include changeover or refuge stations near the borehole, communication links, etc.

6. Mine Emergency Management System (MEMS) Status

Underground mines in Queensland participate in a mutual response system organised through the Queensland Mines Rescue Service (QMRS). In 2004 there was a move to adopt the Incident Control system (ICS) used by the Emergency Services for dealing with catastrophes. QMRS adopted the process and prepared the MEMS course based on the principles of ICS. To date over 80 personnel have been trained in MEMS with the mines with most trained personnel being Broadmeadow, Grasstree and Oaky North. Kestrel Mine has trained personnel in the ICS process. Of the three mines which have used MEMS/ICS for their incident response at the Level 1 Exercise there was an improvement in the incident control, however, because they had not got sufficient numbers trained in the process and had not practiced the net result was still poor.

Kestrel mine has used the process for several mock incidents at site and found it beneficial. Broad onsite acceptance of the system has developed to the stage where the tools and structures are used routinely in the management of operational and low consequence incidents. This familiarity with the system out side of an emergency situation will hopefully lead to successful deployment if ever required at a critical incident.

Risks if MEMS/ICS is not endorsed.
The application of a Mine Emergency Management System (MEMS) ensures that all vital management and information functions are carried out and that an incident is dealt with in the most effective manner.
If a mine site does not employ a system to manage an emergency, a variety of problems will inevitably be encountered. They may include:

- Competent control not being established
- overload of individuals and fatigue
- inappropriate action being taken by personnel working without direction/supervision
- delayed or inappropriate decision making
- no plan being established to combat the incident
- time delay in response
- communication problems being encountered
- safety of personnel being compromised
- ineffective planning
- no or poorly planned and implemented changeovers

If we don’t make change we will still get what we all ways had in other words Fail to Plan, Plan to Fail.

7. Use of the GAG in Inertisation.

QMRS has submitted an ACARP proposal to address the issues of the GAG applications. A précis of the application is:

The primary focus of the proposed project will be on developing systems involving borehole delivery of GAG exhaust through docking to pre-drilled surface boreholes into underground workings. The study will examine attainable designs for panel boreholes and how the GAG docking to boreholes can improve delivery of GAG exhaust. A series of GAG operational tests will be undertaken on the surface to examine operating constraints of the GAG and its behaviour in handling exhaust back pressure generated by the relatively small diameter borehole. Measurements from tests will be compared with the theoretical predictions derived from thermodynamic theory. Any use of the GAG must examine its interaction with the complex ventilation behaviour underground during a substantial fire and fire simulation exercises will be undertaken using Ventgraph software.

The project aims to examine the possibility of a wider and proactive application of GAG in Australian mines during final closure of mines or mine sections, in response to or recovering from mine fires, for spontaneous combustion heatings or elimination of the potential explosibility of newly sealed goafs. Inertisation systems for handling these underground situations have been accepted as important safety approaches within the Australian industry. Sponsoring mines will have both a detailed design developed for specific borehole locations appropriate to their mine plan and simulation scenarios developed on how GAG exhaust could be utilised in elimination of the potential explosibility of newly sealed goafs or in combating goaf spontaneous combustion heatings.

Objectives

ACARP C14025 project on inertisation has recently been completed. This project was in many ways a scoping study for actions planned in this project. Three of the main conclusions from this project are the objectives of this proposed project

- Positioning of the GAG inertisation units is a major determinant of potential success for most efficient suppression of a specific fire. Studies undertaken with most Australian underground collieries have concluded that the current situation is not well placed to effectively inert most colliery priority fires.
- There is a need to examine attainable designs for GAG inerting using panel boreholes under Australian conditions with current drilling technology. Part of this is to calculate design considerations to overcome back pressure. There is a limit to the ability of the GAG jet engine to deliver exhaust down smaller dimension borehole. The objective will be to define the
    - Hole designs (diameters and depths) that can deliver directly without assistance of any fan,

- Hole designs that can deliver with modifications to the jet engine to improve thrust to overcome back pressure required for this delivery to be attained, and
- Specifications of boreholes design parameters that cannot achieve delivery even with full GAG jet thrust.

- There is a need to examine the use of the GAG for production or proactive uses in a wider application in Australian mines responding to recovering from mine fires, spontaneous combustion heatings, elimination of the potential explosibility of newly sealed goafs or inert mines or mine sections on closure. Some of the current uses of low flow inertisation facilities could be more effectively undertaken with the GAG unit.

