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MINE COMMUNICATION
& INFORMATION SYSTEMS FOR
REAL TIME RISK ANALYSIS

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Abstract : Coal is Australia's highest export earner and Australia is the world's largest exporter of coal.

With coal now being extracted from deeper reserves under increased risk profile, and in the interest of aiding the stability of coal supplies, Japan is funding a number of safety projects in Australia and China. The CSIRO, Australia's premiere research organisation with the country's largest exploration and mining research group, are currently undertaking a jointly funded Japan-Australia safety project at *Anglo Coal's* new *Grasstree Colliery* in central Queensland.

The project, entitled *Mine Communication and Information for Real-time Risk Analysis*, will deliver step-change capabilities in data integration, decision support, gas monitoring, geo-technical monitoring, emergency response and personnel safety to the *Grasstree Colliery*.

Some key activities include: developing and installing underground coal mine Ethernet LAN components, real-time monitoring of gas and geo-technical sensors, MODBUS serial to TCP/IP converters, e-reporting of underground conditions, emergency guidance systems and underground trials of Internet Protocol telephone and video.

The project seeks to integrate (in real time) key data sets from the comprehensive and diversified range of propriety system currently in use at mines (ventilation, strata, operations e.g. haulage, pumps, conveyors etc) into a single integrated risk management interface. This interface will filter the data through a rules-based inference engine that will cross reference the various data streams, compare with past events and outcomes associated with the similar historical data and present this "intelligence" to the managers of the operations in a meaningful and interactive interface.

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PROJECT OVERVIEW

Ultimately, this system will provide predictive, real-time risk management and generate pre-emptive responses before safety and operating parameters become accidents and breakdowns – with the added benefit of eliminating the endless stream of false and non-critical alarms that consume energy, resources and valuable time.

The project will further demonstrate that real-time data monitoring, voice communications and video surveillance can all be supported on a battery-backed-up Ethernet network. There advantages of this approach are:

- there is one infrastructure instead of several to install;
- the Ethernet networks offer better reliability, better performance (i.e. higher bandwidth) and lower cost than the technologies they replace, and
- the technology is mature and there exists an abundance of people skilled in maintaining Ethernet systems and applications.

The usual communications issues of planning, redundancy and management remain. Some key communication and information objectives of the parent project include:

- extending the mine Ethernet local area network (LAN) underground;
- demonstrating emergency voice communications over an underground LAN;
- demonstrating video surveillance over an underground LAN, and
- developing Ethernet sensor interfaces.

