CSIRO Exploration & Mining

Advanced Mining Technologies

Qld Mining Industry Safety and Health Conference
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Australian Mineral Industry

The Mining and Mineral Process Industry (covering exploration, extraction and processing) is a critical part of the Australian economy –

- approximately 5% of Gross Domestic Product (GDP)
- with the Quarrying Industry (clay, sand, gravels and crushed rock) it represents 6% of GDP and employs over 1% of the workforce
- Australia's largest export earner contributing $57.7 billion to Australia's commodity export earnings in 2005-06
- contributes annually $1.9 billion in high-technology exports
- accounted for 19% of the value of Australia's fixed assets and natural capital
- has added around $500 billion to Australia's wealth in the last 20 years

Australian Mineral Industry

Australia is currently enjoying the global increase in commodity demands, however –

- many countries have lost their mining and associated support industries
- primary resource industries continue to play a less significant role in first world economies
- Europe and the USA have both been through this transition and both have seen steady declines in mineral production, exploration and the associated knowledge industries
- Key drivers are a declining role of minerals in wealthy (developed) nations and the ability and expectation of the minerals industry to play a role in managing social and environmental impacts

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In this international context, there has been a climate of global decline in R&D in the sector –

- USA: US Bureau of Mines closed in 1995. OH&S research through DOE and NIOSH
- UK: British Coal Technical Services and Research Executive (TSRE) closed in 1994 ending 47 years of state research
- France: Cerchar (Centre d'Etudes et Recherches des Charbonnages de France) ICT and Automation research terminated
- In 1994, as a prelude to privatisation, the British Coal Corporation closed its Technical Services and Research Executive (TSRE), into mining problems

Australia has opposed this trend –

- over the period 1994-95 to 2003-04, R&D expenditure by the mining industry more than doubled from $303m in 1994-95 to $783m in 2003-04
- the mining industry's contribution to all industries R&D expenditure rose from 9% in 1994-95 to 11% in 2003-04.
- Australia's premiere national R&D organisation, the CSIRO, invests approximately $35m per year into R&D through its Exploration and Mining Division
- CSIRO EM employs around 200 full-time researchers, scientists, engineers and support personnel based in three major centres across Australia (Brisbane, Perth and Sydney)

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Australia has opposed this trend –

- creation of a new CSIRO National Research Flagship, known as Minerals Down Under, is in direct response to the major challenges confronting the minerals industry in Australia
- recently announced in the federal budget, this new Flagship will receive and additional AUD $34.6m over the next four years to focus on National Challenges of
    - T1 Discovering Australian Mineral Resources
    - T2 Transforming the Future Mine
    - T3 Releasing New Ore Reserves
    - T4 Minimising Industry's Footprint
- collaborate with industry, universities, OEMs, technical service providers and other R&D institutions to coordinate research which will help Australia unlock key commodities in our underground mineral reserves.

Risk, specifically *technical risk*, is increasingly being seen as higher in Australia than some other countries who hold significant amounts the global mineral endowment

In the truly global market place, this risk is being traded against the *sovereign risk* inherent in operating in less stable nations

But technical risk can be reduced by new technology and this paper addresses some of the R&D activities being undertaken by CSIRO to overcome the technical challenges facing Australia's mining industry

Exploration & Mining R&D Structure

Research Areas

- **Safety and Productivity**
- **Resource Utilisation**
- **Environment and Sustainability**

Research Capabilities

- **Mining Geoscience**
- **Mining Automation**
- **Mining Systems**
- **Specialist Services**

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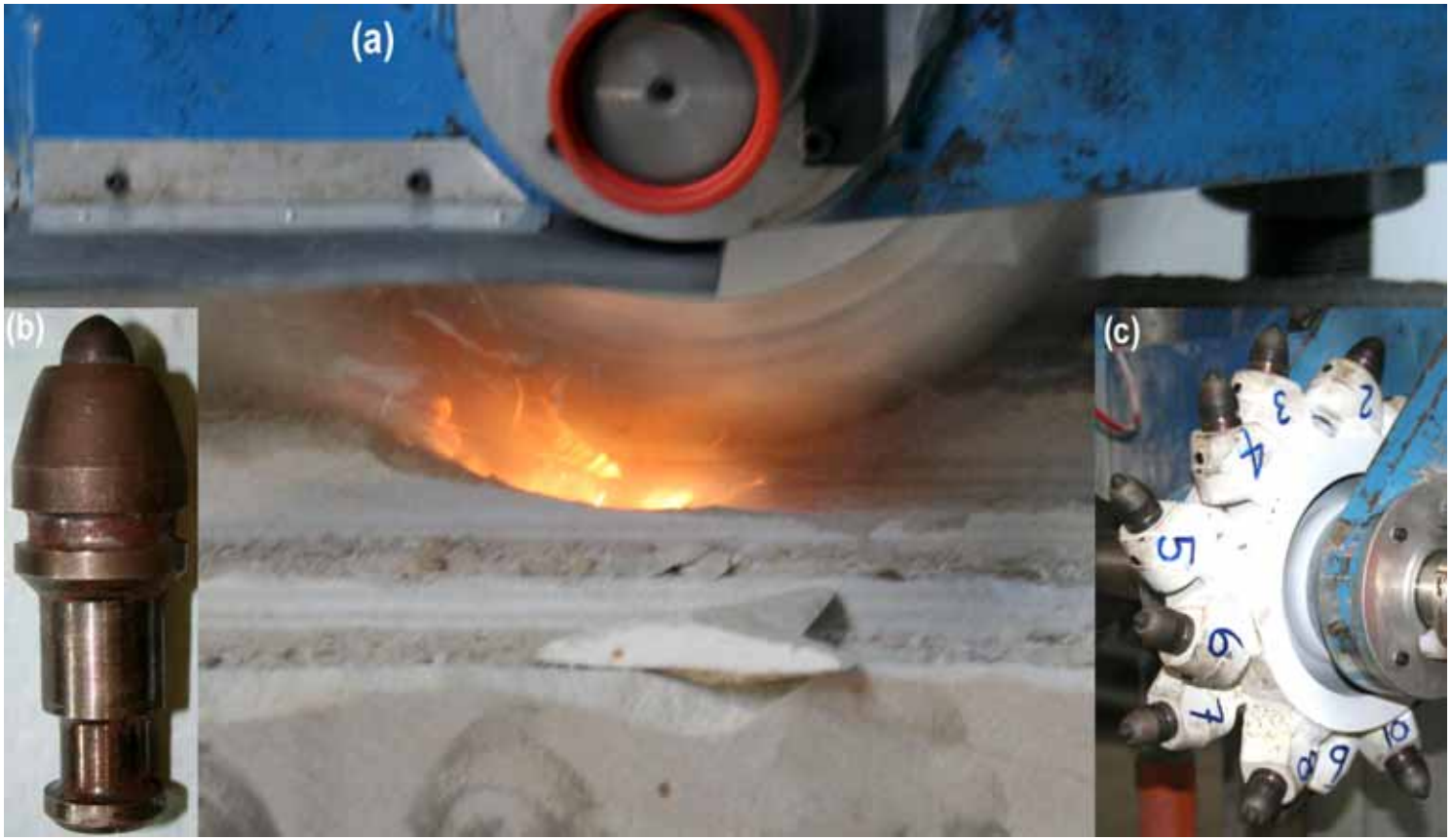
CSIRO SMART*CUT TECHNOLOGY



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HARDROCK CUTTING

Cutting Harcourt granite (UCS=180 MPa)
v = 20 mm/s, RPM = 350, DOC = 55 mm, Pick: TSDC

MASS MINING
Large Open Pits

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An international research project into the stability of rock slopes in large open pit mines, funded by 11 multinational mining companies that collectively account for approximately 70% of the world's production of gold, copper and diamonds (including Rio-Tinto)

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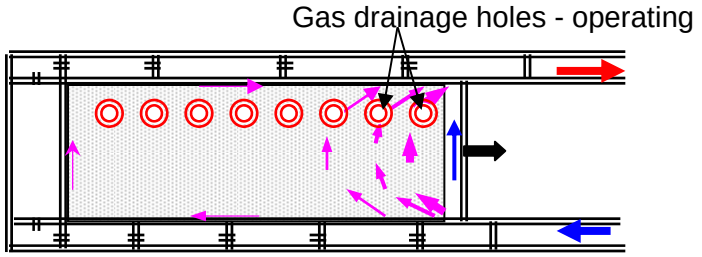
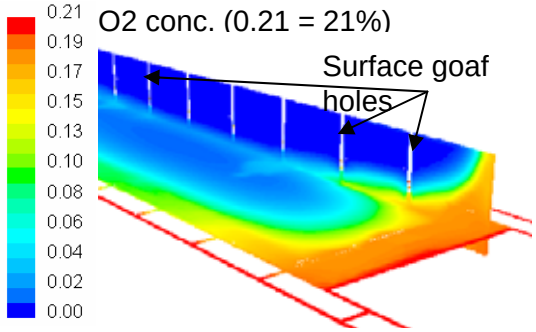
Longwall goaf gas drainage

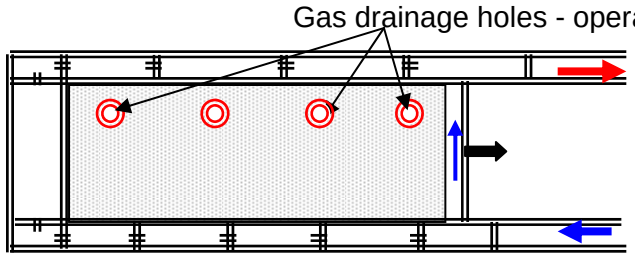
- Gas drainage levels increased by ~ 50% - 200%
- Success even in sponcom prone mines
- Enabled production increases over 10,000 t/wk (equates to ~ $20m/yr per mine, significant impact)



(a) Traditional approach



(b) Goaf gas control investigations



(c) Optimum designs & strategies

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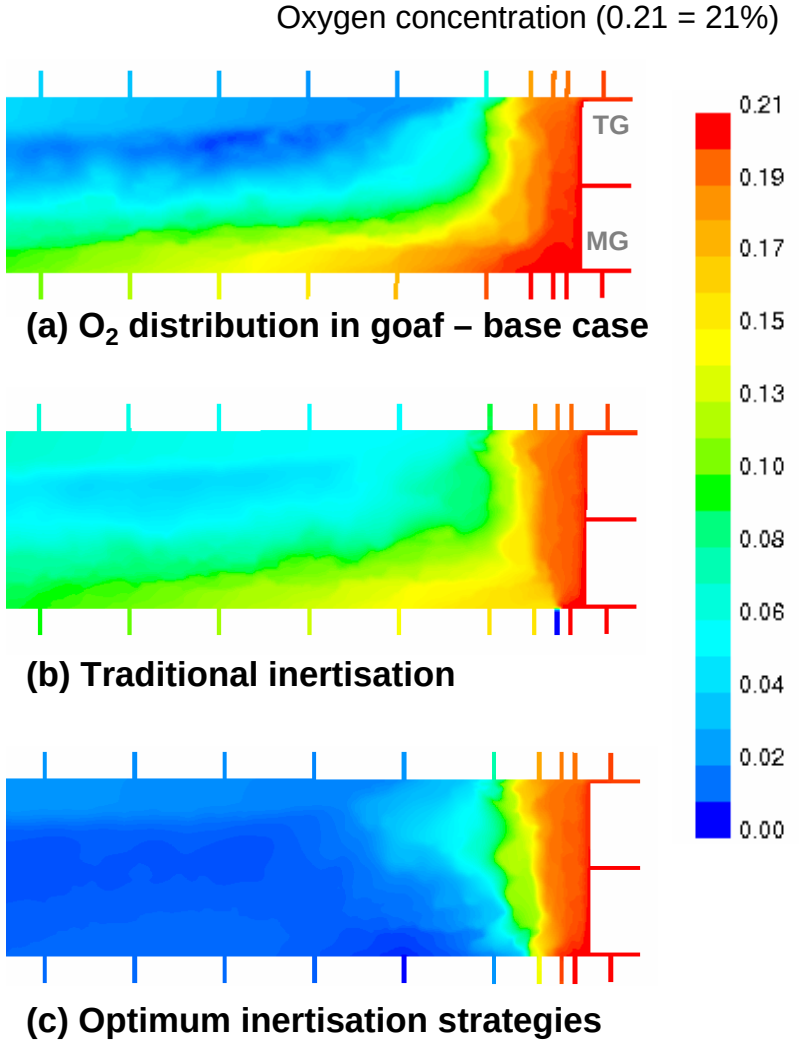
Fire control

- Developed effective inertisation strategies – deep, inbye, rate, continuous, boreholes, vent, ..
- Controlled heatings/fires in a no. of panels
- Resulted in changes in industry practices
- Huge impact on the industry –
- (LW's, wks/months saved ~ equates to > $100m)



(a) O_2 distribution in goaf – base case

(b) Traditional inertisation

(c) Optimum inertisation strategies

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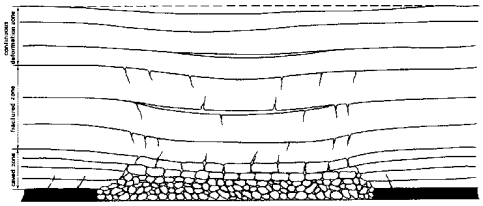
COSFLOW – COMPLEX INTERACTIONS

Mining induced strata fracture/deformation

Change in permeability and reservoir pressure



Change in effective stress

Caved, fractured and deformed zones

Ground Water Flow

Change in reservoir pressure and relative permeability

Gas diffusion and flow

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COSFLOW–FEATURES

Combined three-dimensional mechanical/one or two phase Darcy flow finite element code with rock fracture coupled to other processes

Optimised for underground coal mine design issues involving layered rock deformation and fracture, and water and gas flows

- Cosserat formulation for efficient simulation of fracturing in layered rock
- The complex interactions previously identified are incorporated
- Parallel processing

