Department of Mining Engineering
ISM Dhanbad

Developments in Automated and Geospatial tools and Techniques for improving Safety and Productivity in Metal Mines

Welcome !

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Possible applications of IT in UG metal mines

- Semi Automated /Automated Systems
  - Driverless trains : Automated rail management
  - 'Intelligent' driverless trucks
  - Remote control 'intelligent' drills
  - A pathway to fully automated mine-to-mill operations
  - Automated excavators
  - Automated loading, transport and dispatch systems (OITDS)
  - Smart sensors and mine safety technologies
  - ‘Smart’ communication and tracking systems
  - ‘Smart’ head mounted portable device (HMDs)
- Robotic Mining
- Armchair Mining
- Plant/Office Automations : ERPs, MIS etc.
- Mine Modeling and Simulations : CAMPAD, VR, FEM, BEM etc. for forecasting
- GPS, GIS & Remote Sensing: Mine positioning, facility locations and layouts, land use patterns, reclamation & rehabilitation planning

Major GUI Software Packages in Mining

Mine Planning & Design:	**SURPAC** **DATAMINE** **MINEX** **MICROMINE**
Mine Simulation & Modeling :	**ANSYS, FLUENT, VENTSYS** **FLAC, STRAND, UDAC** **VR SIMULATION SOFTWARE**
Drilling & Blasting :	**JKSIMBLAST, BLASPA, DataVis, Master Blaster™ , SHOTPlus®-i pro, BLASTWARE**
Fragmentation analysis :	**Wipfrag,Wipware & Other image processing software**
Mine Surveying	**LISCAD, AUTO-PLOTTER** **SKI-PRO, GEO-OFFICE, T-COM,**
GIS, Remote Sensing & Photogrammetry	**ArcGIS** **ERDAS** **GEOMEDIA** **MICROSTATION** **LPS**
ERP	**SAP, BAAN , RAMCO SYSTEM AND OTHER ERP PACKAGES (Customized for mining applications)**
OITDS	**DynaMine**

IT in Mining Industry

During 1960s

mini ERP comprising of preparation of pay rolls, listing of store items, manpower control etc

During 1970s

designing of civil engineering constructions, laying of tracks, roads, etc

During 1980s

MIS, MPS and TDS

During 1990s

GPS and GIS (a visualizing technology that captures, stores, checks, integrates, manipulates and displays data using digital mapping)

Automation in Mining : Thrust Area

- Drill and shovel monitoring for ground characterization
- Machine health and maintenance monitoring
- Automated mine design
- Geo-sensing and artificial intelligence
- Image analysis
- Communication
- Radio Frequency Identification technology
- Drilling intelligence and control
- Machine guidance and tele-operation
- Systems safety and human factors

AutoMine

- An automated loading and hauling system for underground hard rock mining.
- flexible modular system that can successfully be adapted to small scale operations, as well as massive block caving applications.

Modules of AutoMine

- PCS – **Production Control System**, for planning, optimization of production execution & reconciliation of production inputs and outputs especially for block cave mines.
- MCS – **Mission Control System**, supervisory system controlling and monitoring the autonomous operations including traffic management and provides the remote operator's user interface.
- MineLAN – Broad band, high speed, data/video communication system for connectivity to automated underground loaders and trucks and associated equipment.
- **Onboard automation systems** – for machine control, monitoring, and navigation.
- ACS – **Access Control System**, for isolating the autonomous operating area to ensure safety of personnel.