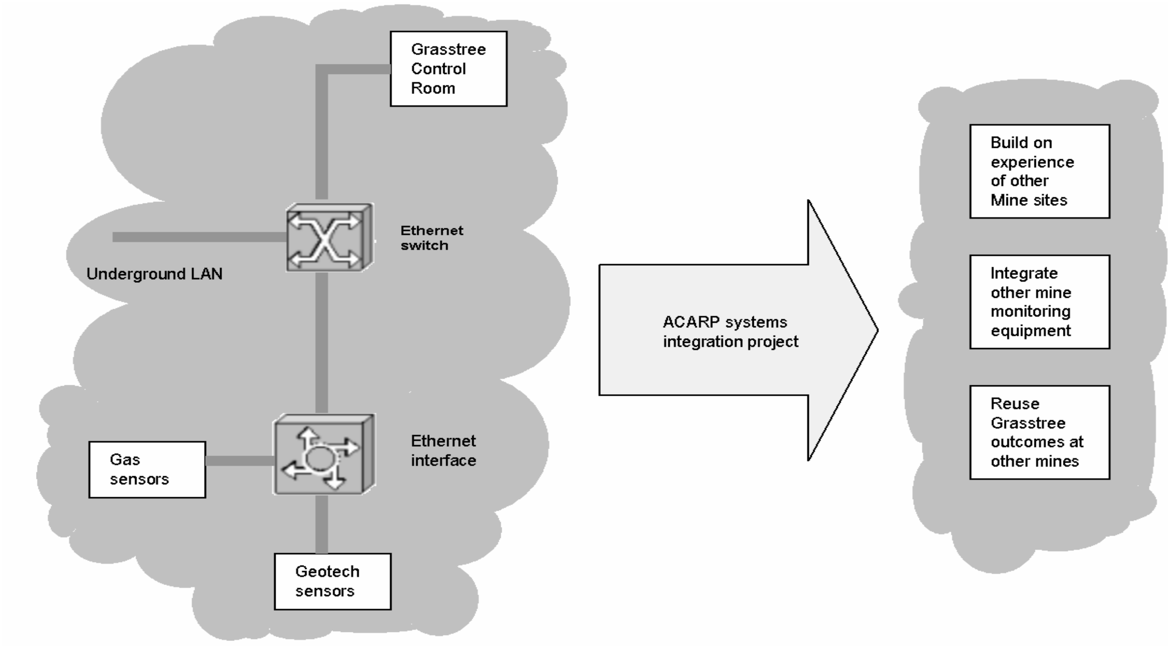

Fig 1.1 Project concept

A possible mine-site layout is given in Figure 1.2

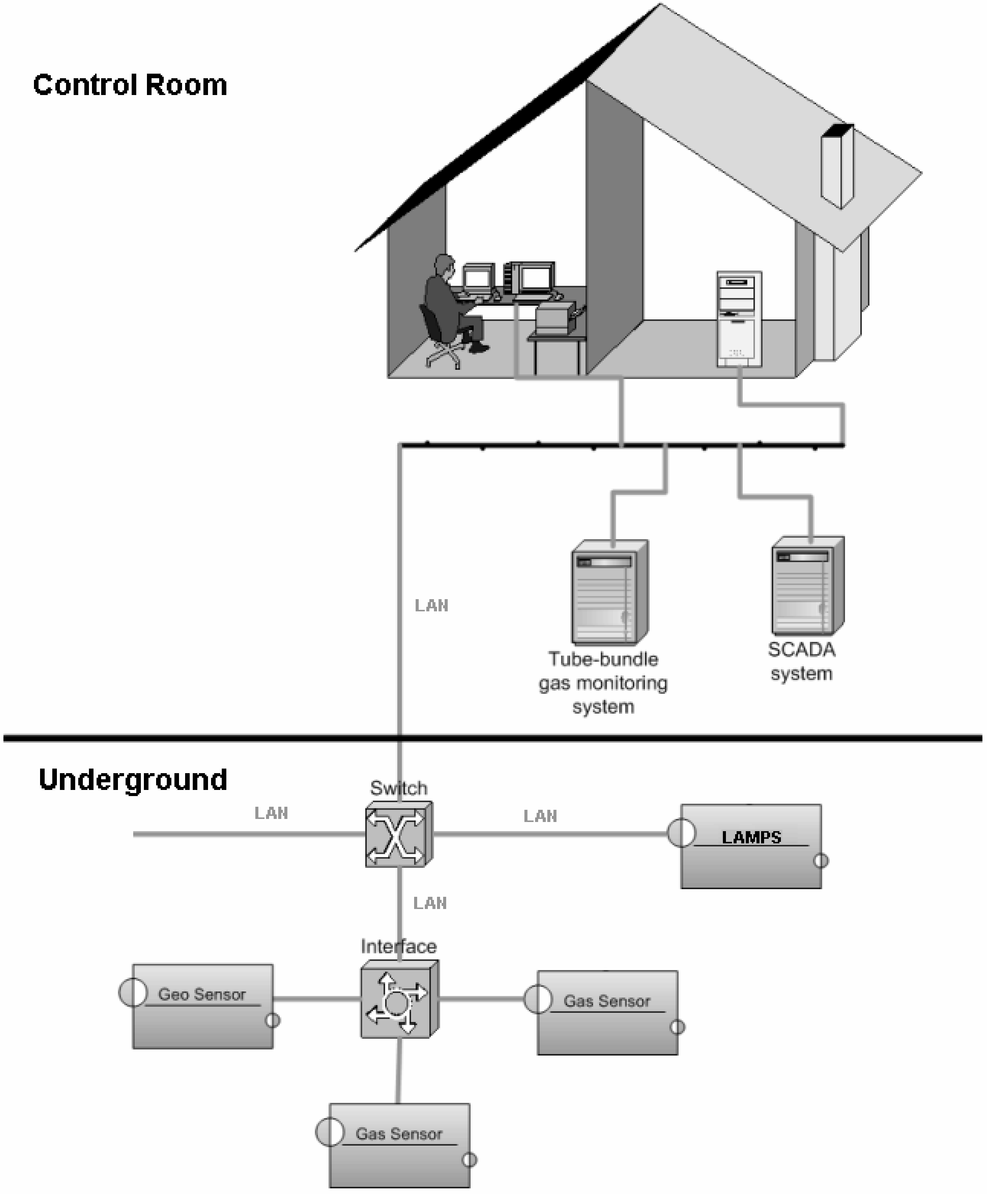

Fig 1.2 Illustration of a possible integrated safety system

A shortcoming of many existing mine equipment communications systems is that the data interfaces are proprietary. The use of proprietary interfaces tends to lock mines into a particular vendor. This precludes the participation of mine staff, third party contractors and vendors in ongoing expansion and maintenance activities. Proprietary systems can be expensive. For example, the costs of mine-wide SCADA-based and leaker-feeder-based software management systems can exceed $5M and $20M respectively.

Different systems sourced from competing vendors are often not interoperable. Consequently mines tend to install multiple systems in parallel. For example, the bulk of mine equipment monitoring is handled by SCADA systems, video is provided by separate CCTV systems, a mixture of DAC intercom, analogue telephone and leaky feeder systems support voice communications, and tube bundle systems are usually employed for mine-wide gas monitoring.

In contrast, Ethernet LANs are open systems which can, in principle, support a wide range of applications. In general, integrated systems are preferable to disparate applications co-existing on the same platforms. Increasingly, mines desire to select interchangeable systems from different manufacturers and vendors, depending on the application, performance, reliability and support. It follows that a key for successful integration is a common protocol. There are numerous application layer protocols for transporting sensor and equipment data over Ethernet. These include Modbus/TCP, Ethernet/IP (or CIP), Profibus on Ethernet and Foundation Fieldbus High Speed Ethernet.

Ethernet networks support IP telephones, also known as voice over IP (VoIP) telephones. VoIP telephones are in use within urban organisations throughout the world. Typically the VoIP telephones are lined powered and connect directly to a RJ-45 wall socket, ethernet hub or switch. An international VoIP standard (H.323) exists and is fully compatible with public networks. The open architecture allows a mix of VoIP phones from different sources to be used, instead of relying on phones from one PBX manufacturer. VoIP telephony can be used over 802.11b equipped laptop, palm and industrial GP-104 computers. A mine trial of VoIP technology for emergency mine communications is a planned outcome of the parent project.

Some mine operators have nominated video applications as one of the top three Ethernet services priorities - after equipment/sensor monitoring and personal communications. International video coding and transmission standards (H.261, H.263) exist. However video streaming must be planned and implemented so that adequate bandwidth remains available for the higher priority tasks. Therefore in critical situations, it is recommended that separate subnets be established for underground video monitoring. A mine trial of video over Ethernet is a planned outcome of the parent project.

The project team has considerable experience in the application and development of Ethernet technologies and has focussed its initial development strategy on the outcomes of a scoping study it undertook of all underground longwall mines in Queensland completed in October 2002.

System Structure

A proposed structure for the integrated real-time management system is shown in Figure 1.3. The bottom physical layer comprises existing mine equipment, new developments emerging from the parent project and will include stubs for future expansion. The data link layer will consist of low-level software drivers that communicate with the mine equipment. The protocols for data communication from underground to the control are managed in the network layer. The presentation layer integrates and provides access to all the functionality of the underlying layers. The safety monitoring applications are defined in the top layer as shown in the figure. The application layer will include stubs to support additional applications being accommodated in response to emerging mine requirements.

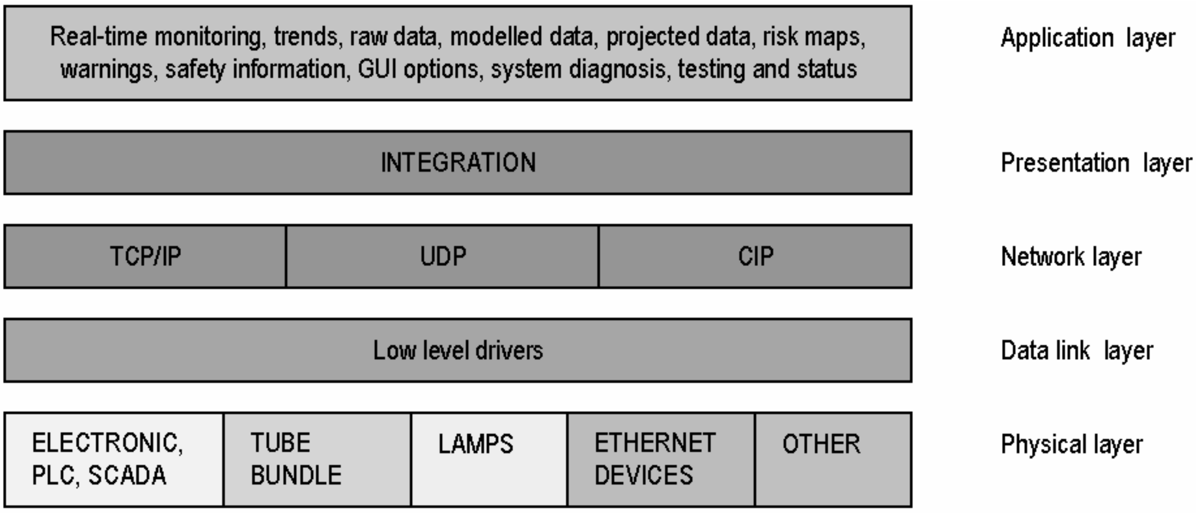

Fig 1.3 Proposed structure for the integrated safety system

Software Structure

The system spans the new and existing mine monitoring equipment, the Ethernet network and through to the applications. A simplified diagram pertaining to the software structure is shown in Figure 1.4. Three major components are shown: an application layer system, an integration layer and a communication layer.

The application layer includes the graphical user interface that is displayed on the end user's computer. The display will provide an overall picture of the current risk profile of the mine and show specific sensor data and process data when requested. All the data displayed will come from the integration layer.