OPERATIONAL CONTROL
Subsidence Control

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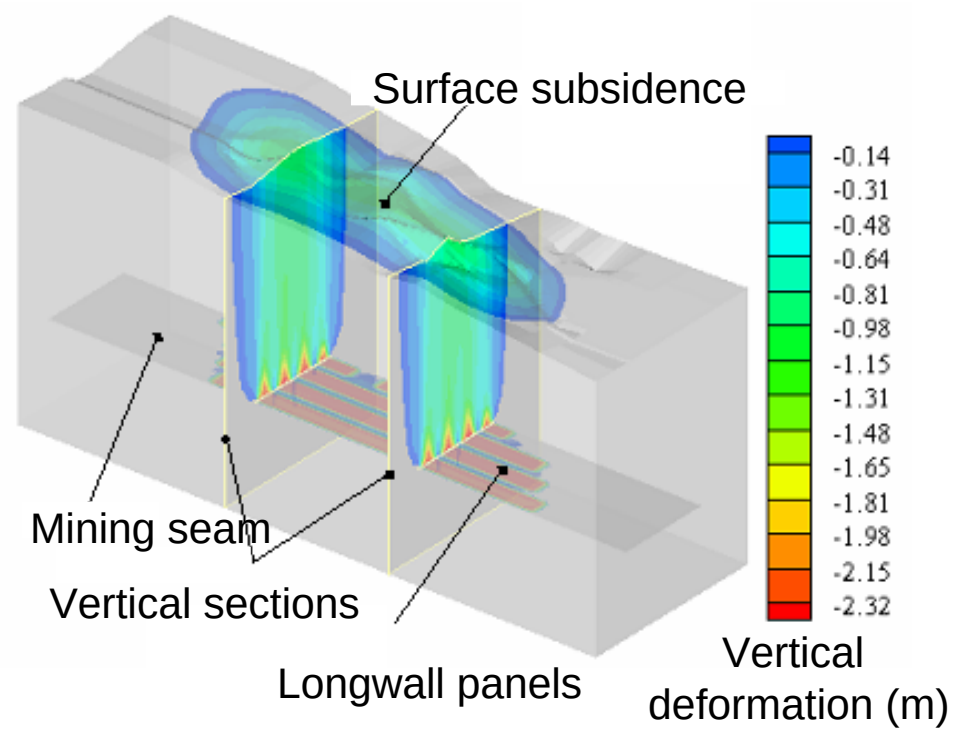
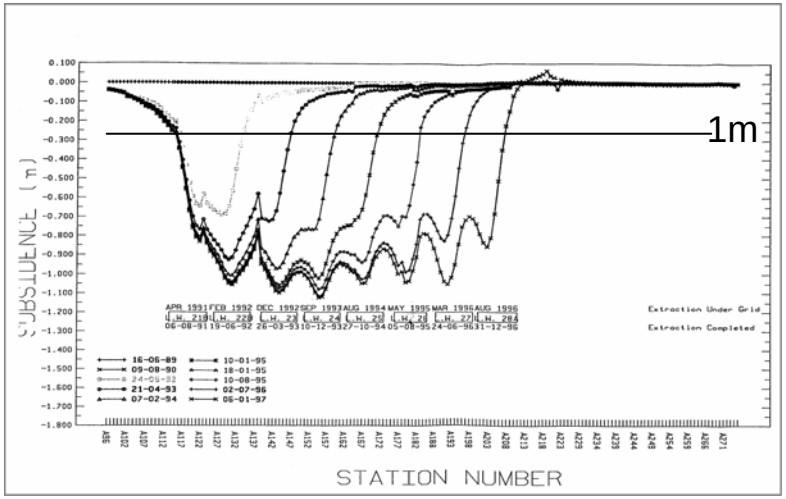
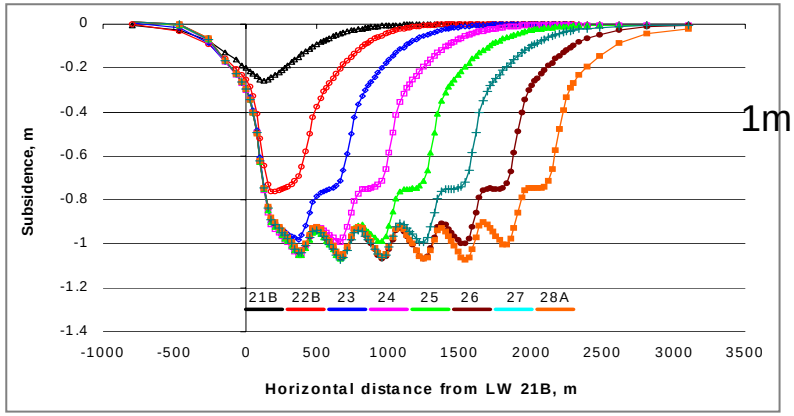


Measurements





Simulation

OPERATIONAL CONTROL
Subsidence Control

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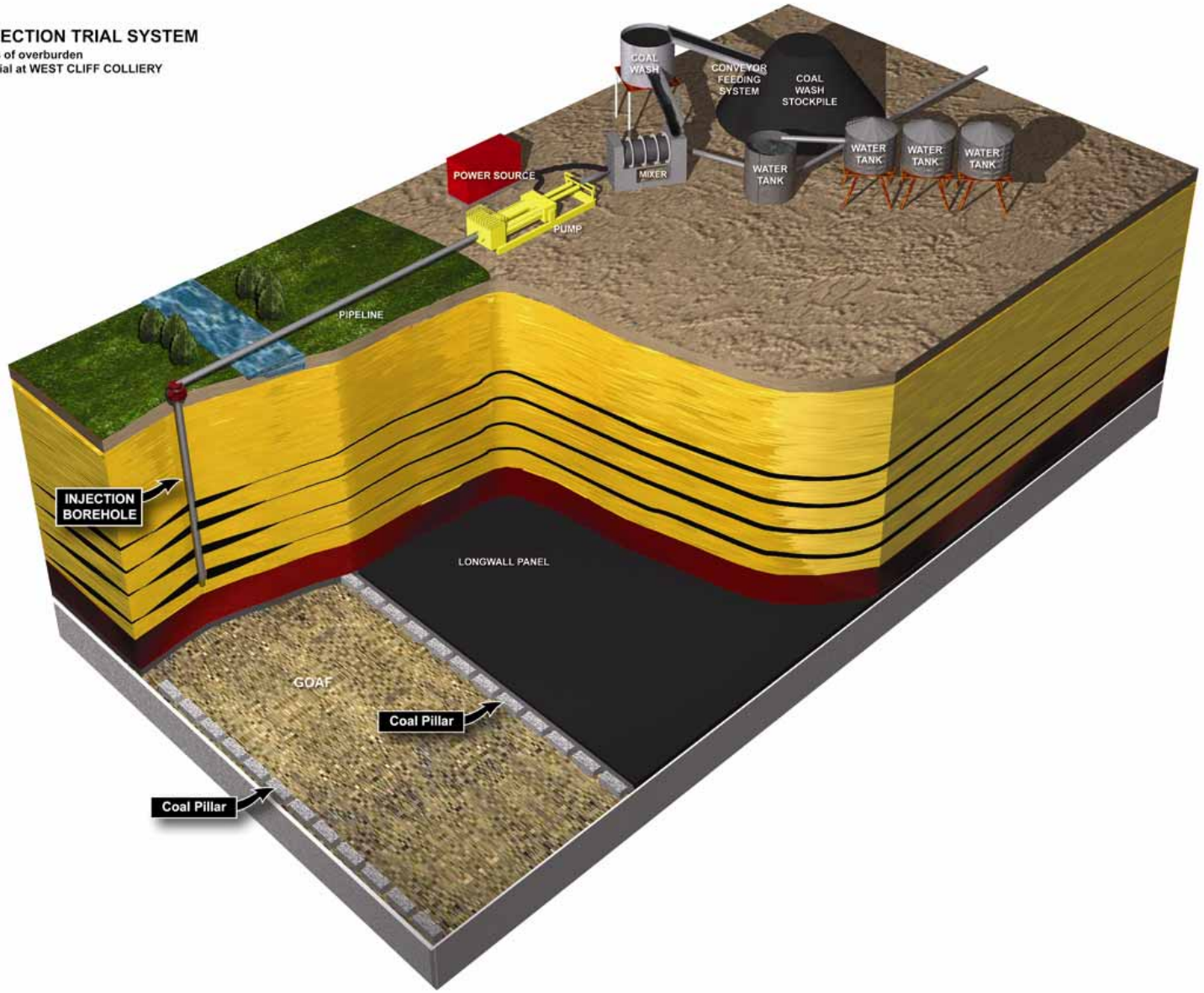
GROUT INJECTION TRIAL SYSTEM

Key components of overburden
grout injection trial at WEST CLIFF COLLIERY



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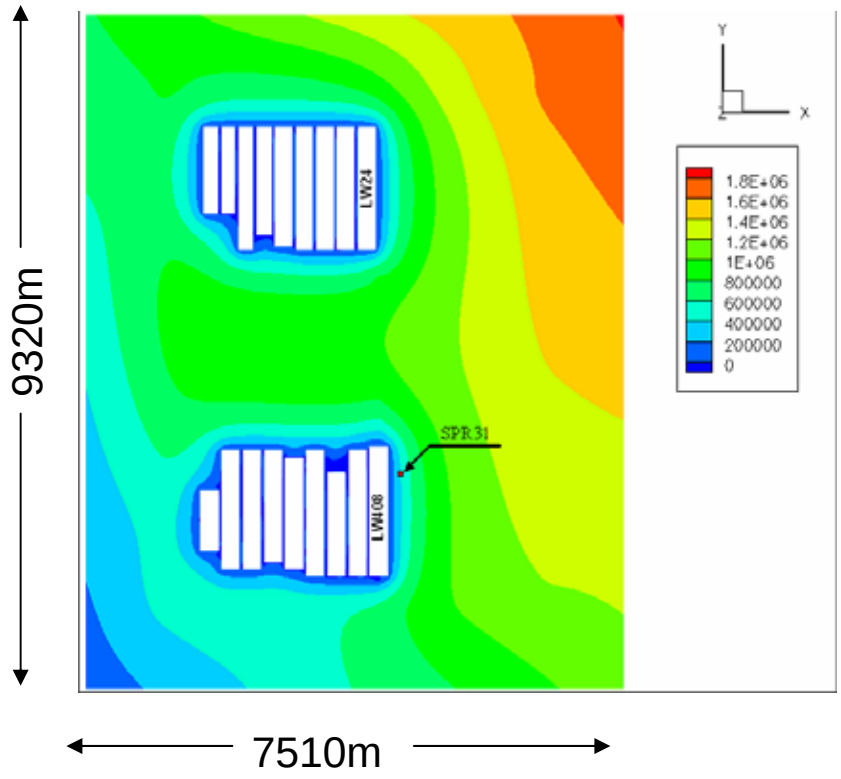
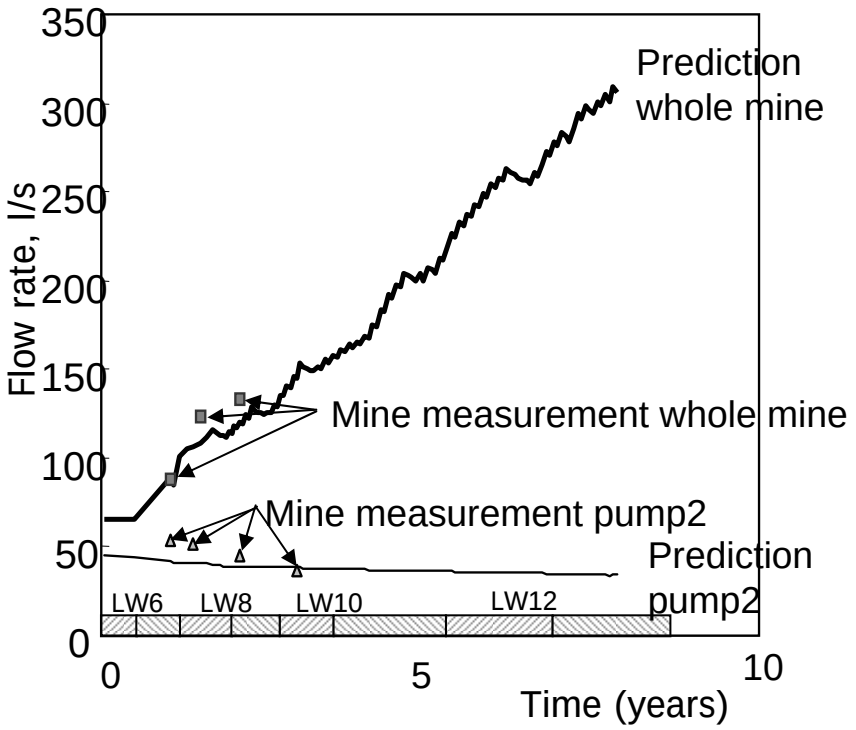
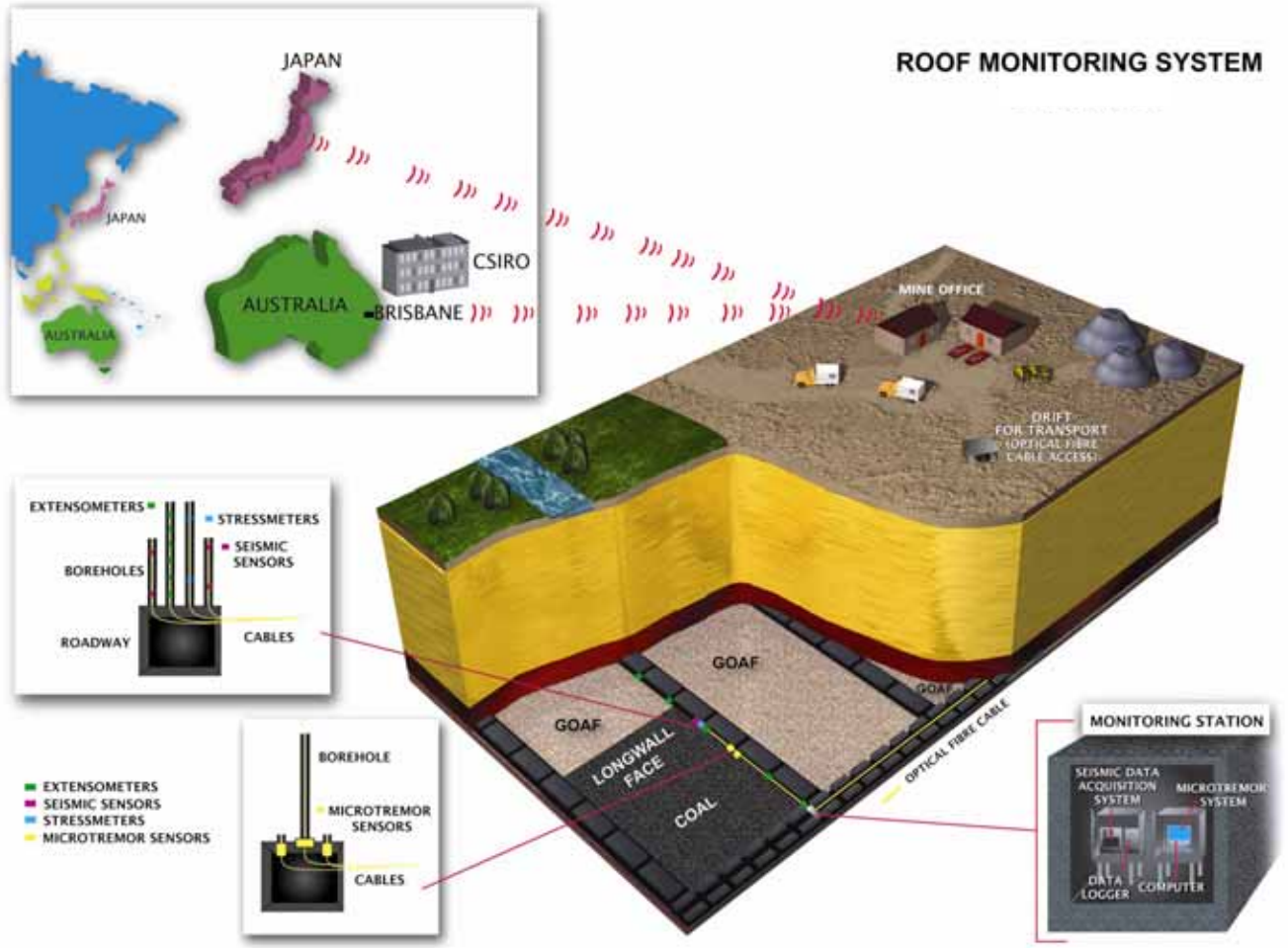
Predicted pore pressure (Pa) at the sloping coal seam





Predicted and measured flow rates

OPERATIONAL CONTROL
Real Time Geotechnical Monitoring



MINE WASTE MANAGEMENT

- **Greenhouse emission measurement, prediction and mitigation**

  Examples:

  - VAMCAT (1% methane turbine system) prototype unit under development for demonstration in China with Australian Greenhouse Office support
  - Carbon composite systems for dilute methane and carbon dioxide adsorption under experimental development

- **Reducing mine environmental issues through:**
  - Integration of methane mitigation, waste coal and mine water systems
  - Combined power generation and desalination plants
  - Option evaluation for mine water management systems
- **Evaluation of potential legacy issues in post-mining land use**