8. SCSR Simulator.

Simtars has applied to ACARP for funding to investigate the options for a self contained self rescuer (SCSR) simulator. A précis of the application is:

Recent industry forums have identified the need for improved training in the wearing of self contained self rescuers (SCSRs). Forums include the 2006 Queensland Level 1 Emergency Exercise, at Broadmeadow Mine, where the following recommendation was made:

> *"Training in donning and use of SCSRs needs to be addressed, as indicated by previous level 1 exercises, and highlighted in recent forums in the USA (see Appendix 3). It is recommended to industry that a similar competency based training regime to that proposed by the USA mining industry (at three-monthly refresher intervals) is implemented, as well as ensuring that all mineworkers have used a real SCSR or a training rescuer that has simulated heat and resistance capabilities."*

The Fight or Flight seminar held in Emerald on 18-19 September 2006 also made the following recommendation:

"Training in use of SCSRs

All persons working underground should :

- *experience the heat and breathing resistance associated with SCSRs as part of their training program*
- *have the experience refreshed on a regular basis."*

As a result of the Fight or Flight seminar, three subcommittees were formed and sub-committee 1 made the following recommendation:

"Referred matters

SC1 Breathing simulator – resistance and heat

Simtars for ACARP study. Treadmill with hot air with oxygen that can simulate SCSR (including over-breathing). What settings to make, health monitoring, see Navy and Thornton test station. Put on trailer with controlled environment and circulate from mine to mine. Availability to contractors"

This project aims to give industry the solution to these issues by identifying what, if any, equipment is available, determining the equipment specification, budgetary pricing and medical supervision requirements for the use of the simulator(s).

It is also proposed a possible follow up/extension project will be required to procure, assemble and test/demonstrate a prototype simulator to industry in Queensland and NSW.

Objectives

The objectives of the project are to:

1. Identify what, if any, comparable equipment is currently available to replicate the use of an SCSR as a training method, with the main emphasis being on the breathing characteristics of a SCSR including:
    a. Temperature
    b. Breathing resistance
    c. Humidity
    d. Air (oxygen) supply (litres/minute).
2. Determine what medical supervision/monitoring would be required during the testing and proving and final use in training.
3. Provide an equipment specification should a suitable simulator not be currently available

9. Emergency Management and Decision Making/Communications

The significant improvements in the capacity to get people out safely from underground and even quickly deal with an incident, have not been matched by improvements in emergency management. There has been no take up of the research or the technology developed to improve information management – in part because some of the new systems are not for daily use.

The basis for effective information systems can be simply derived by identifying who needs what information, when and where this information will come from. Systems can then be developed appropriate to the capabilities of the personnel and resources available to the mine. These systems need to be dynamic, able to adapt as the circumstances and resources change. Experience from the level one exercises in Queensland indicates this has not been done.

Experienced people use Naturalistic Decision Making processes where they match the available data to their experience to determine what is happening and how to control it. This implies that they have enough data and the experience to make the correct match. Often the decision making process has been disrupted by the movement of personnel into or out of the Incident Management room, or by phone calls coming into the room. Structured decision making is rarely undertaken and only rarely was a formal decision making process undertaken that was documented. Problems can arise when information is misheard or mis-recorded. Simple systems to display key information are readily available whether they are electronic or plain white boards. It is imperative that someone is charged with the responsibility of keeping them up to date of course otherwise they will lead to misinformation and poor decision making.

Incident control rooms seldom contain the resources to assist in the decision making process. For example very few had copies (hard or electronic) of their principal hazard management plans, relevant legislation and guidance material, mines rescue guidelines, contact details for key personnel(internal and external), or access to the mine environment monitoring system. You would never know we were in the 21st century – the information age. All these documents are readily available electronically and can be accessed from any PC connected to a network or web. Portable access can be obtained via laptops and pocket PC's. Advice from experts is only a phone call away and all information could be quickly emailed to them for assessment – assuming of course that the information is in electronic form. Some incident control rooms did not even have access to current mine plans.

Another of the concerns is the effect of stress on the decision-making process. It is unlikely that people will be pre-screened for their roles in incident management teams based upon their ability to handle stress; therefore steps must be taken to keep the stress to a minimum. The only way to reduce the stress is to minimise the need to make value judgements, the more decisions can be based on facts and deduction, the less stress there will be. Frameworks for decision making should be established prior to an incident occurring. People who are tired are more prone to make mistakes and bad decisions, so there needs to be a planned change over of key staff, and someone tracking the fatigue levels of key personnel. Systematic tracking and display of key information reduces confusion and uncertainty and optimises the effectiveness of decision making.

Conclusion

Queensland is well placed to remain at the forefront of industry best practice and by doing so, has a high potential for avoiding the disasters of the past.

This paper identifies some of the opportunities that exist for further research and improved safety standards for underground mines, Where much of the research in the past has been a direct result of mine disasters, it is important that our research now acts proactively in preventing future disasters or as a minimum, minimising their effects.

The Fight or Flight seminar has achieved a united focus for the industry to go forward in a structured and logical manner. The unknowns have been identified and now it is the researchers who need to provide the answers as soon as practicable.