The integration layer processes sensor data, according to its specific area: gas monitoring, geo-technical monitoring, personnel monitoring, or any other type of sensor system that needs to be monitored. The data for the area is read and monitored through the communication layer.

The communication layer processes a range of incoming mine sensor data. The data may come from either sensors or from existing systems. A common protocol will be used to read this data and at the same time allow for easily integration onto other future systems.

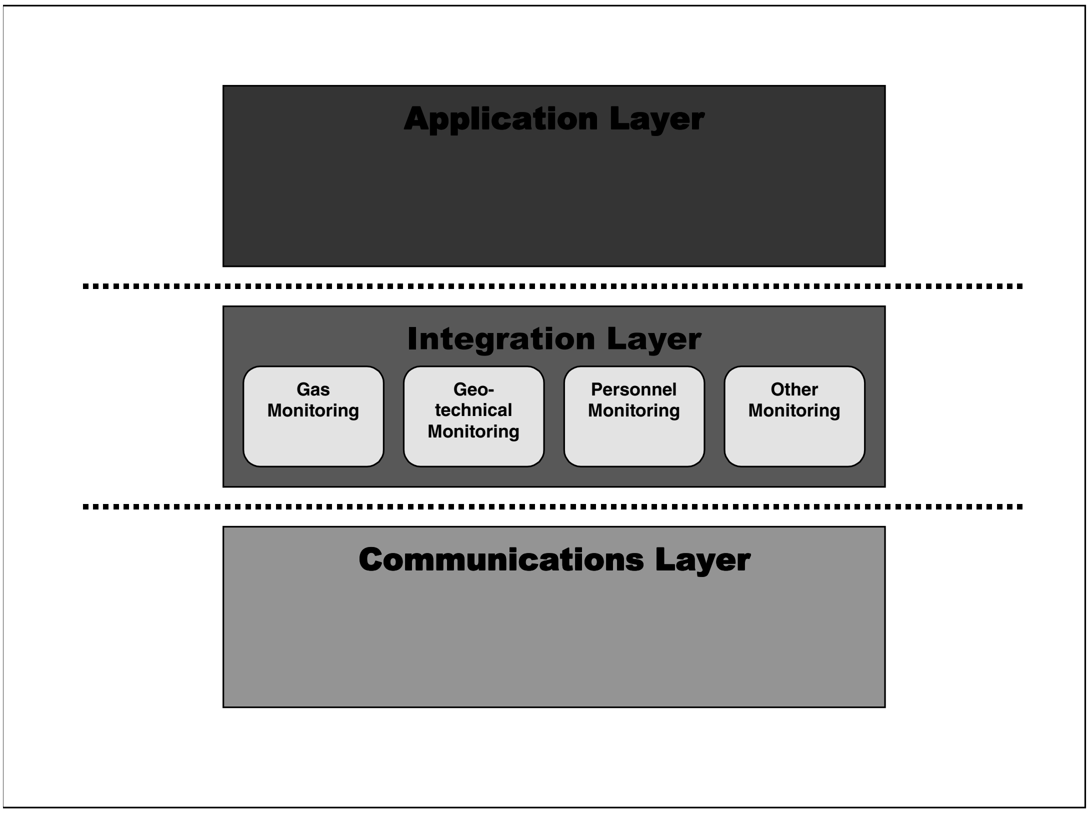

Fig 1.4 Simplified diagram of the software structure

COMMUNICATION SYSTEMS

Aim: The objective is to develop and demonstrate advanced communication and information technologies for real-time risk management in modern underground coalmines.

(a) Underground intrinsically safe (IS) ethernet switch: The communication infrastructure will be an ethernet-based multi-mode fibre optic backbone using standard TCP/IP protocols. An essential element of any such infrastructure will be an intrinsically safe ethernet switch. A study has been concluded into the practicalities, application and appropriate design criteria for such a switch. The design calls for a managed switch with 8 multi-mode fibre optic ports (100Mbps) with V-LAN 802.1Q trunking, matching IS power supplies with optional copper → fibre media converters.

(b) Wireless communications for roadway monitoring: A wireless extensometer prototype has been developed to enable roadway monitoring to be conducted in difficult underground environments where manual reading of extensometers is awkward or dangerous, and running cables for data acquisition would be unpractical. The prototype is based on an extensometer commonly used in Australian underground coal mines and involves short-range radio communications from the extensometer to a personal computer.

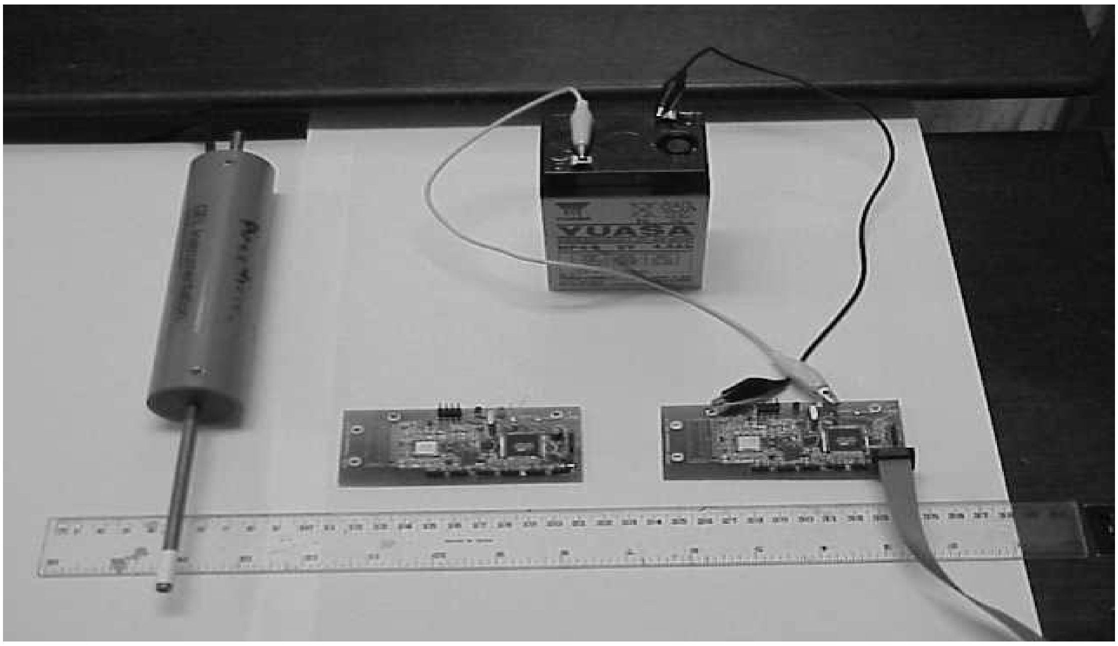

Fig 2.1.1 Wireless Extensometer Prototype

A prototype was tested successfully in a laboratory environment with tests up to a range of 40m being undertaken with a strip line antenna. It is anticipated that this range could be improved with the use of a higher gain antenna.

There remain issues with IS compliance and certification that require resolution prior to the system being available for use in Explosion Risk Zone (ERZ) areas of an underground coal mine.