DREDGE MINING METHOD

Dredge, and dry mining methods used

UNDERGROUND MINING METHOD
Unconsolidated

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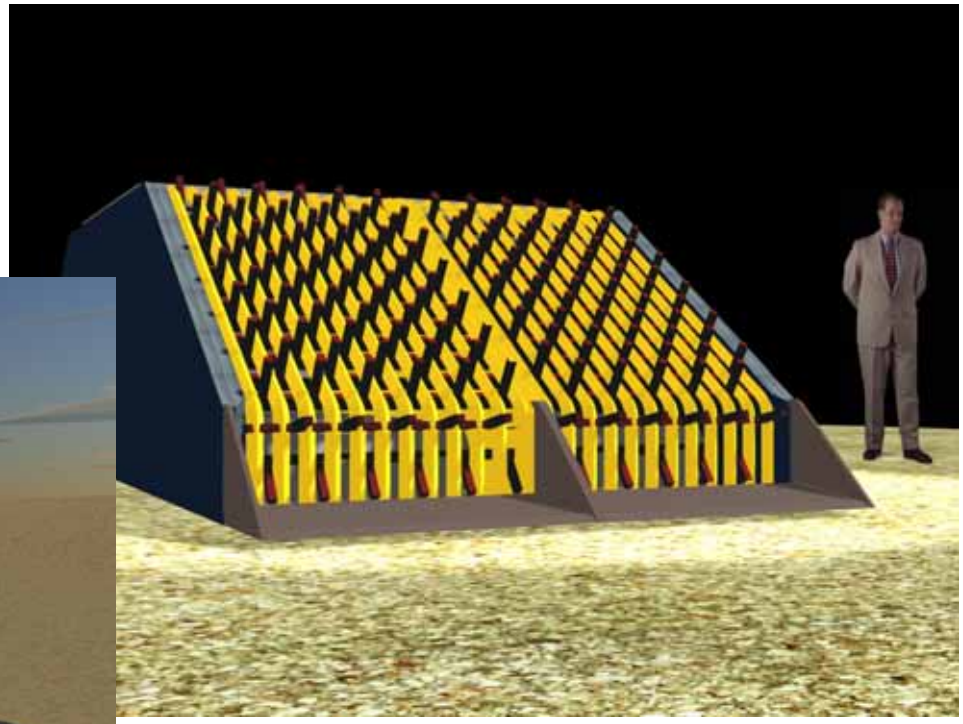
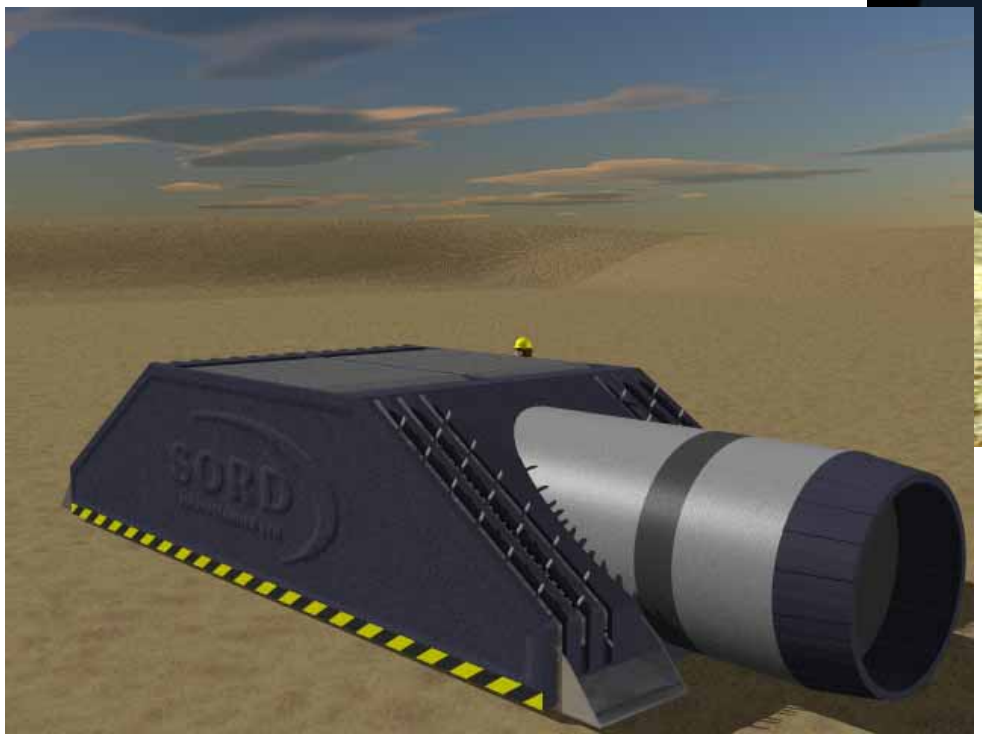
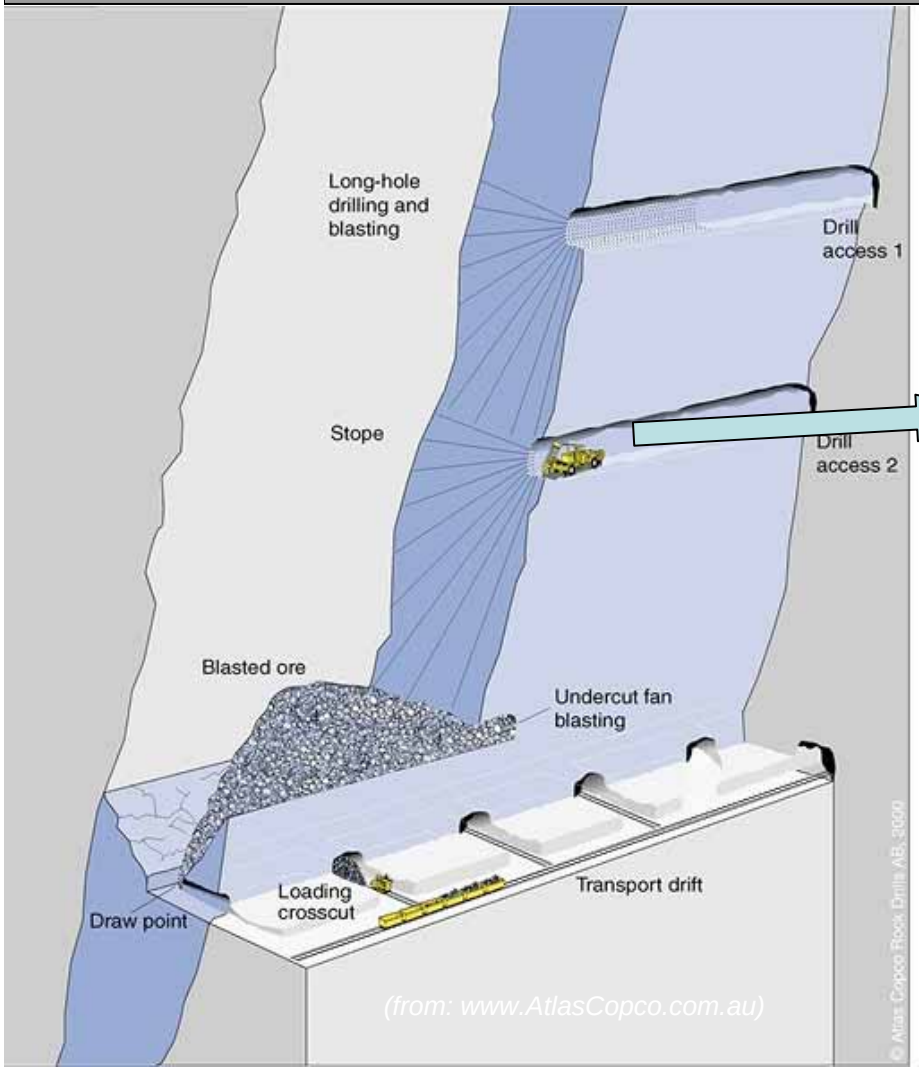
Sord Technologies, SORD & Shield miner





Existing Sub-Level Open Stope (SLOS) Mining System



Transformational Remote Ore Extraction System (ROES™)

A remote controlled/automated mining method.

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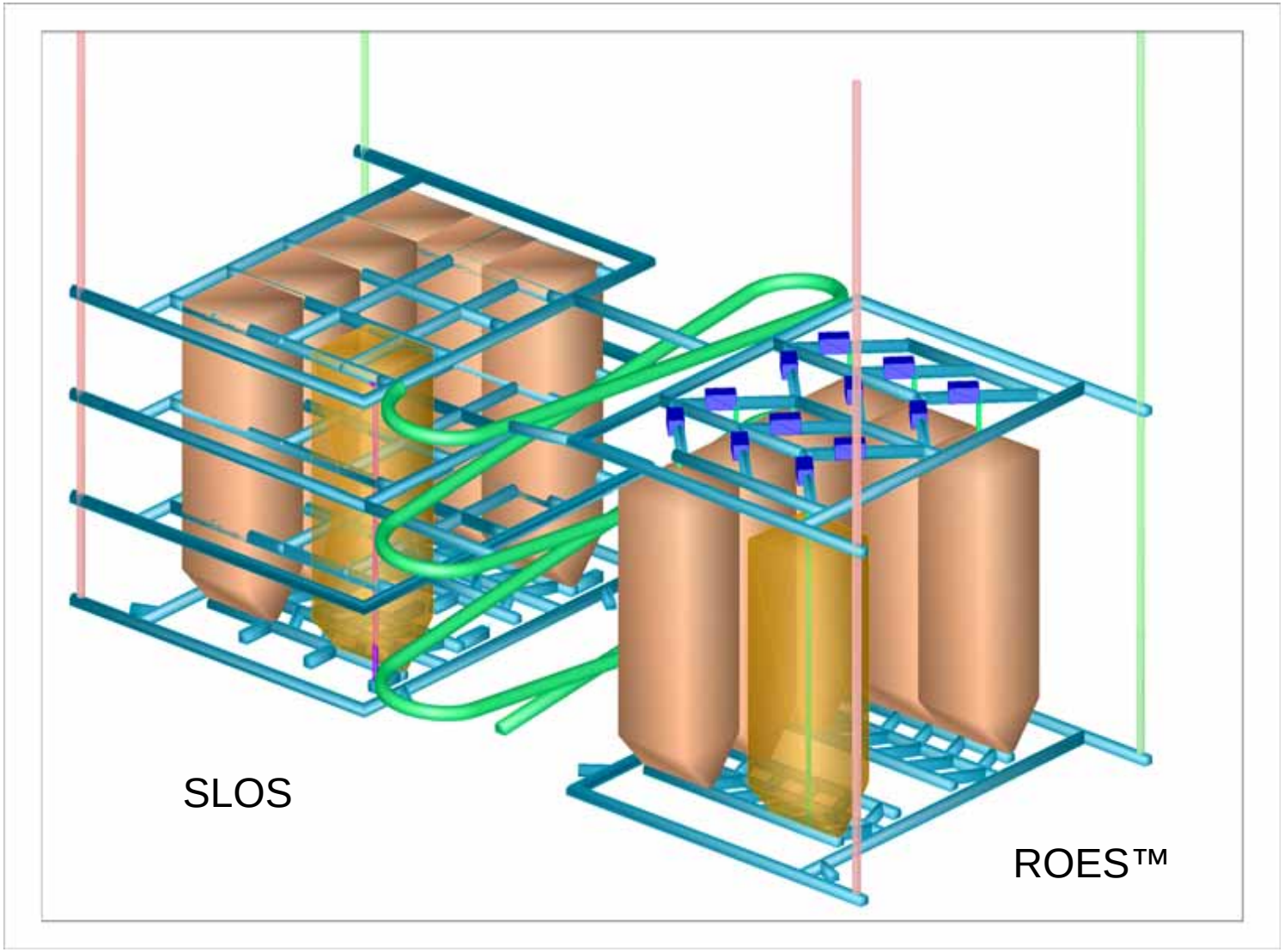

ROES™ Concepts

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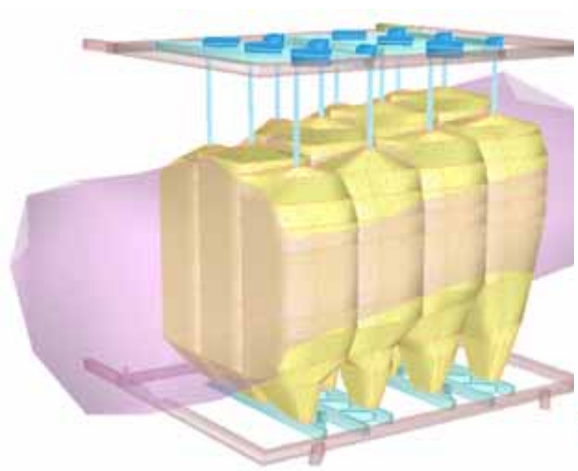
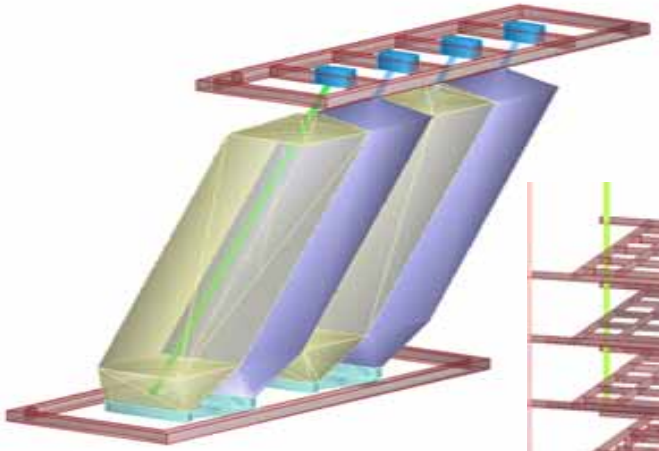
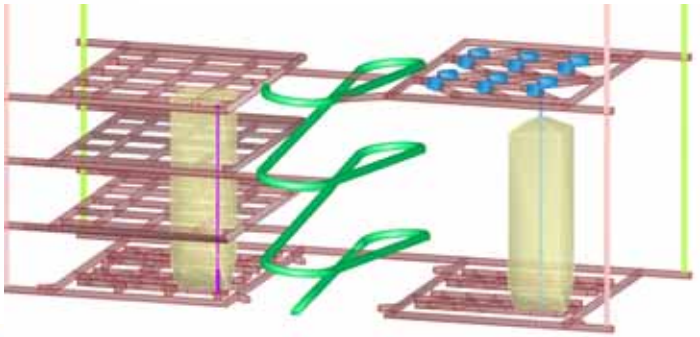
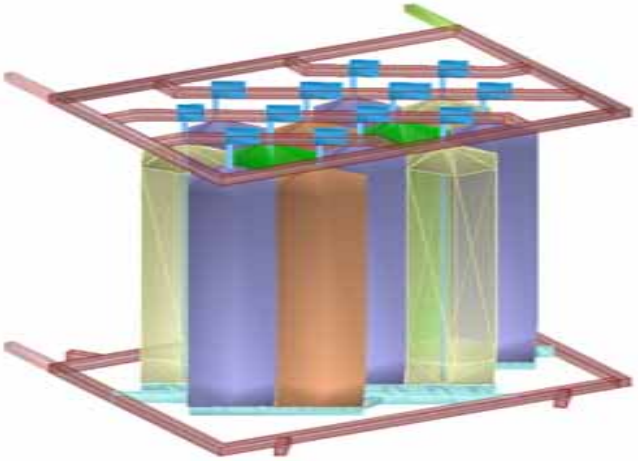
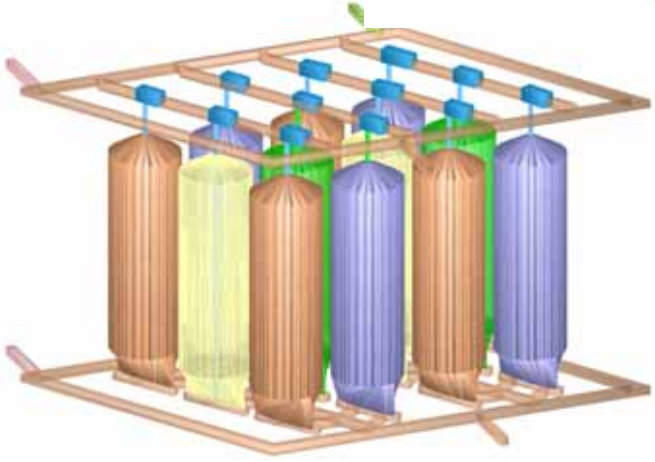










ROES™ Benefits compared with SLOS

Primary operating & capital costs:

- Less than ½ the horizontal tunnelling
- Lower ventilation (& services) requirements for same production
- Reduced time to develop & bring stopes into production
- 10% to 20% typical reduced mining costs

Safety

- Drill & blast remotely
- Mine operators away from: large excavations, mobile equipment, heat, dust & fumes
- Reduction in fatalities and serious injuries (25% to 50% ?)