Existing Mine Communications and Tracking Technology

Technology	Description	Communications Capability	Tracking Capability	Manufacturers	Advantages	Disadvantages
Ethernet (TCP/IP)	Ethernet (802.11x) communications system for tracking, paging, voice, and data transmission. Combination of wireless (WiFi) and wired (fiber or CAT5) networks usually used.	Yes - Voice over IP (VoIP)	Yes - some systems track location by detecting hotspot used by IP radio. Accuracy limited to zones as defined by access point placement.	Northern Light Technology, Hard-Line Solutions, iPackets, Ekahau	Open architecture. Mine monitoring from any location via internet. Two-way voice, data, video on one system.	System uses combination of wired and wireless ethernet. Damage to lines or equipment may disrupt service. Most systems are powered by cap-lamps and installation at existing mines requires purchase of new cap-lamps and charging racks
Intrinsically Safe (IEC Ex ia Certified) fast ethernet switch	Fully managed, VLAN capable, ethernet switch (10Mbps and 100Mbps) over fibre optic cable	Allows ethernet communications to remain live during power outages, fan stoppages and gas-outs	Enabling technology	CSIRO	Enabling technology for deployment of an IS Ethernet communication systems underground. Provides connectivity to Wireless ethernet communication systems.	Requires IS power supply. Require integration with ethernet backbone
Intrinsically Safe (IEC Ex ia Certified) serial to ethernet protocol converter	Converts any serial communication protocol into the ethernet UDP and / or TCP/IP protocols	Allows the array of existing IS serial devices to be connected to a single ethernet based communication infrastructure	Enabling technology	CSIRO	Removes the limitations on distance and transfger rates currently suffered by serial communication systems	Requires IS power supply. Require integration with ethernet backbone
Leaky Feeder	Leaky feeder cable and amplifiers are strung through all areas of mine. Voice, data, video can be transmitted by RF coupling to leaky feeder cable.	Yes - radios couple to leaky feeder.	Yes - if optional RFID readers are coupled to leaky feeder. Accuracy limited to zones.	Minecom International, Mine Radio Systems/El-Equip, Varis Mine Technology, Tunnel Radio, FHF, Becker	Two-way voice, data, video.	Damage to leaky feeder cable or amplifiers may disrupt service. No inherent tracking capability.
Through the Earth	Loop antennas on surface of mine transmit LF signal to receivers integrated into cap lamps. Text message or flashing cap lamp alerts miner to emergency.	Yes - most systems are one way alarming and text messaging to underground. Transtek system has two way voice to 500ft.	No	Mine Site Technologies, Transtek, Mine Radio Systems/El-Equip	Wireless. Systems with transmitting loops on surface are not disrupted by explosions or rock falls.	Large or deep mines may require tranmitting loop antennas underground which may be damaged by rock falls or explosions. No tracking. No voice communications for most systems. Powered by cap-lamps and installation at existing mines requires purchase of new cap-lamps and charging racks
Medium Frequency	Radio at 280 to 520 KHz using signal propagation on existing pipes, wiring, etc. Requires repeaters for full mine coverage.	Yes	No	Conspec	Less dedicated wiring needed than leaky feeder.	Repeaters necessary to cover all areas of mine. Damage to communications lines or repeaters could disrupt service.
Radio Frequency Identification (RFID)	Active (powered) RF tags are worn by workers or installed on mobile equipment. Tags are interogated by tag readers placed in zones throughout the mine.	No - limited to data exchange (one way paging may be possible). However, these systems are usually used in combination with a communications system.	Yes - accuracy limited to zones as defined by tag reader placement.	Mine Site Technologies, Mine Radio Systems/El-Equip, MineCom International, Varis Mine Technology, Becker, Saco, iPackets	Real-time tracking of miners and equipment. Other safety applications possible such as controlled access, proximity warning.	Systems require separate communications infrastructure such as leaky feeder, wire, or ethernet. Cannot pinpoint location of tag - only last known zone. Damage to communications lines or readers could disrupt service.
2-Way RF Paging and Locating	Active (powered) RF tags equipped with LCD message screen and 4-button response menus are worn by workers. Paging messages can be sent to each tag and each tag can reply to the message via fixed menu options. Location is determined by Readers placed in zones throughout the mine.	Yes - 2-way paging and response	Yes - accuracy limited to zones as defined by tag reader placement.	Under development by CSIRO	Real-time tracking and 2-way non-verbal (important in irrespirable atmospheres) with minerworkers. Stand-alone system that does not require modification to cap-lamps. Other safety applications possible such as controlled access, proximity warning.	Systems require integration with existing communication systems - either wire or ethernet. Damage to communications lines or readers could disrupt service.
Distributed Antenna System	RF antennas are tapped into a coaxial cable backbone where coverage is needed.	Yes - Voice, data, video, IP.	No	Catron-Theimeg	Reconfigurable as mine layout changes. Antennas are placed only where needed, reducing cost. Relatively simple to install.	System requires coaxial cable backbone to all areas where communication is needed. Damage to cable or equipment may disrupt service.
Seismic Monitoring	Portable system using seismic monitoring sensors on the surface that can detect sounds generated by trapped miners.	One-way communications from miners to surface, limited to simple codes generated by tapping.	Yes, if trapped miners signal as they move.	Not known - MSHA had only systems in existence which have now been transferred to FEMA.	Trapped miner locating system that does not depend on integrity of mine communications. Portable.	Emergency system only. Limited to mines 1500 ft deep or less. Depends on trapped miners signaling the surface by tapping on mine structures.

Figure 1 Overview of Current Australian Technologies