*(c) Ethernet sensor interface:*In order for the ethernet-based communications system to carry data from the range of existing current loop serial sensors, robust high bandwidth protocol converters have been developed. Currently, the Trolex TX9042, illustrated in Figure 2.1.2 and TX9044 devices are widely used in the mining industry, because of their IS compliance.

Fig 2.1.2 Trolex TX9042

However these devices use Serial RS485 as the communications protocol with the host. In order to make it easier for mines to migrate to a TCP/IP-based communications backbone, this project has developed an IS serial-TCP/IP converter. This converter will connect existing Trolex devices to the ethernet backbone, which will in turn be connected to existing integrated control and monitoring systems such as CITECT and/or RSView.

The Trolex devices use the MODBUS protocol as the communications standard, which can easily run over TCP/IP and Serial (RS232, RS422 and RS485) communications links. The protocol converter also needs to be Modbus-aware since there are differences between the implementation of Modbus-over-RS485 and Modbus-over-IP. Such converters can now be purchased off-the-shelf, but the available devices are without firmware and are not IS. The hardware and the firmware for this device are being developed by CSIRO, but it is necessary to have a simulator to validate and debug this device.

At this point in time, a configurable serial debug application has been written which allows the user to input hex characters, translate them to bytes (ignoring any white space or non-hex characters) and send them out the serial port. It can generate a CRC-16 value from the string. It then reads the input response, translates each byte into an ASCII character pair and displays them on the GUI. As an extra feature to aid in debugging, it reports on whether the returned sequence has a valid CRC.

Numerous Modbus commands have been tested successfully, and the code has been placed into SourceSafe, our quality assurance system.

Similarly, a TCP/IP debug application has been written which also sends and receives specific bytes of data. A TCP/IP socket connection can be established with another device on the network, and the status of the connection is continually monitored.

It is possible to use both applications on one computer, using the serial and network ports, to communicate with and examine the behaviour of the protocol converter

(d) Personnel and Vehicle Locating Devices: The original concept was aimed at pedestrian traffic within bord and pillar mines, in which active tags carried by personnel reported every 100 seconds to any nearby battery powered wireless readers, nominally spaced 30 to 50 metres apart.

The technology has now been further developed to accommodate personnel travelling in vehicles within longwall mines The tags report to strategically spaced readers that can be sustained by UPS batteries and integrated to mine communication systems. The survivability philosophy remains the same with the readers operating independently of mine power and multiple redundant connections providing some robustness to failures.

GAS AND VENTILATION MONITORING

Aim: To improve the efficiency of gas control and ventilation through implementation of comprehensive real time monitoring and analysis systems. The additional interpretations and input to the mine information systems will significantly improve the risk management and emergency response systems.

(a) Ventilation and gas concentration monitoring. The environmental (gas and ventilation) monitoring system implementation of the following components:

- Ventilation flow and pressures monitoring
- Gas concentration levels monitoring in roadways – for gas control/ventilation optimisation (in additional to statutory monitoring points)
- Pre-drainage flow and pressure monitoring
- Other environmental monitoring, such as CO and H_2S
- Real time communication systems
- Software development for data processing, interpretation and integration into the mine information systems.

The key major mine development milestones that are important to this project are as follows:

Shaft to the seam	July	2002 (completed)
Initial development to connect the shaft	Nov	2002 (commenced)
Tailgate development of LW801	Oct	2003 (originally Jul 2003)
Maingate development of LW801	Oct	2004 (originally Apr 2004)
LW801 production	Jan	2006 (originally Mar 2005)

The gas isopac model of the mine and evaluation of the various gas and ventilation monitoring systems for their compatibility with the real-time risk analysis system has been completed.

Current development plans feature :-

- 2.6m working section height within German Creek seam,
- 3 heading gateroad developments,
- 250 m wide longwalls, up to 4 km in length,
- up to 130,000 t/week production,
- mining depth ranging from 250 m to 500 m of cover,

The in-situ gas content in the working seam ranges from 6.0 to 12.0 m^3/t and consists mostly of CH_4. The permeability in the working coal seam is estimated to be about 10 to 15 md. Consequently, it is anticipated that extensive pre-drainage will be required to mitigate against hazards of:

- Gas outburst potential,
- Frictional ignition of face gas emissions,
- Excessive gateroad rib emissions, and
- Excessive longwall goaf gas emissions

Previous analysis of gas content distribution (GeoGAS, 1998) has identified high medium and low gas domains in the Aquila and German Creek seams. That is, gas content values with respect to the average expected at sample depth are shown in Figure 2.2.1.

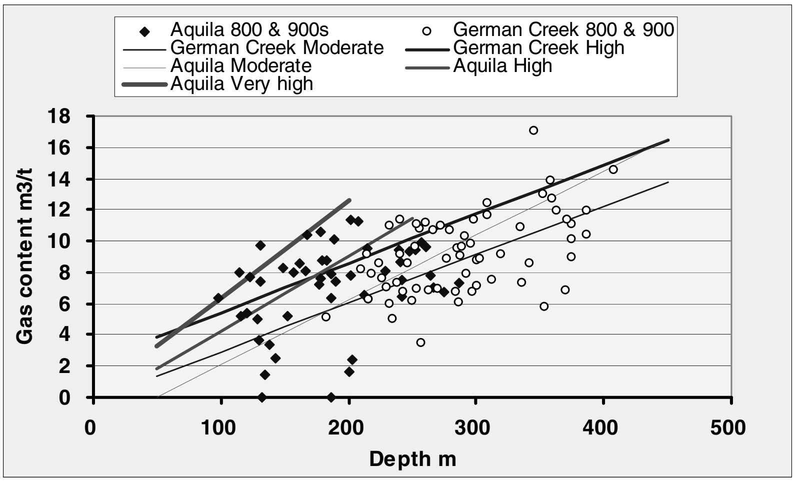

Fig 2.2.1 Aquila & German Creek 800 & 900 Gas Contents With Depth

A detailed review of the monitoring sensors available and gas/air monitoring systems being used in Australian coal mines has been produced.

(b) Gas drainage monitoring:

The colliery has implemented a new pre-drainage technology called "Tight Radius Drilling (TRD)" to pre-drain the coal seams near the shaft sinking area. Although this technique achieved a significant success in degassing the small areas near the shaft, preliminary analysis of the results show that the TRD technology needs to be developed further for wider application in pre-drainage of the coal seams. In view of this situation, the mine is currently looking at field trials of another new pre-drainage technology called “Medium Radius Drilling (MRD)” to pre-drain the gateroad development area of the first longwall panel. It is proposed to conduct a detailed field monitoring of the performance of the MRD technique under this project to investigate the effect of various geological and operational parameters on gas drainage efficiency of various holes.

These two new pre-drainage techniques involve drilling holes from surface and therefore offer substantial advantage in terms of lead-time available for gas drainage or to reduce the gas content below the threshold limits in gateroads development. It is to be noted that increased drainage lead-time results in a significant reduction in the number of holes required, cost saving and offers more flexibility in mine scheduling.

(c) Software assessment and designs: A presentation on the software program developed by Dr Masahiro Inoue of the Kyushu University was provided to the project team on Monday 10th March 2003. A copy of the program was generously left with the team for further study and evaluation.