Other

- Rapid feed-back of operating data stope survey, fragmentation, crown pillar condition etc
- Shorter & straighter blast holes
- Improved & consistent blasting – tuned by rapid feed-back – good breakage
- Measurement while drilling
- Integrated mine data management
- Convenient Integration with automated LHDs etc.

ROES™ ~ Potential Applications

Bulk Mining

- Massive orebodies (ROES™ shaft “vertical”)

Thick Tabular

- Such as the Mount Isa lead orebodies

Narrow Vein

- Provided ore can be accessed using a straight ROES™ shaft

Shaft stripping

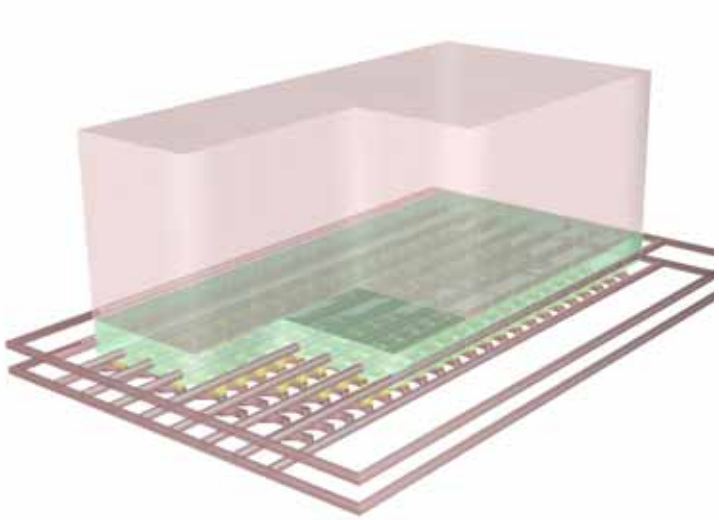
- Used where Horadiam is used

Block Cave

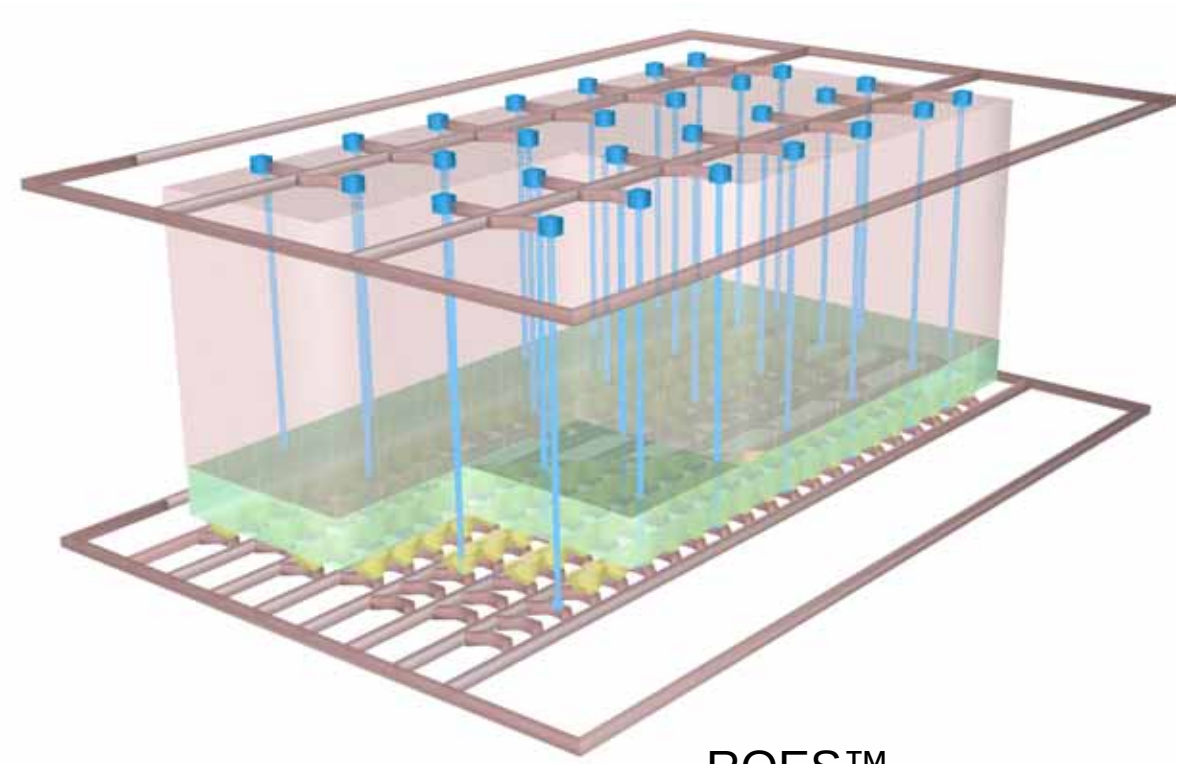
- Safe pre-condition
- Frozen zone recovery
- Alternate development of undercut
- Easy monitoring of cave

Underground Quarrying

ROES™ & Block Caving



Conventional



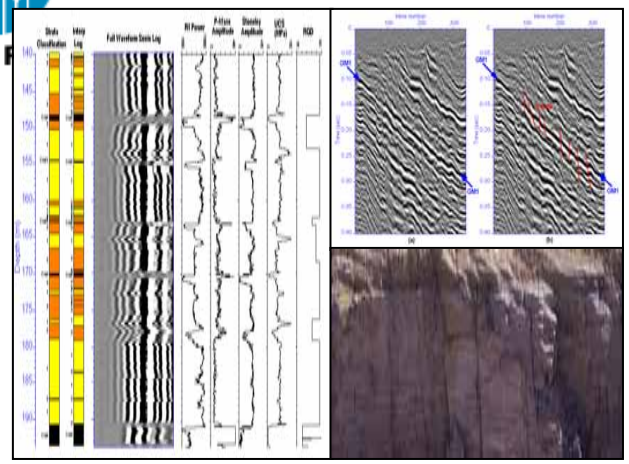
ROES™

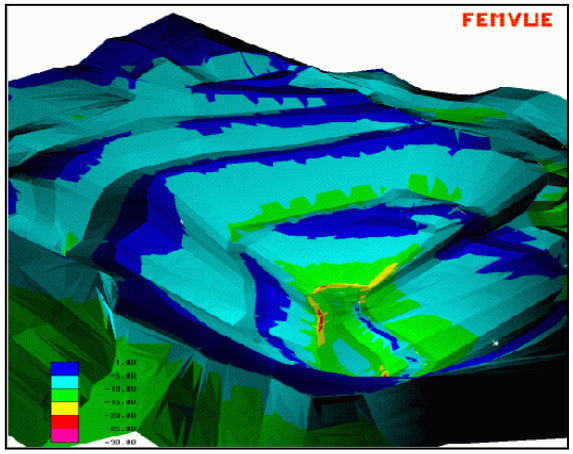
Including undercut development

Advantages of ROES™/Block Cave Hybrid

- Allows safe precondition throughout orebody or in more competent blocks
- Reduces the risk of frozen ground
- Allows easer recovery of frozen ground
- Can develop undercut including draw bell extensions from ROES™ shaft
- Substituting horizontal development in the undercut for vertical development using raise borers
- Development can be more evenly spread throughout the orebody if required
- Provides easy monitoring of the cave voids and caving progress using remote controlled survey equipment

Open Pit Design





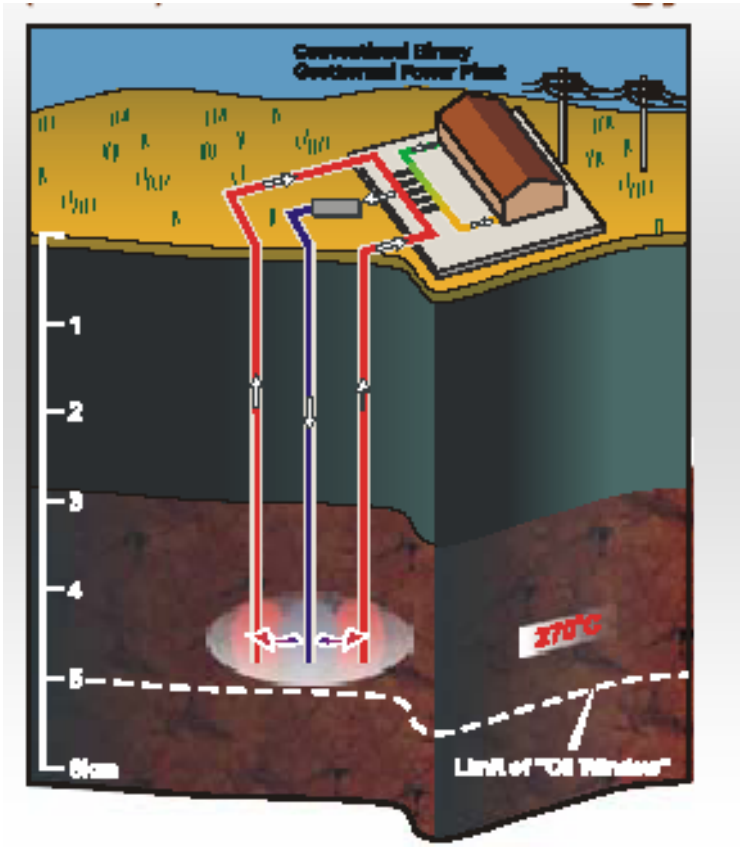
- Mapping & rock mass characterisation
- Block modelling & stability analysis
- Slope monitoring & risk management

Mine environment and society covers a diverse range of different disciplines

Research topics

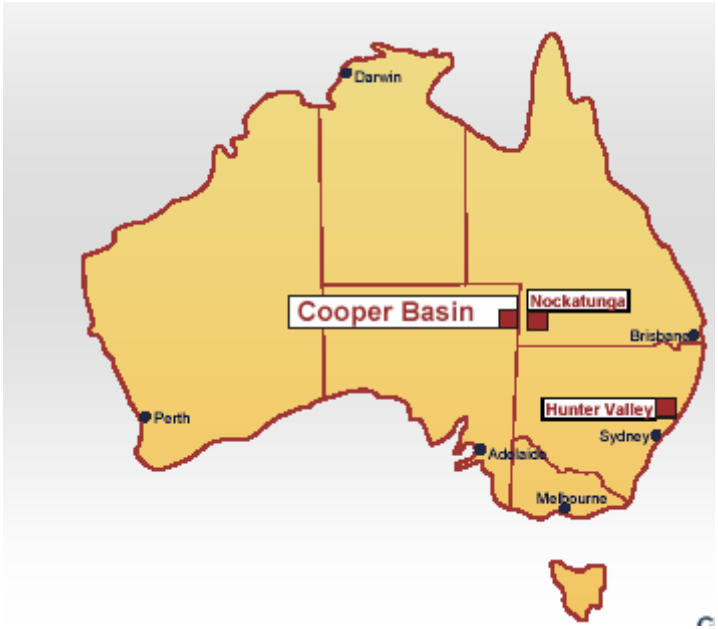
- Greenhouse gas emission mitigation
- Waste management
- Social acceptability of technologies
- Mine safety and health issues
- Post-mining land use
- Underground coal gasification

Geothermal Energy Development



1. Extract heat energy from earth
2. Clean, renewable energy source with zero emission
3. Abundant reserve (e.g. in Cooper Basin)

4. Water circulation through Hot Fractured Rocks (HFR) underground



Geothermal Energy Development

1. Several HFR operations overseas (e.g. Fenton Hill - USA; Soultz - Europe; Hijiori - Japan)
2. 1st Australian operation at Cooper Basin (4.5km deep)

3. Increasing number of companies in Australia for HFR operations (Geodynamics, Scopenergy, Tasman Resources, Petratherm and Green Rock Energy)

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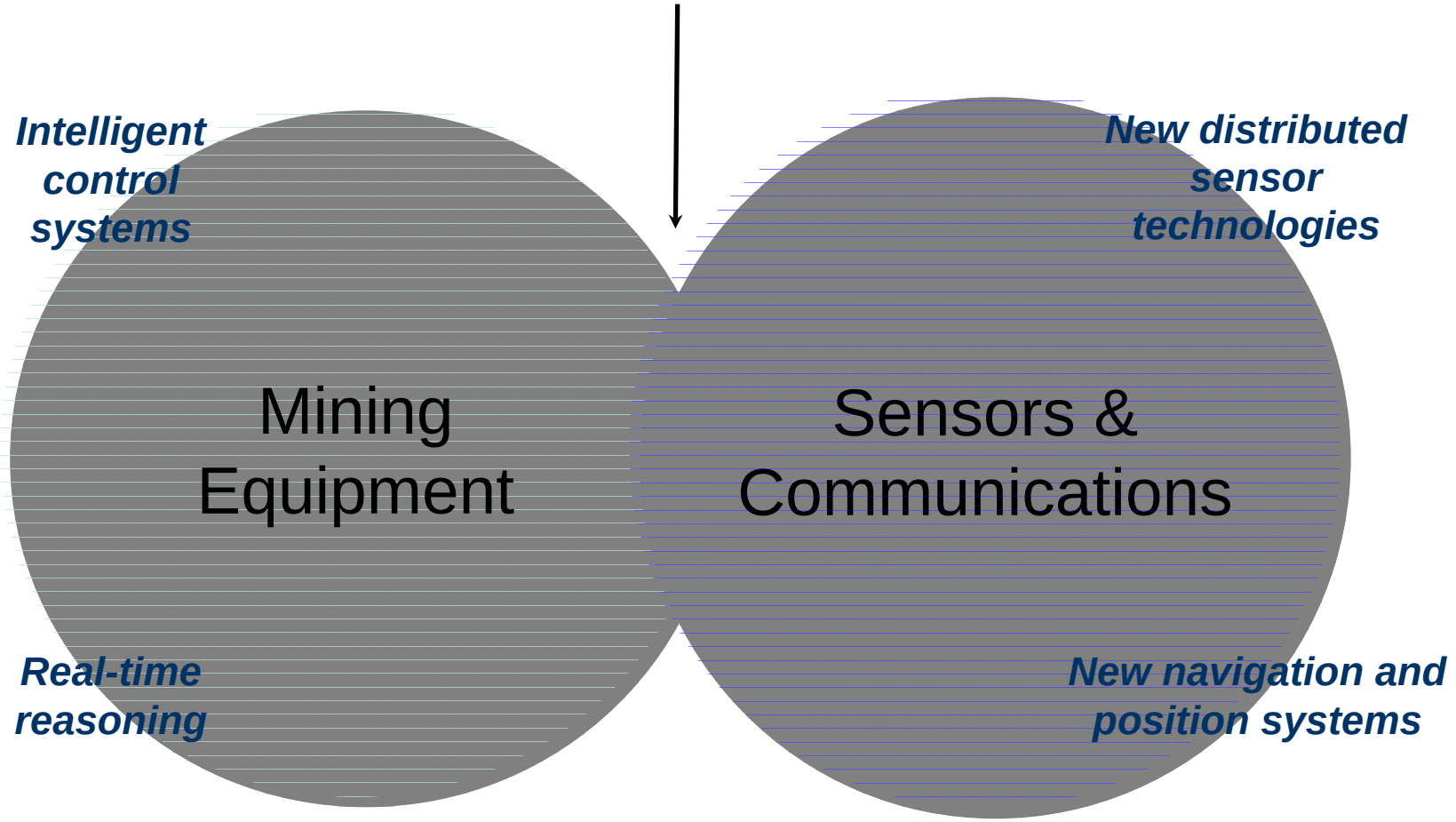
Intelligent systems for the autonomous operation of mining equipment