Additionally, a scoping study involving personnel from the project team, University of Queensland’s Minerals Industry Safety and Health Centre and SIMTARS are reviewing current ventilation simulation software and monitoring packages for modification and upgrading to suit possible application in the real-time risk analysis model.

STRATA MONITORING

Aim: To provide timely information for ongoing mining risk management, mine planning and mining optimisation at the mine through design and implementation of real time geotechnical monitoring and interpretation system.

(a) Interactive geological and geotechnical 3D visualisation model: A real time geotechnical model (RTGM) has been developed to integrate strata monitoring and longwall chock monitoring data with geological, geotechnical, mine design and operational data. The current software comprises the four following modules linked by a main control page on PCs at mine offices:

- Extensometer displacement module;
- Chock pressure module;
- Chock convergence module; and
- 3D data display module.

In addition, the RTGM manages the storage of monitoring data in an integrated database and communicates with mine design software for the transfer of geological and geotechnical data.

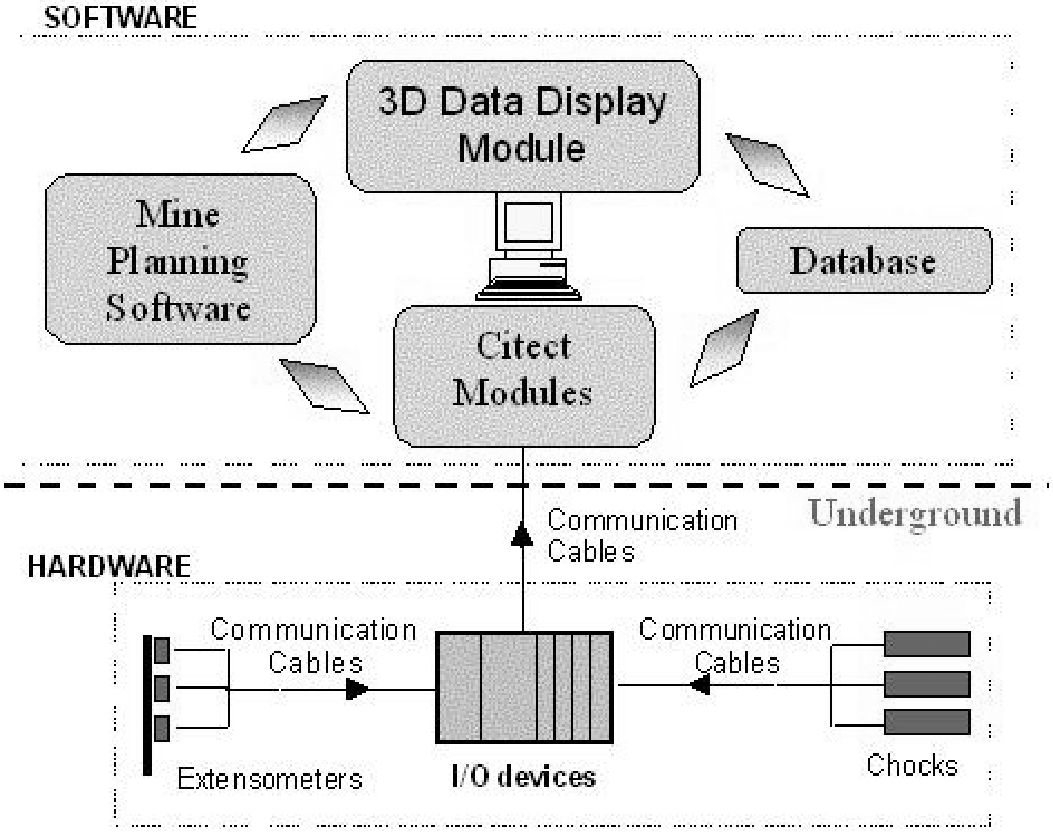

Fig 2.3.1 The Real Time Geotechnical Model

All modules except for the 3D data display are written in the Citect system, a standard software system for mine communication and control. The 3D data display will be created as a stand-alone module written in VC++ and OpenGL, for advanced 3D graphics display and communication with existing mine design and planning software such as Vulcan and ECS.

(b) Roadway wireless monitoring system. The wireless monitoring of inaccessible, difficult or unstable areas of a mine is another key to successful real-time risk management. A production extensometer system based on radio communication would be particularly useful in underground environments where running cables for data acquisition would be impracticable, such as convergence monitoring of the tail gate of a longwall or manual monitoring of instruments that are awkward or dangerous to reach.

The purpose of this work is to show that the linear movement of an extensometer commonly used in geotechnical instrumentation (GEL Instrumentation Pty. Ltd.) can be monitored by a microprocessor based module and to show that this information can be transferred wirelessly over a short distance to another module connected to the serial port of a computer.

Three possible system configurations are

(a) a reader node connected directly to a PC
(b) a reader node connected via a mine-wide communications system, or
(c) a hand-held reader feeding data directly into the mine-wide communication system. This would greatly speed up the process of data recovery with the data collected in the hand held reader being transferred to a PC on return to the office.

Future work includes the following;

- Design the system to be Intrinsically Safe for use in underground coal mines and gain appropriate certification.
- Design suitable packaging and battery supplies for the system.
- Develop the software to allow for data logging and multiple node communications and also the communications with a mobile hand held reader.
- Develop software interfaces such as MODBUS so that the system can easily be interfaced with typical mine-wide communication systems.
- Develop analogue signal conditioning so that the analogue to digital converter in the Atmel microcontroller can be used to measure geotechnical instruments other than potentiometer type extensometers, such as strain gauged roof bolts, load cells and pressure transducers.

(c) Other strata monitoring systems: Chock pressure and convergence are two important parameters which can help to understand the response of the roof strata to longwall mining. The Joy longwall mining systems have built-in transducers to measure the hydraulic leg pressures and convergence for each chock. These data are collected at the maingate control unit and can be transmitted through the PLC network to surface computer for recording and analysis. Traditionally, the data are used to evaluate the chock performance rather than the roof condition. However, increasing attention is paid on how to utilise the chock monitoring data to evaluate the roof geotechnical conditions.

Several studies have been conducted previously by CSIRO and AMC using the chock pressure data and convergence data to help understand the local roof conditions and hence a better longwall face management. Preliminary conceptual study is being conducted in this project using the leg pressure data, convergence and accurate longwall shearer position to back-analyse roof condition.

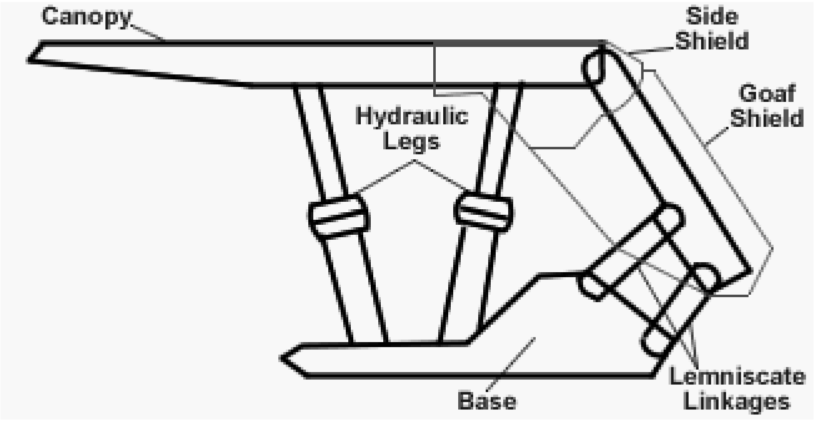

Fig 2.3.2 Four leg hydraulic powered roof support unit (chock)

A chock is a hydraulic powered roof support unit interconnected with up to 250 other chocks along the length of the longwall face. The main functions of the powered supports are to control strata movement and to protect mining personnel and equipment at the longwall face. A chock consists of 2 or 4 hydraulic legs, a canopy, a base, side/goaf shields and lemniscate linkages, see Figure 2.3.2. A standard chock is approximately 1m in width.