DRAGLINE AUTOMATION

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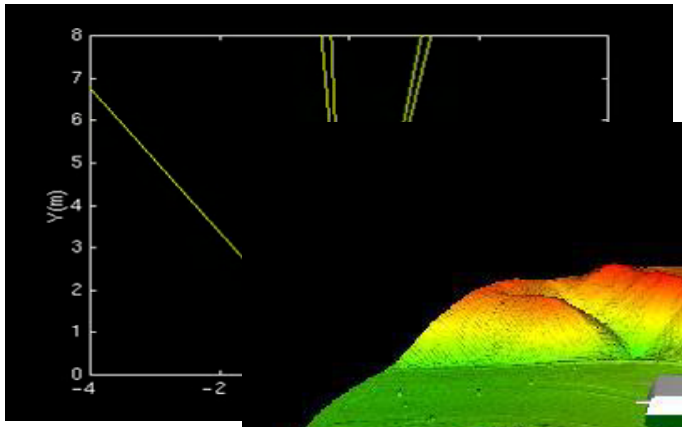
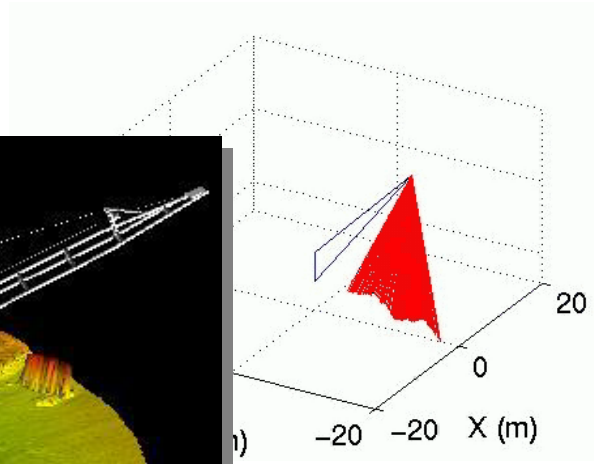
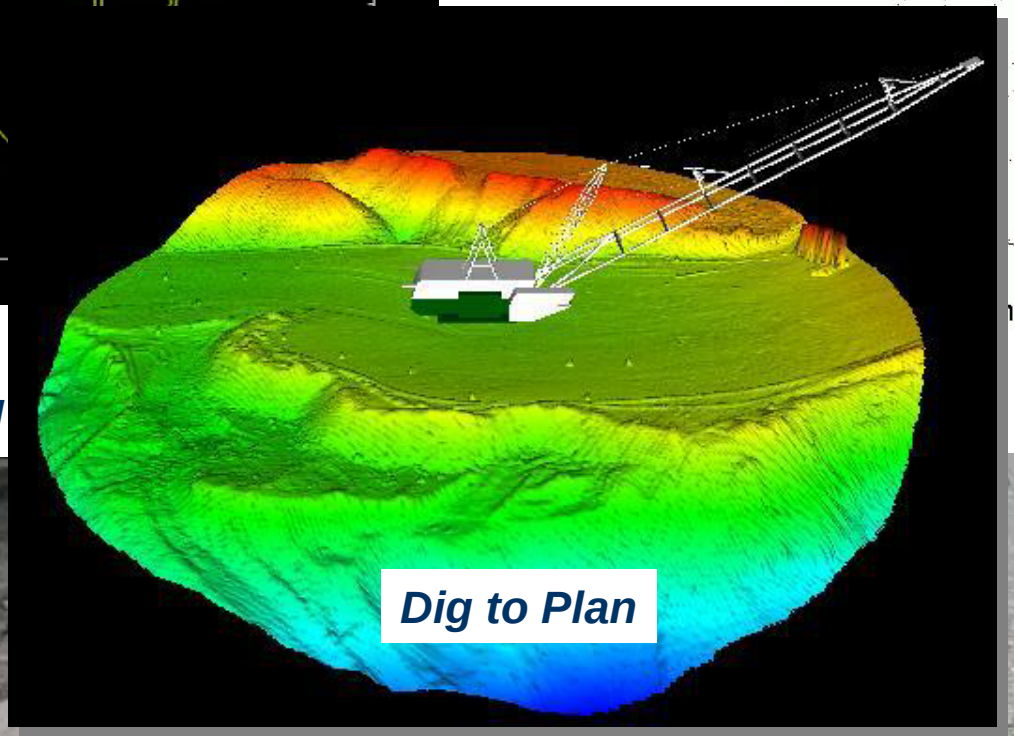
Laser Bucket Tracking

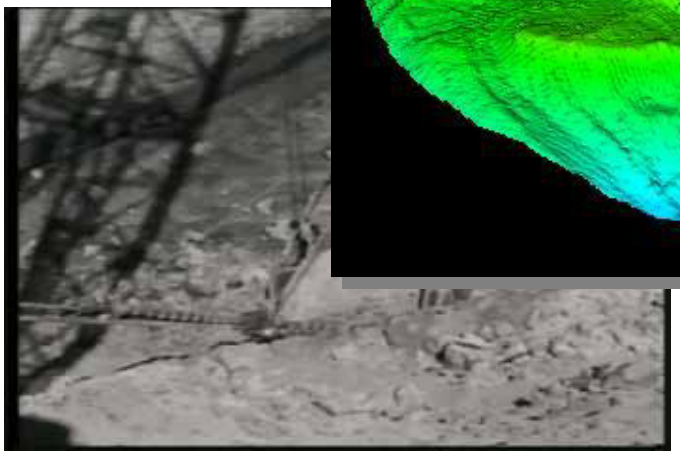


Laser Terrain Mapping

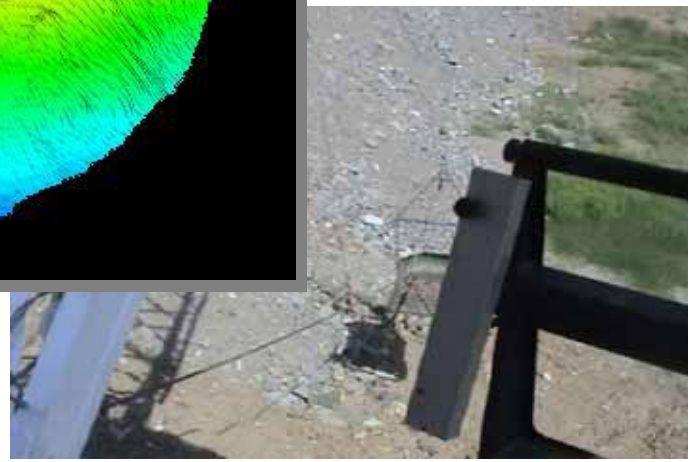




Dragline Swing



Terrain Following



MINING ICT & AUTOMATION

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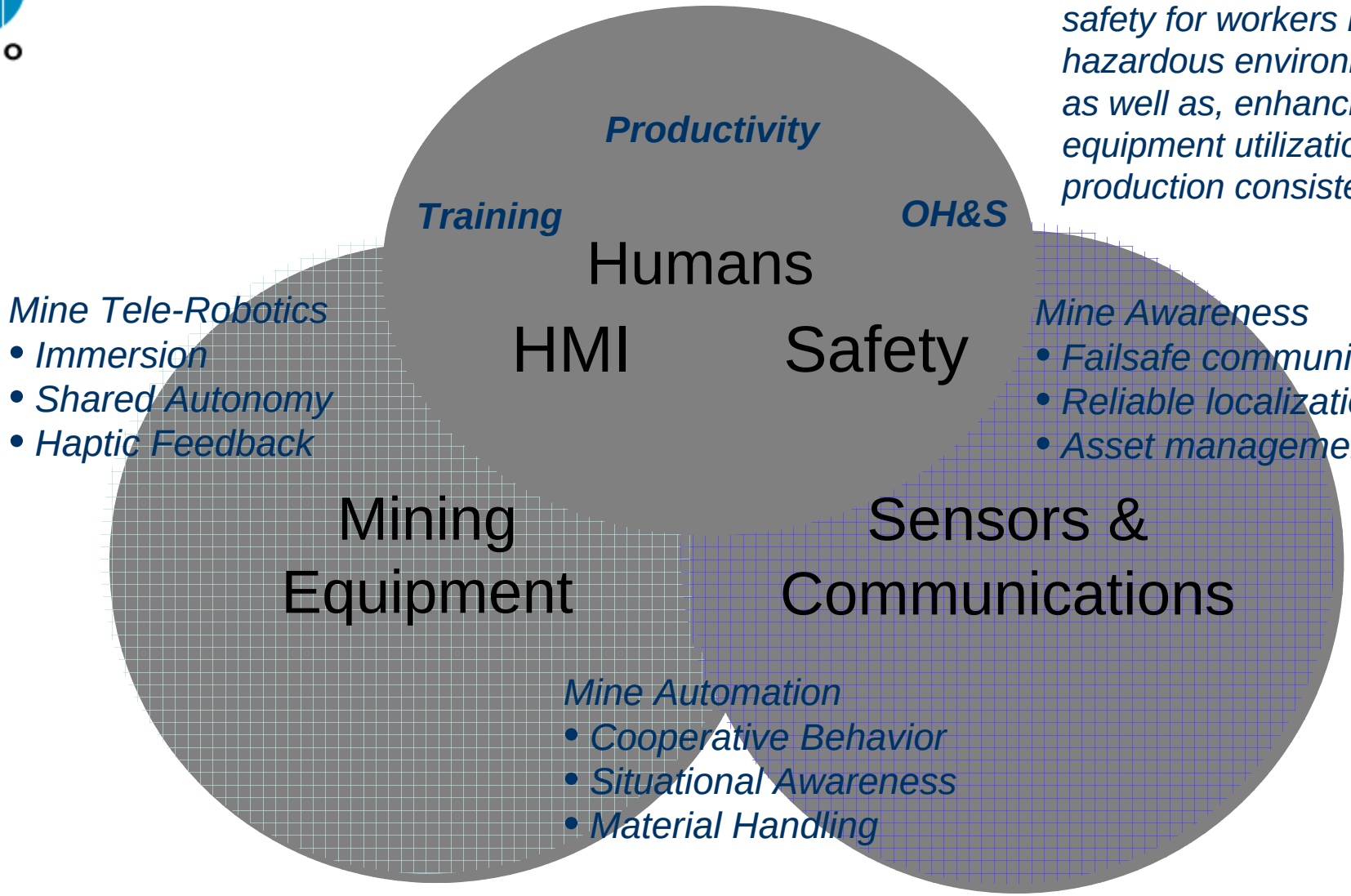
Improving health and safety for workers in hazardous environments, as well as, enhancing equipment utilization and production consistency.

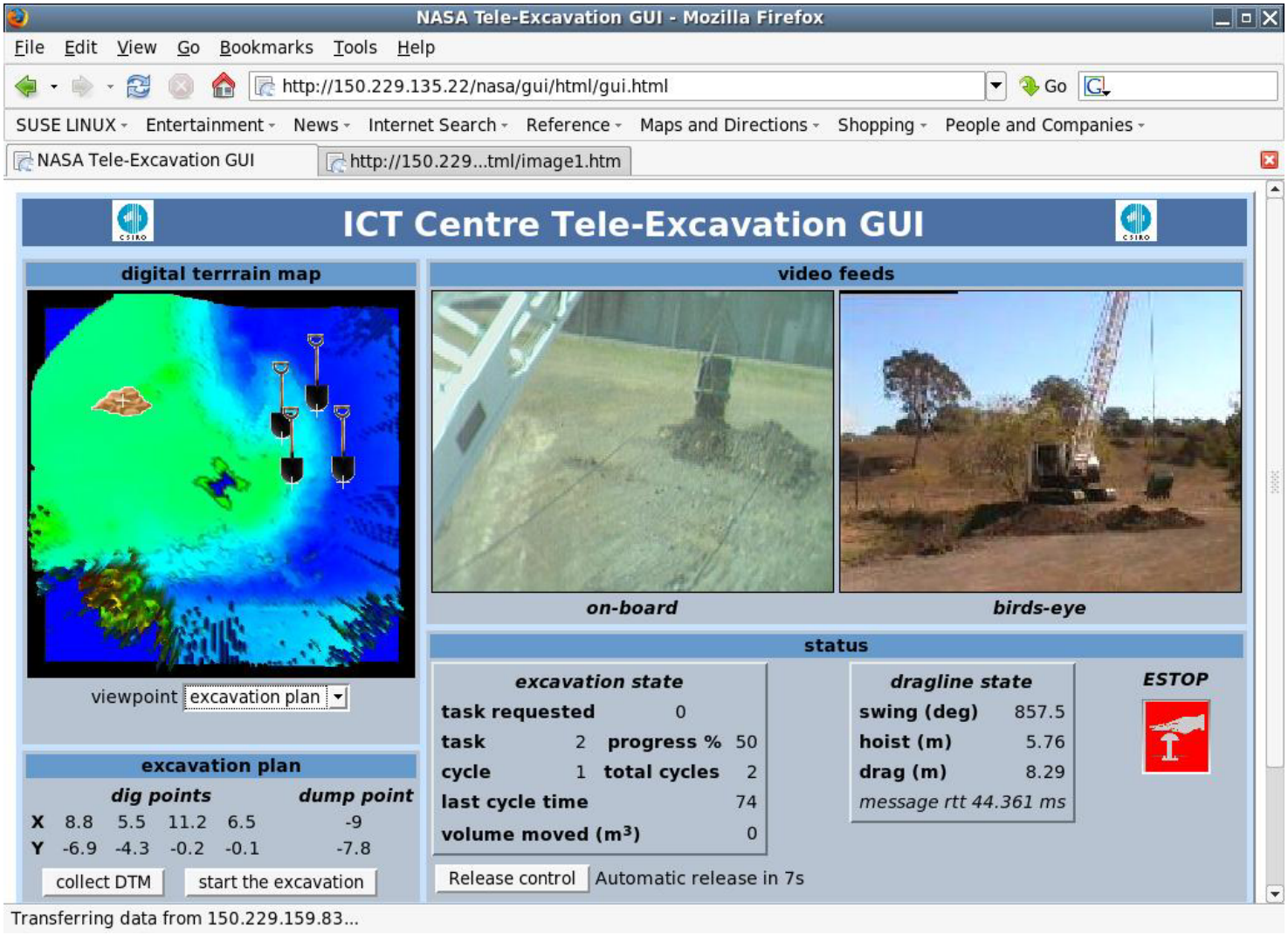


Mine Tele-Robotics
- *Immersion*
- *Shared Autonomy*
- *Haptic Feedback*

Mine Awareness
- *Failsafe communications*
- *Reliable localization*
- *Asset management*