Chock pressure and chock convergence are two important parameters that can help to understand the response of the roof strata to longwall mining. They represent the direct interaction between the chock and the roof strata.

The use of tilt transducers to measure longwall closure has previously been the subject of CSIRO investigations (Kelly et al, 1999). These trials were of moderate success, but problems with the reliability of data logging equipment hampered efforts to demonstrate the effectiveness of the system. In previous trials the data was stored onto compact audio cassette tapes and then converted to closure data at a later time.

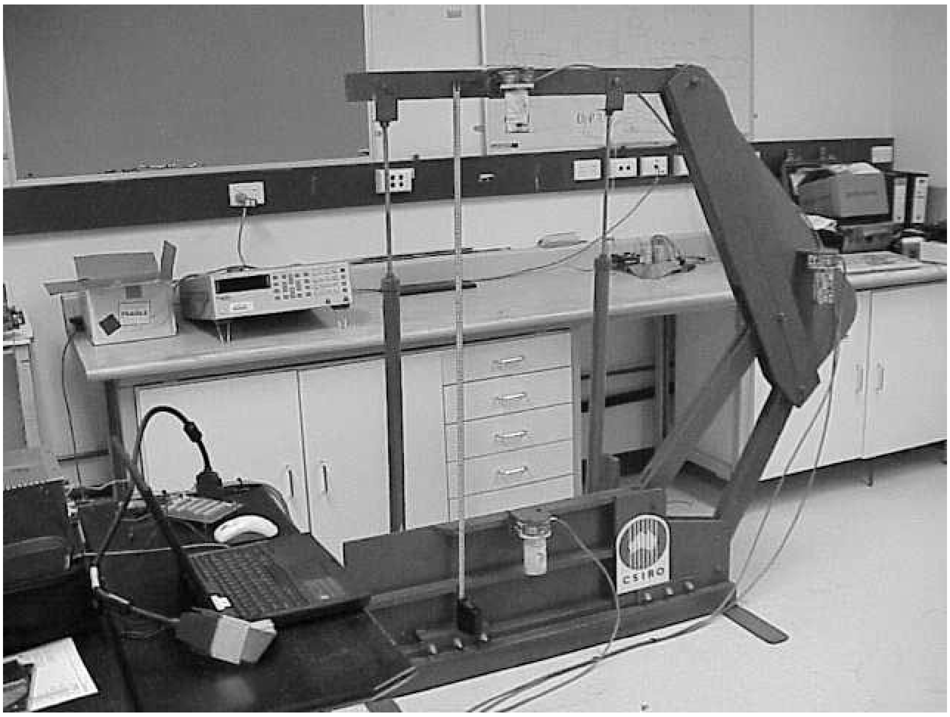

Fig 2.3.3 Experimental System on ½ Scale Model

The Intrinsically Safe monitoring system, although quite accurate, was old and unreliable leading to significant loss of data. The method of data storage was not convenient and time and resources were needed to process the data. The main purpose of this laboratory experiment was to demonstrate the longwall Support Closure Monitoring System on a half scale laboratory model with the results displayed on a computer screen in real time.

EMERGENCY RESPONSE SYSTEMS

Aim: The principal objective is to develop innovative emergency response systems utilising the advanced communication, rescue and safety systems.

(a) Emergency response system development:

Underground: Outcomes from a series of full scale mine emergency exercises, together with causal analysis studies of past disasters in the mining industries, indicate a pressing need to develop solutions to a range of fundamental issues. Clear evidence is available that mineworkers are perishing in toxic, post-incident atmospheres simply because they cannot see. Smoke and dust laden atmospheres rapidly reduce visibility to the point where people become disorientated, cannot locate their emergency oxygen caches or navigate their way along their designated escape routes.

An integral part of this project is the development of an inertial guidance system that can, through a novel and unique interface, guide workers rapidly to places of safety in zero visibility and along a chosen or pre-determined route.

Coupled with the ability for the surface control to locate people underground, these 2 components will solve the major challenge faced by those involved in emergency response - finding people in the labyrinth of underground workings and for those workers, autonomously, to find the quickest and most direct route to a place of safety.

Surface: Control rooms must be designed with people in mind. They must be structurally able to withstand an event and capable of protecting / isolating the people and equipment inside from the consequences of that event. Ergonomics must form an essential design function as must the thermal, visual and auditory environment. Alarms, interfaces, displays and coding techniques must allow smooth and non-distracting flows of activity to continue during emergency responses. It is one of life's mysteries why, at a time when it is essential for people to act coolly, rationally and calmly that we design their work environment with a plethora of alarms, lights and whistles designed deliberately to distract them.

Since the commencement of the project, a series of concepts have been explored on how to provide essential aid to persons working underground when an emergency occurs. In addition to those mentioned above, such concepts include :-

- technology for electronic capture and reporting of inspection status that can broadcasts the conditions in any one part of the mine to all other parts of the mine
- digital video imaging along conveyors - a major source of fires in underground coal mines
- next generation decision support systems such as 3-dimensional Trigger Action Response Plans (TARPS)

In relation to decision support systems, it is recognised that the mere collection of a myriad stream of real-time data, although exciting in concept and challenging in attainment, is of little value unless such data can be converted into "intelligence" and such intelligence can be acted upon with "wisdom". Throughout the expansion of the machine and computer into all facets of our lives, it could be argued that the computerisation of the human-machine interaction has, in general, created more problems than it solved and, also, failed to solve the old problems completely. One need look no further than current alarm systems (Stanton, 1994) to become concerned about the "solutions" so far presented to industry. Fundamental issues raised by the Control Room operators during our survey of underground longwall mines were the issues of false alarms, the need to constantly upgrade graphic interfaces and the difficulties in exercising control over the computer interfaces themselves.

So while engineers initially had eagerly welcomed human-computer interaction as the long-sought solution to all human factors problems, they gradually realised that there was more to controlling a process than designing an impressive graphical interface. One consequence of that was yet another change in the terminology, this time to emphasise the notion of a system, leading to labels such as 'human interface systems engineering' or even a revival of the term 'human-machine system'. Even though the preoccupation with terminology, in some sense was a distraction from the basic problems of how humans use technology, it also helped to broaden the perspective and provide valuable experiences. Thus, one essential difference between the study of human-machine systems and the study of human-computer interfaces is that the former recognises the problems that come from coping with a dynamic process or a dynamic world. The tasks considered in the field of technology have typically been user-paced rather than task-paced, hence focused on working with computers rather than through computers. In other words, the application has in all essence been residing in the computer rather than in a complex, dynamic and often unpredictable environment.

There has been little need to consider how users could handle multiple simultaneous tasks, and how they could manage to do so under serious time constraints. The tasks considered by human-machine systems, on the other hand, are typically complex and dynamic. Therefore, they cannot be dealt with one at a time, but must be considered as a whole - even though the whole may be incompletely understood. The tasks are dynamic because the requirements and conditions, more commonly known as the context, change over time even if the operators do nothing at all. Dynamic processes are thus spread out in both time and space, and differences in process speeds may easily cover five orders of magnitude.

In order to control the processes properly, operators must have an adequate understanding of both time and space that matches the time/space characteristics of the physical process well enough for actions to be planned and carried out. The design of the interaction between people and processes must consequently encompass both time and space, and the interface must provide an adequate representation of the dynamics and topography of the process (Hollnagel. 2003).

Emergency, and even normal operational, responses generated from within a Control Room must focus on problems that operators have in managing the processes of which they are expected to be in control. In the structural view, the focus is on how a sub-system with one set of characteristics (such as a human) can most efficiently interact with a sub-system with another set of characteristics (such as a computer). In the functional view, the issue is how the overall system - the human-machine ensemble - can achieve its goals, given that the environment is dynamic and partly unpredictable and given that many parts of the functionality become automated and thereby - intentionally or unintentionally - hidden from the operators.

The almost definitive condition occurs when people do not understand what is happening or what they are supposed to do. This condition unfortunately appears with increasing frequency. However, it is not just a concern for the proper design and use of technology, but also for the softer issues such as training, procedures and co-operation. The solution requires a cross-disciplinary collaboration and understanding that can lead to the development of new models and methods.

(b) Human activity monitoring: In theory vital signs could be integrated with the real-time risk analysis system and could be used to provide a personnel monitoring system which is capable of remote heart pulse rate measurement, relative motion detection and body positional (tilt) data. Developed capabilities include the use of a commercially available heart rate monitoring system from *POLAR* together with some locally developed interfacing electronics. Figure 2.4.1 illustrates the *POLAR* chest strap together with developed vital signs printed circuit board (PCB).

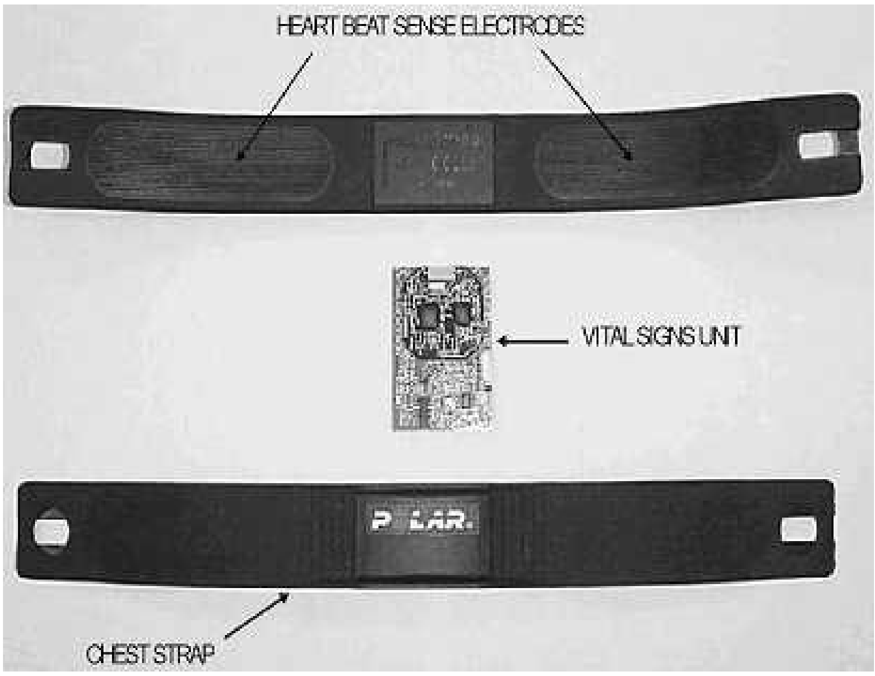

Fig 2.4.1 Polar chest strap transmitter and vital signs PCB

Heart rate is provided in beats per minute sampled at 15-second frame intervals using a chest strap and RF link to the user battery pack. Respiration rate can also be provided from the chest strap, though this is not implemented in the delivered version. The signal transmitted from the chest strap is decoded in the battery pack module where two axis tilt and accelerations are monitored from DC to 5 KHz. For the present application, these tilt signals are reduced to a simple 2- bit string for each component, multiplexed with the pulse rate signal and coded for transfer. Six status indicators (optionally enabled) are available on the receive board for performance monitoring.

(c) Interactive models and risk assessment: The innovative design of the user interface under development in this project utilises not only state of the art technology, but incorporates a new concept in control room operations – a rule based inference engine capable of analysing separate data sets, seeking new or required data, comparing the results of initial analysis with

historical events and making recommendations based on logic strings developed and pre-coded by skilled and experienced experts.

This key analysis tool, refer Figure 2.4.2, will enable this project to provide something not yet available to any mine – the ability to predict future events based on past history, current data and personal and corporate memory. All data streams, no matter how real-time, are measures of the past. The ability to use that data to alert operators to a current change in the risk profile of the operation and then predict a range of likely outcomes from that data - even to suggest a range of possible corrective and pre-emptive actions, presents a fundamental shift in the ability of mine's to manage risk.