Mine Automation
- *Cooperative Behavior*
- *Situational Awareness*
- *Material Handling*

DRAGLINE TELE-EXCAVATION



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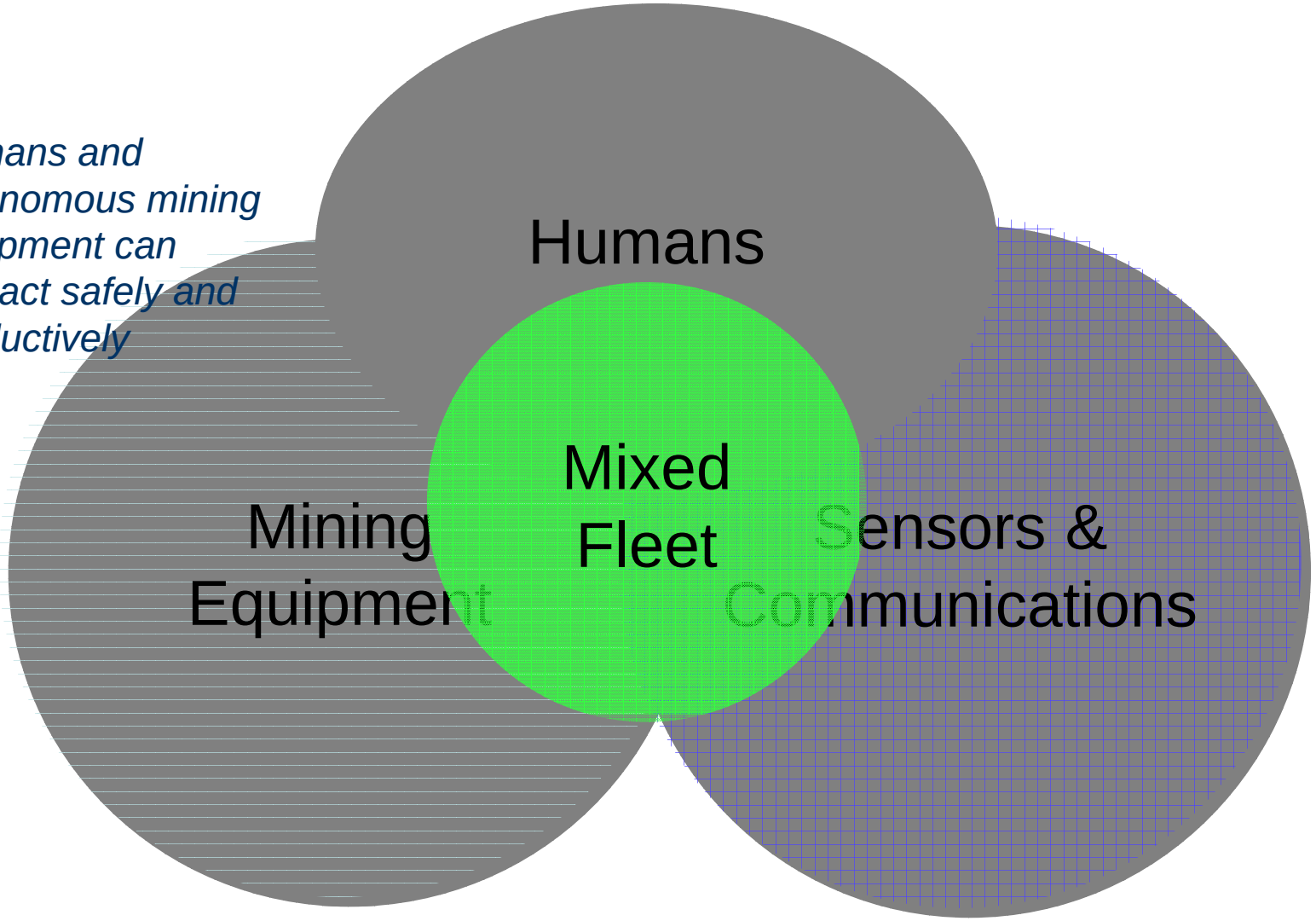
Humans and autonomous mining equipment can interact safely and productively



RAPID ROADWAY DEVELOPMENT

ACBM – Autonomous Conveyor & Bolting Module

LONGWALL AUTOMATION
Project overview

ACARP “Landmark” Longwall Automation Project

$10M total investment

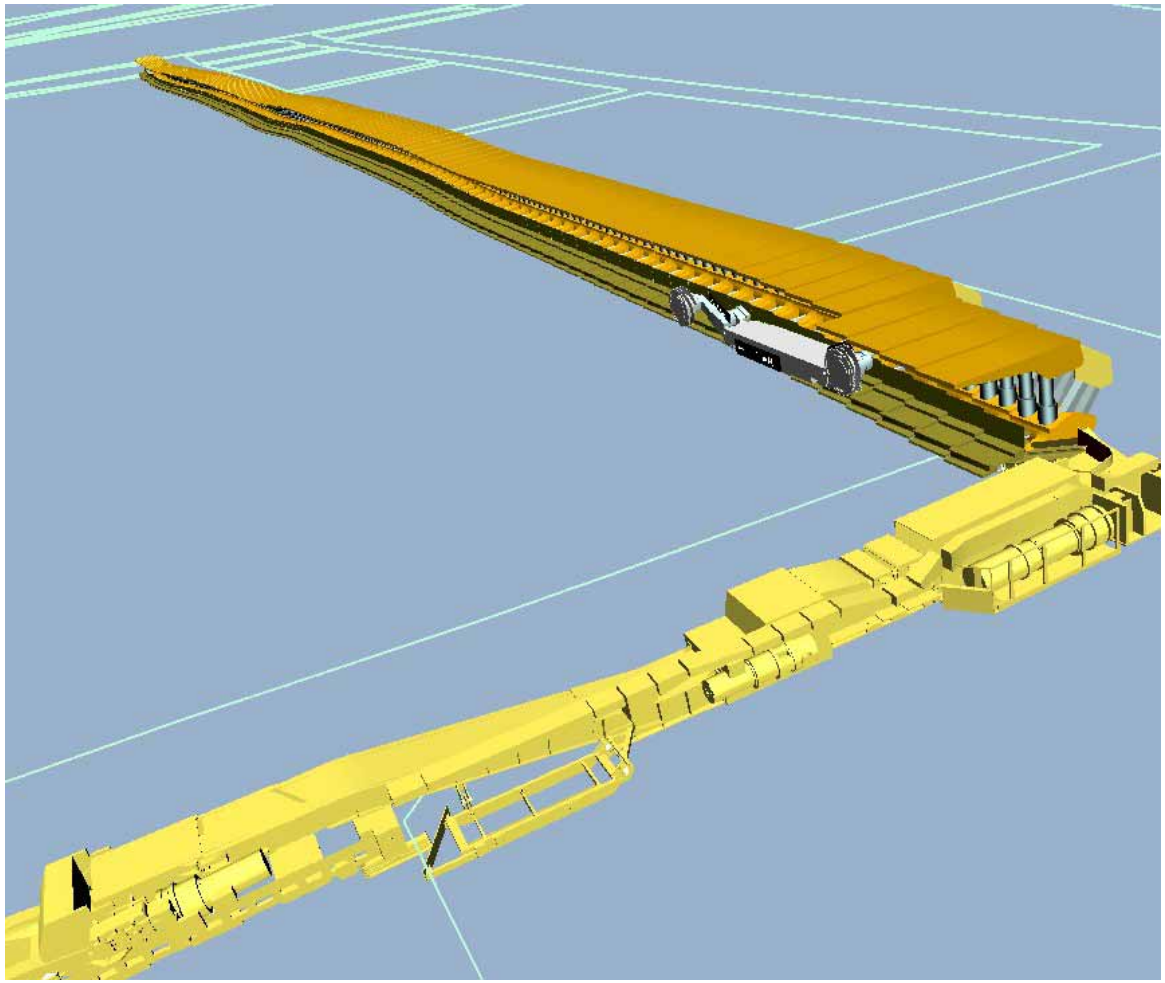
August 2001 - March 2007

Benefits for the Industry

- a higher, more consistent production rate
- removal of face workers from hazardous areas

LONGWALL AUTOMATION
Goals

- Keep the face straight
- Keep the shearer in the seam



LONGWALL AUTOMATION
Shearer Position Measurement

- A new longwall automation sensor
- 3D Shearer position measurement system
- Inertial navigation based

LONGWALL AUTOMATION
Face Alignment

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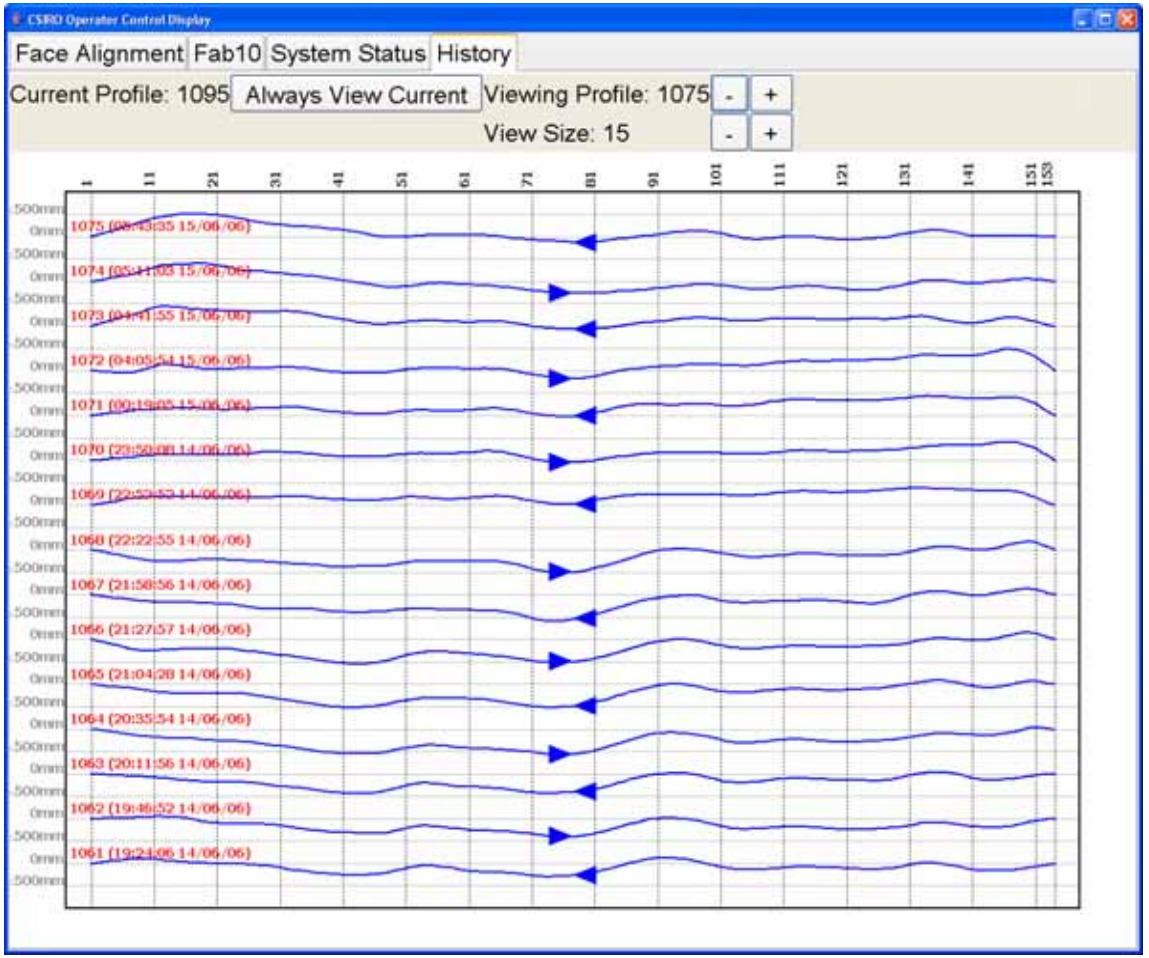
- Production GUI
- Automatic Face Alignment



LONGWALL AUTOMATION
3D Visualisation

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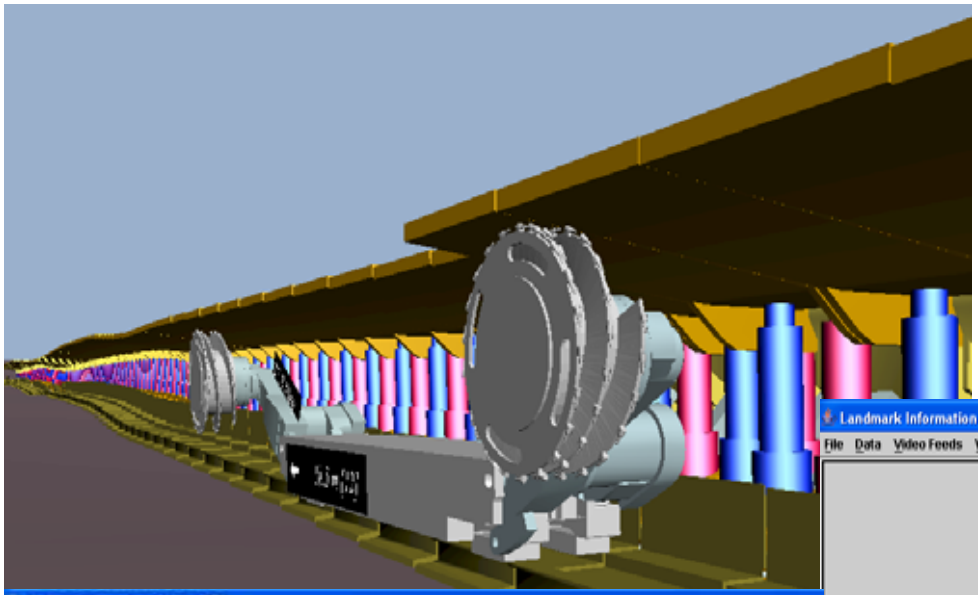
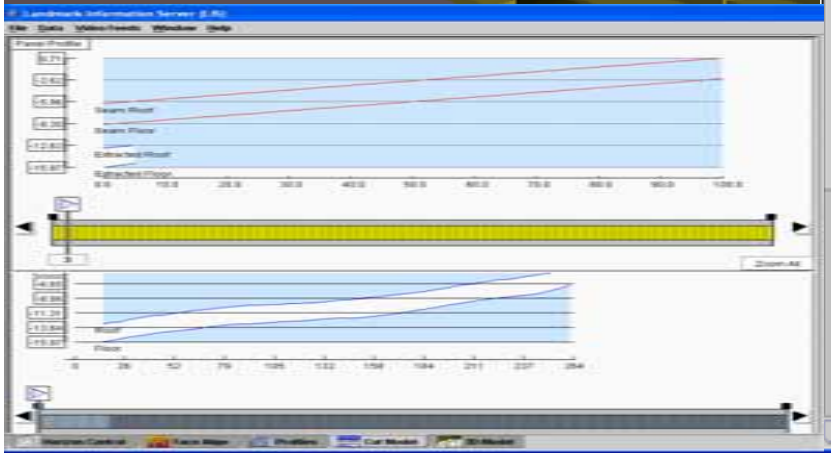
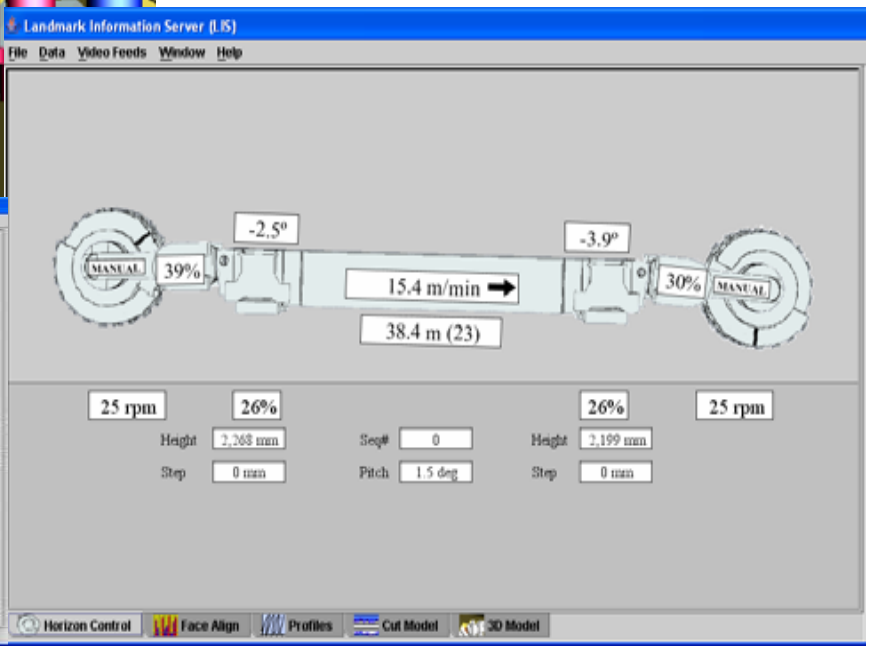
Landmark Information System:

- Architecture for real-time monitoring of equipment sensors in a 3D geological environment







NEXSYS
Real Time Risk Management

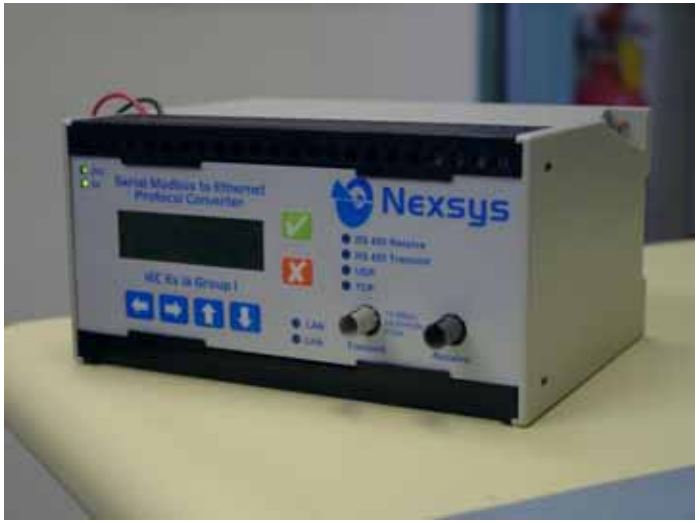
CSIRO

Nexsys

Hazardous Area Electronics (IEC Ex.ia Intrinsically Safe)

- Serial to TCP/IP Protocol Converter
- Fibre Optic Ethernet Switch
- 2.4GHz Wireless Access Point

Fully Managed Fast Fibre Optic Ethernet Switch



Serial Protocol to Ethernet TCP/IP UDP Protocol Converter

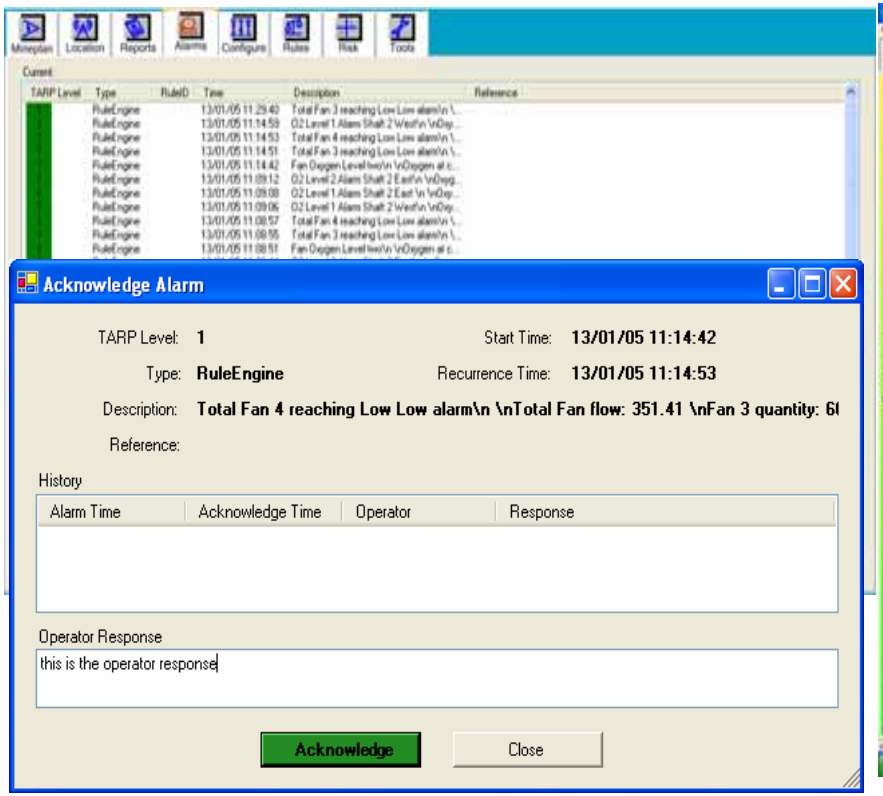
Ingress Protected (IP65) Wireless Access Point

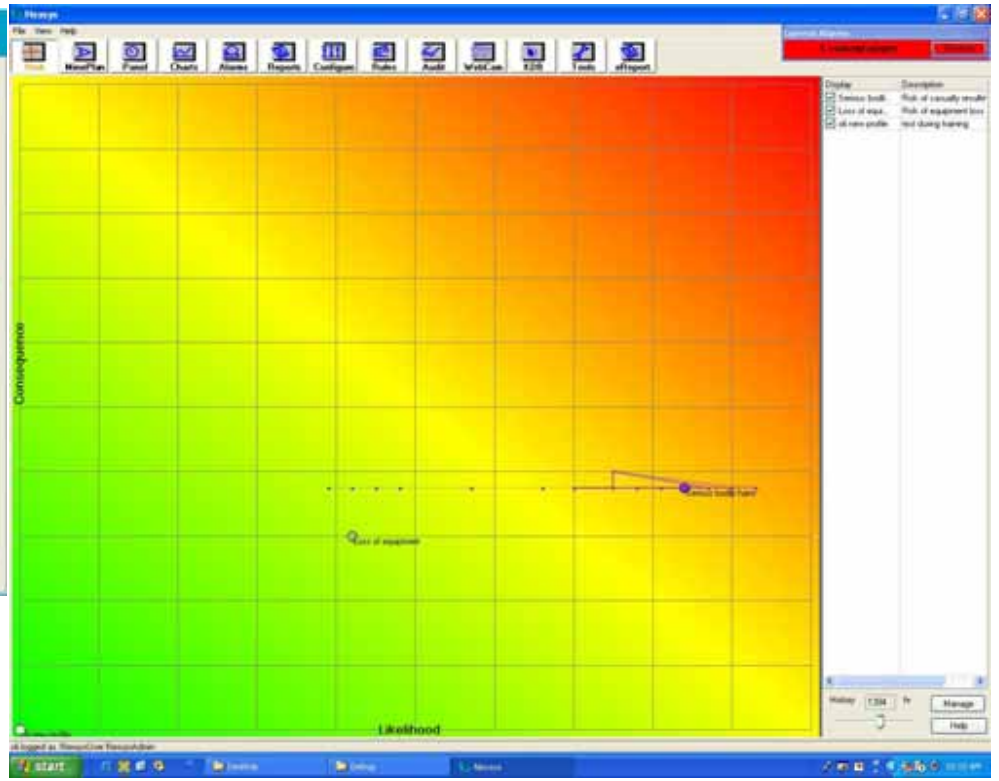
CSIRO

Nexsys Real-time Risk Management System

Nexsys

- Data fusion – gas , ventilation, strata, location, water
- Common communication protocols
- Real-time risk profiling
- Decision support in adaptive environments





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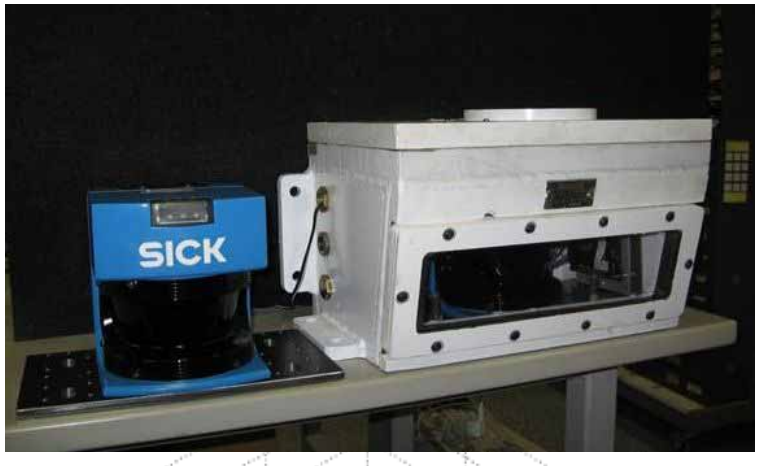
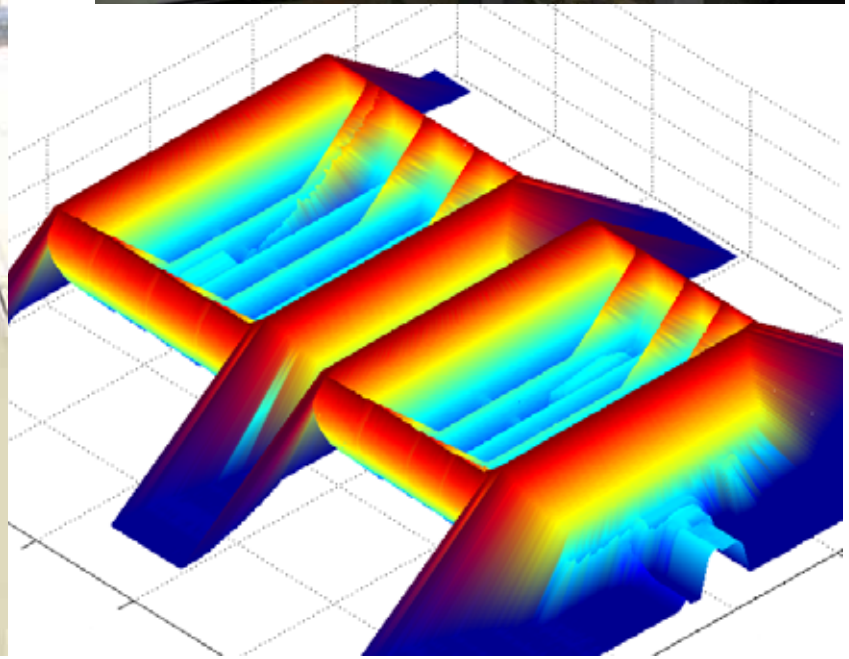
Current Applications

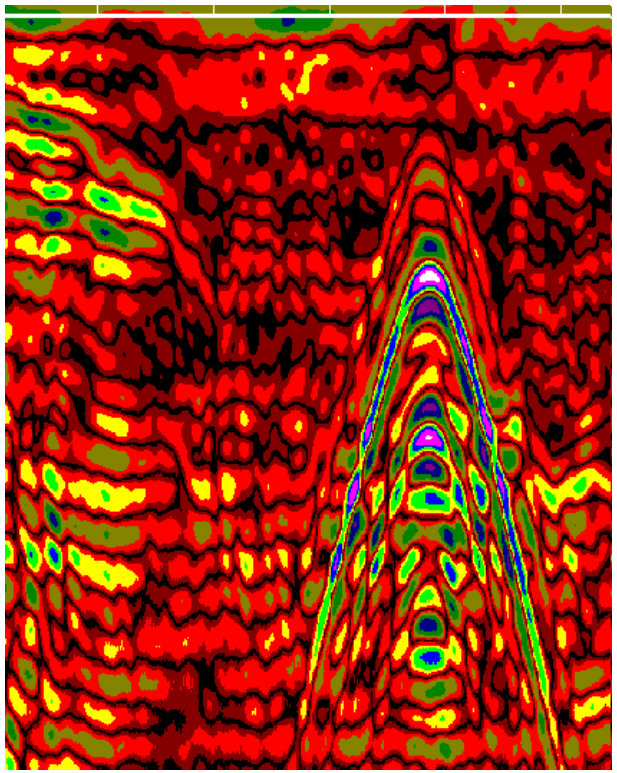
- Train Wagon contamination (carry-back)
- Positioning measurement





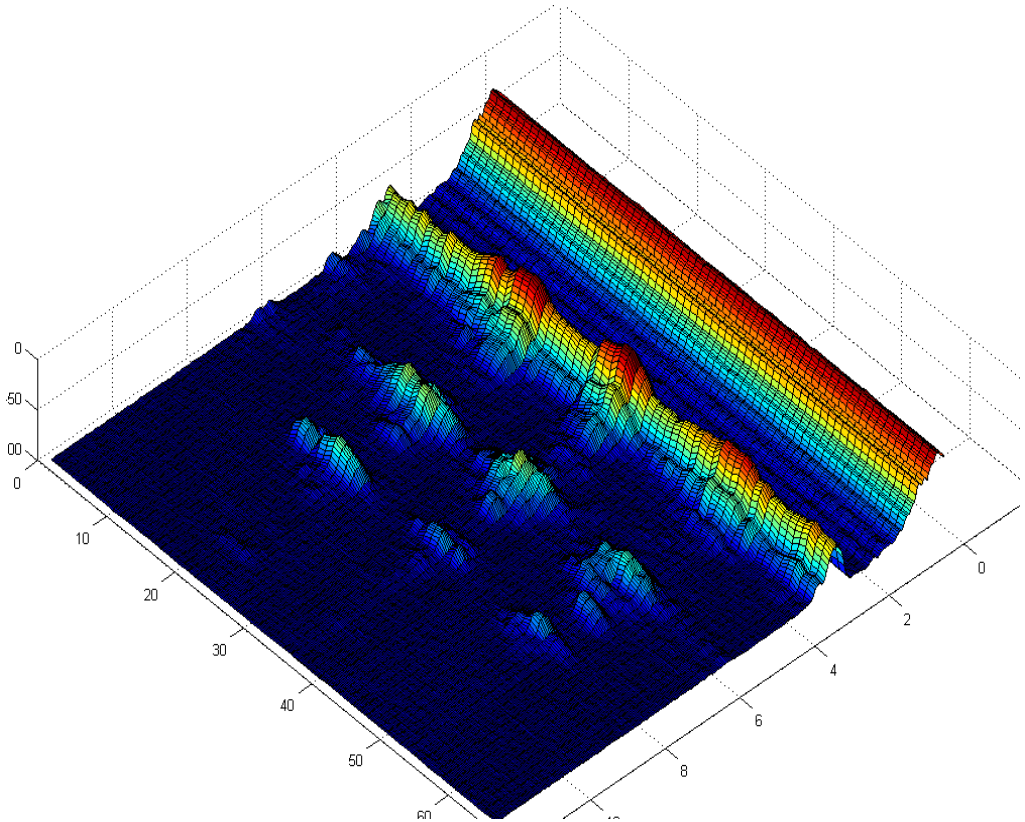
GPR - Open Cut and Underground Applications