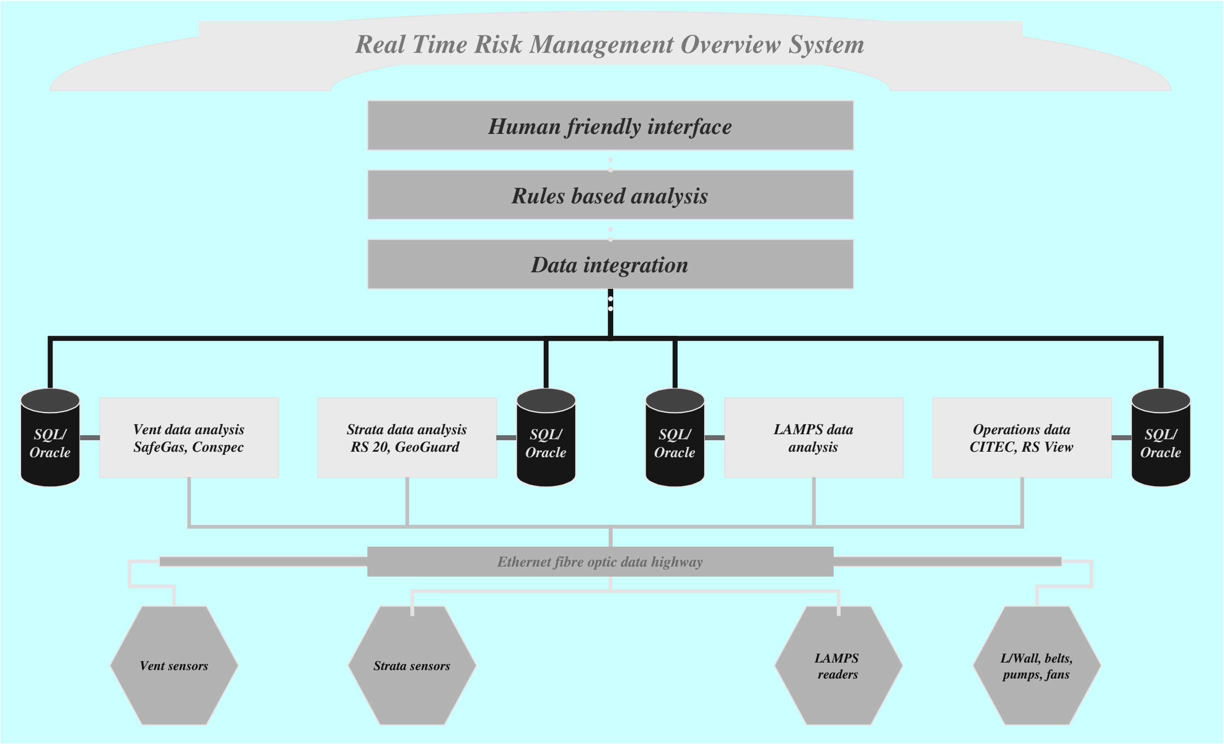

Fig 2.4.2 Decision Support Data Intelligence System

PROJECT COORDINATION AND REPORTING

Aim: As the project involves a number of new developments covering a number of risk areas, project coordination is critical to the success of this multi-disciplinary project. As most of the field trials are planned in a new developing mine it is essential to have well managed project coordination to maintain good relations with the mine and achieve successful outcomes. The project coordinator may also look after the key aspects of risk management and information management systems.

Additionally, a number of Quality Assurance principals have been adopted and knowledge management techniques introduced. Building the right product is about understanding the problems to be solved and the needs to be addressed. The research team will use the following development processes to build the right product:

- Develop the requirements by understanding the customer's problems and needs

- Define a high level solution from the requirements
- Define a detailed solution from the high level solution
- Validate the customer requirements

Developing the Requirements.

Identifying accurately the scope of the system to be built and the requirements necessary to address the customer's problems and needs shall form the basis of project's software development. This "Requirements Document" shall be used as a communication tool that allows all the stakeholders to verify the accuracy and completeness of the identified issues and concerns that must be satisfied.

A "Requirements Document" template for this project has been defined. This template includes a definition of the high level requirements, a list of requirements, and a description of the functions. These requirements fall into one of the following categories:

- Functional requirements – define the system's input-output transformations.
- Interface requirements – specify the hardware, software, and communications interfaces with which the system must interact.
- Performance requirements – specify numerical values for measurable variables used to define the system.
- Operational requirements – specify how the system will run.
- Resource requirements – specify the upper limits on physical resources such as processing power, main memory, disk space, etc.
- Documentation requirements – specify the specific documents required.
- Security requirements – specify the requirements for securing the system against threats to confidentiality, integrity, and availability.
- Portability requirements – specify how easy it should be to move the system from one environment to another.
- Quality requirements – specify the attributes of the software that make it fit for its purpose.
- Reliability requirements – Specify the ability of the system to perform its required functions under stated conditions for a specified period of time.
- Maintainability requirements – specify the ease with which a software system can be modified to correct faults, improve performance or other attributes, or adapt to a changed environment.
- Safety requirements – specify any requirements to reduce the possibility of damage from system failure.
- Environmental requirements – specify any other requirements needed for the environment.
- Other requirements – specify any other requirements needed for the product.

The activities required to build a product also need to be defined and managed. These activities are described in the "Project Plan" and are based upon a development model that is suitable for the project. The development model will include all the processes defined for building in quality. This project will use the incremental development model illustrated in Figure 2.5.1.

This model is about building a product in multiple stages and incrementally releasing parts of it. The development model starts by defining the requirements and then the high level design from the requirements. From the high level design the project is then split into multiple stages, according to the design. Each stage will design a little, build a little, and test a little. Each new stage will build upon the existing product to ultimately produce a single system with all components attached and working. Along the way, system testing will be performed to verify the product development.

A "Project Plan" template has also been defined for documenting the planning and managing activities for each stage of development. This template includes the following:

- The deliverables and milestones
- Project activities
- Resource allocation
- Schedule
- Risk management.

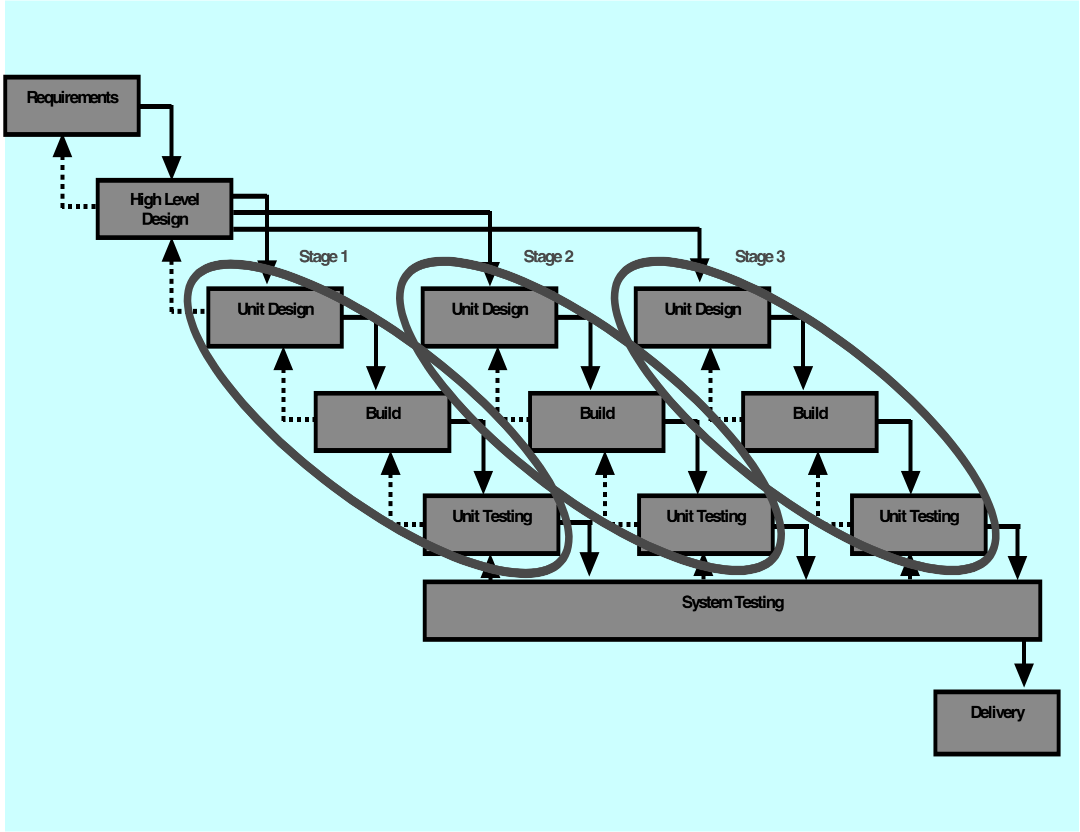

Fig 2.5.1 Incremental Development Model

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