- Reliable seam horizon tracking for machine guidance
- Coal mine roof stability monitoring
- Void detection



UWB Radar for Mining Equipment Navigation

- Infrastructure identification in roadways (bolt plates)
- Advantages:
  - Dust immunity
  - No moving parts
  - Compact and low power



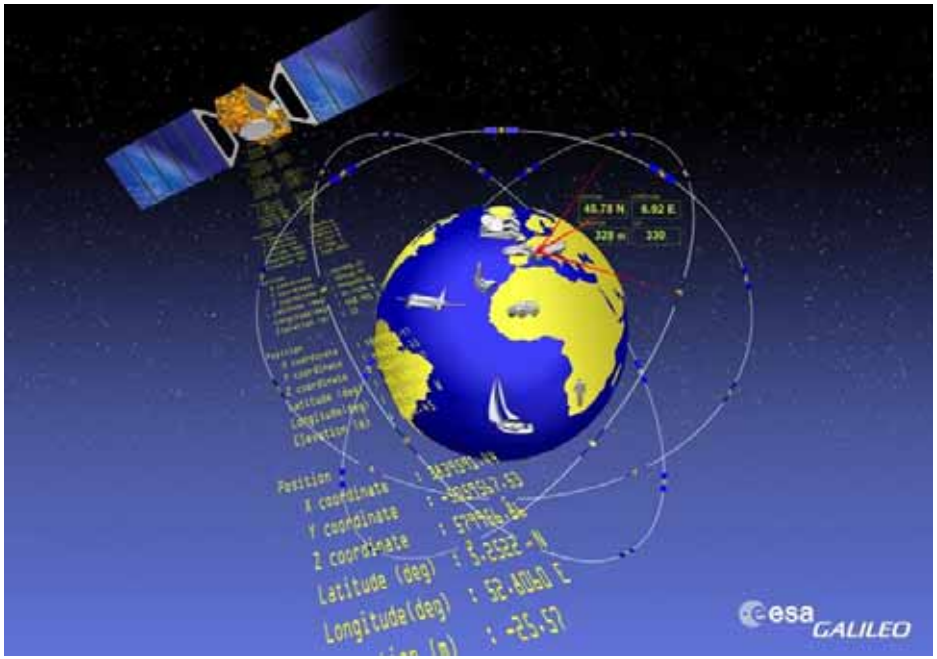
ADVANCED MINE TRAFFIC MANAGEMENT

The setting:

- Heavy vehicle operators need warning about mixed traffic and fixed hazards
- GPS is unreliable within pits (high masking angles result in poor availability) and Differential GPS relies on reliable GPS
- GLONASS constellation is in disrepair

The Advanced Mine Traffic Management project involves:

- Exploiting combination of GPS and Galileo global navigation satellite system
- Developing navigation aid that reports traffic & hazards via Mobile Adhoc Networks
  - Vehicles & pedestrians automatically self report their coordinates
  - Information relayed by vehicles beyond fixed communications infrastructure



KEY CAPABILITIES

Ground Conditions:

- 3D imaging, 3D photogrammetry and 3D data processing
- Geophysical borehole logging data analysis and interpretation
- Structural geology
- Microseismic & 2D/3D seismic data processing, analysis and interpretation

Coal and Ore Quality:

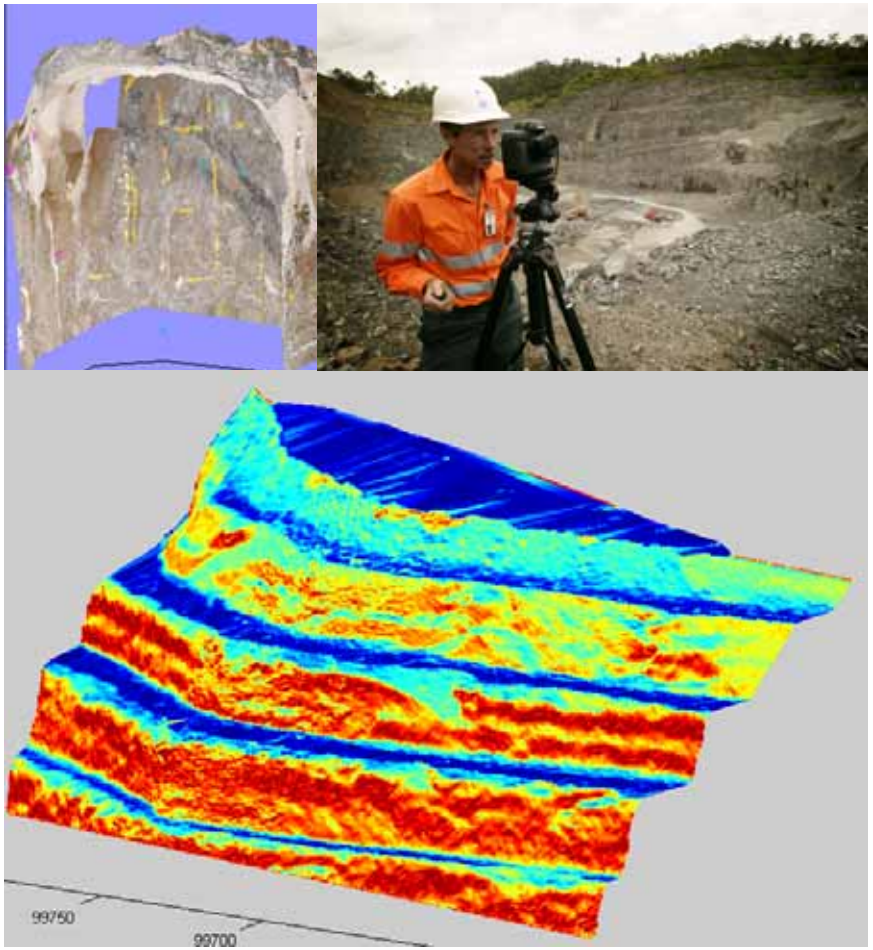
- Petrographic imaging, analysis and interpretation
- Nuclear borehole logging techniques (Sirolog)
- Materials handling

Systems to analyse relationships between complex and disparate, spatial/non-spatial geoscience data (CSOM).

3D IMAGING AND 3D DATA PROCESSING

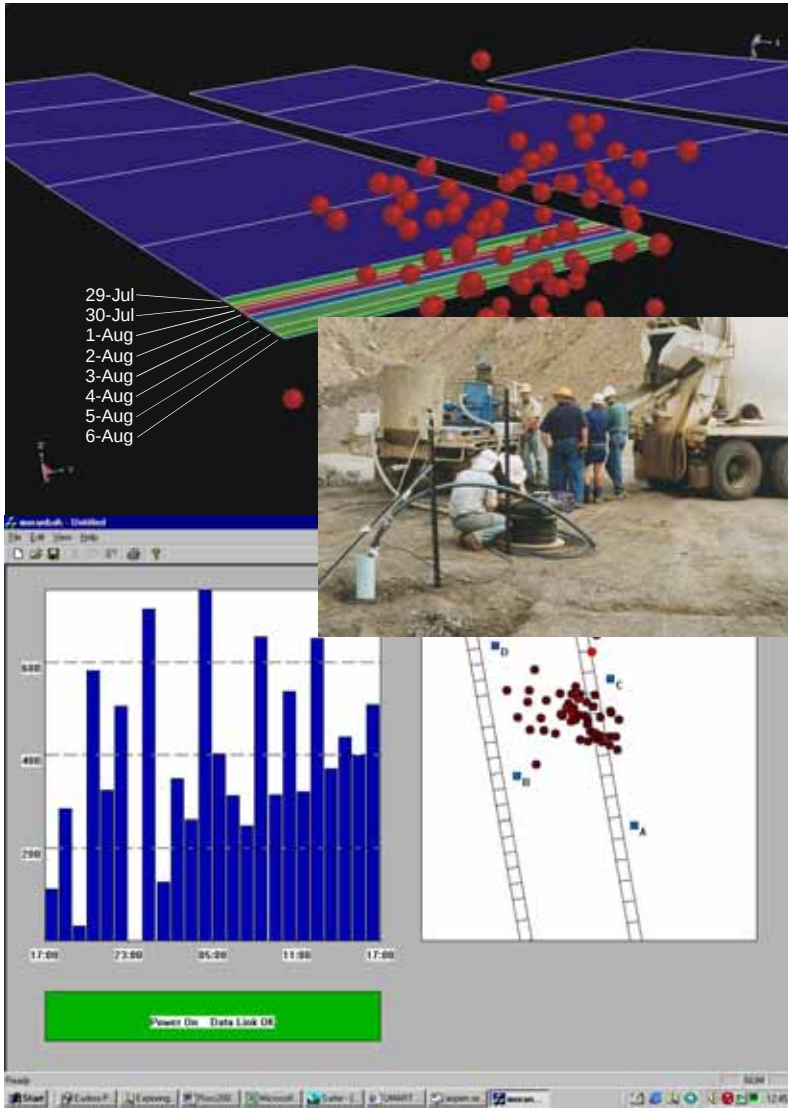
Automated, cost effective, accurate 3D mapping and monitoring of the mine environment and operations through the utilisation of digital photogrammetry (Sirovision®).

- Open pit and underground
- Structural modelling
- Blast optimisation
- Fragmentation analysis
- Drill core profiling
- Real-time input to mining operation



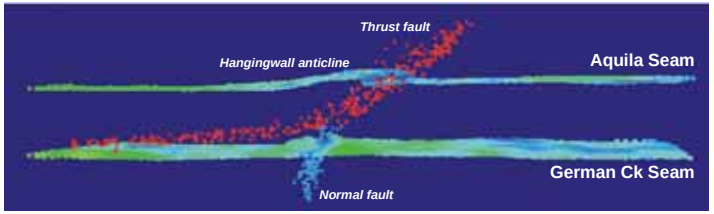
MICROSEISMICS

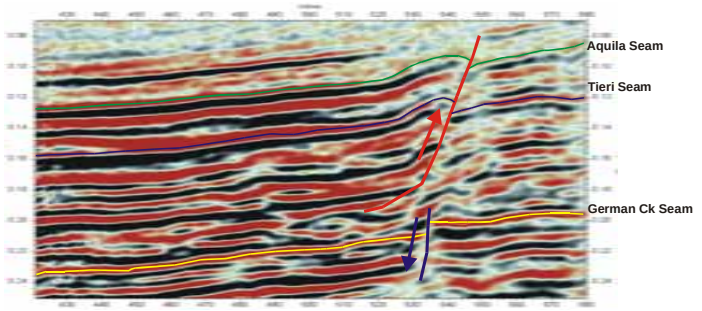
- Understanding and predicting rock failure mechanisms associated with the mining process:
  - 4D mapping of rock fracturing (x, y, z, time) and failure mechanics
- Prediction of impending hazards
- Real-time monitoring and data analysis.

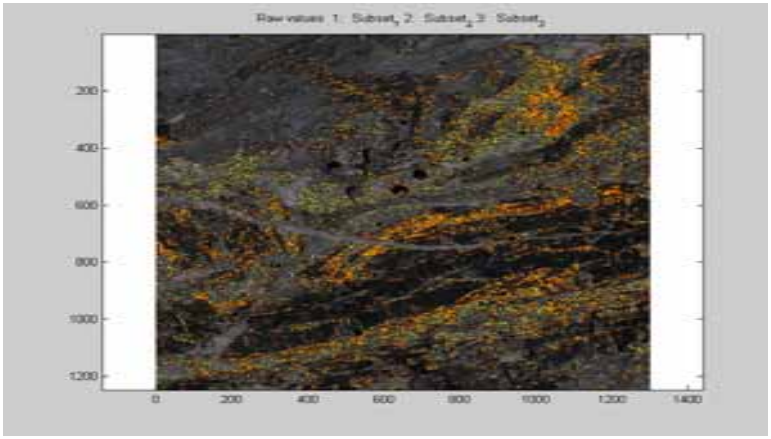


INTEGRATED GEOSCIENCE DATA ANALYSIS

- Structural and sedimentological modelling and interpretation
- Systems to analyse relationships between complex and disparate, spatial/non-spatial geoscience data
- Seismic reflection surveying – 2D & 3D methods, interpretation and incorporation into mine planning
- Time series analysis and interactive seismic/radar interpretation
- Integration of geological, geochemical and geophysical data



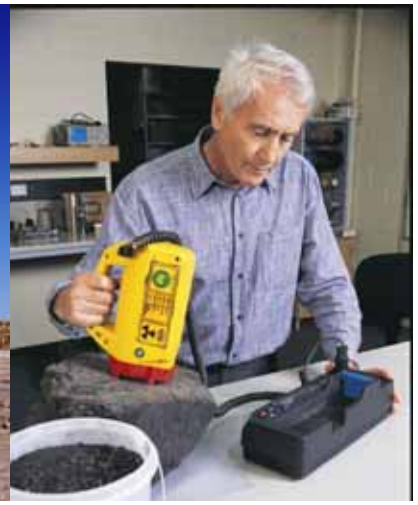


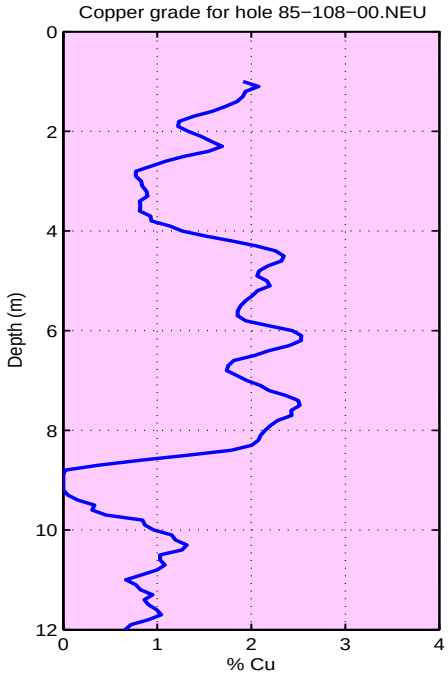


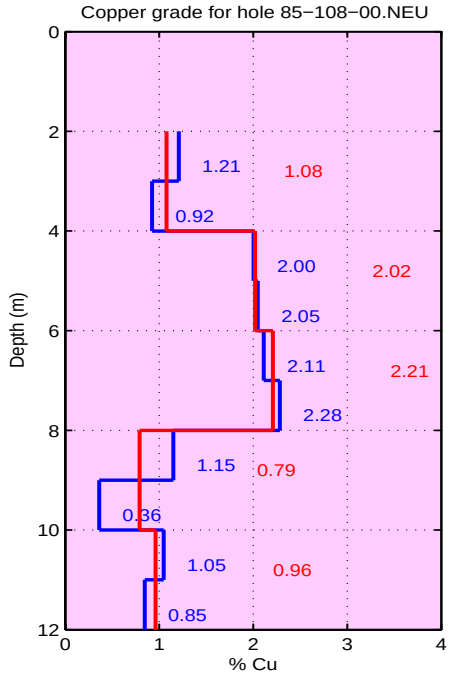
Colour-coded automated mineralogy interpretation from digital photogrammetry using ‘Self Organising Maps’ analysis

BOREHOLE LOGGING

- Development of new instrumentation to measure rock properties in-situ, such as elemental concentration, rock strength and other physical properties
- Development of new interpretative techniques to analyse and integrate disparate borehole data
- Near real-time in-situ borehole elemental analysis







Thank-you

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