AUTOMATION ZONE

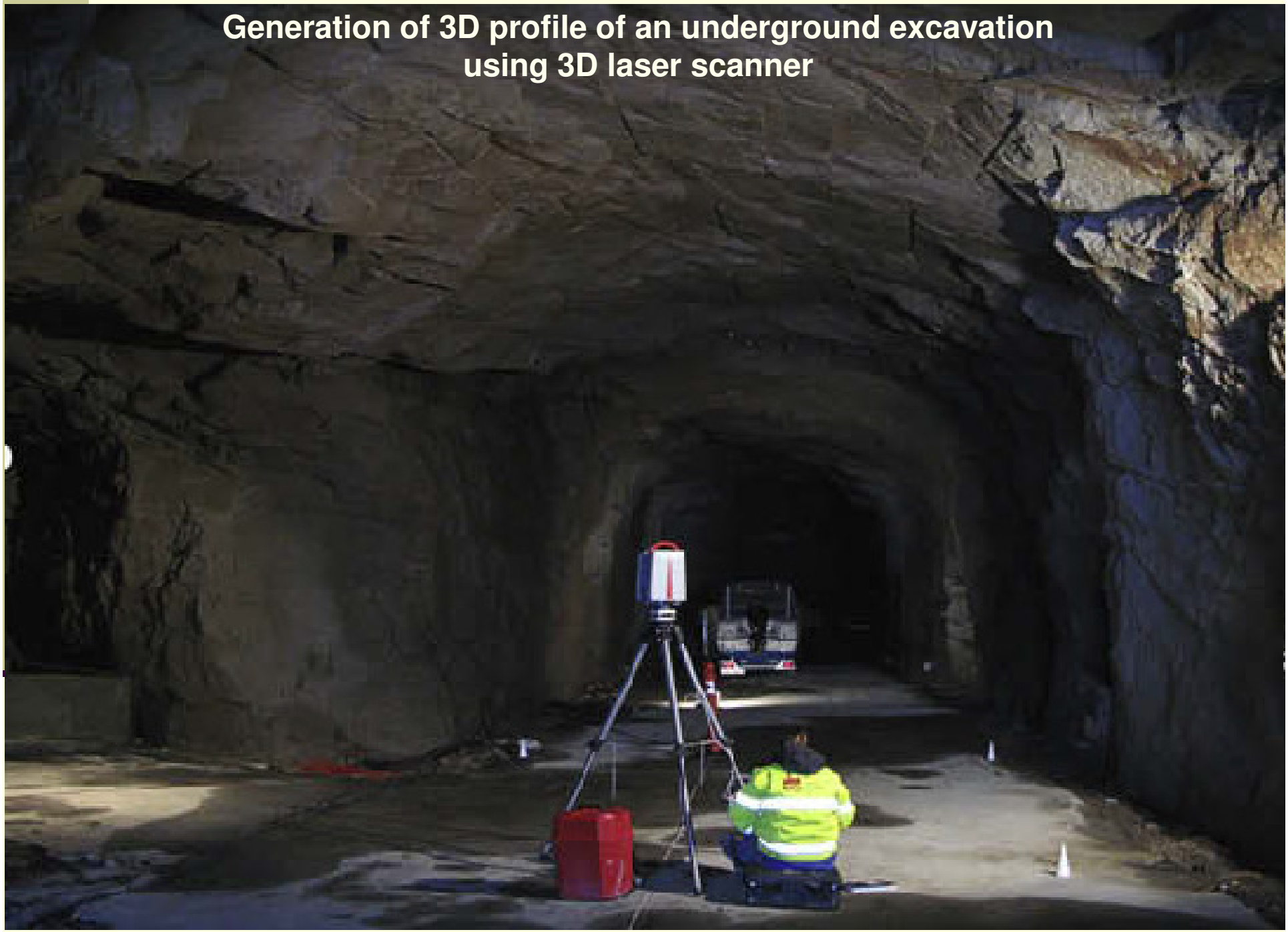
3D Laser Scanning

- accurately map, model and interpret geological structures in a pit
- conduct daily or end of month survey - detailed and accurate model of a stope or development face
- contract volume measurement, truck and shovel load measurement and analysis
- survey for pit production measurement, underground development and void survey
- conduct rapid pre- and post-blast surveys
- conduct airborne surveys for reserves assessments (where topography is critical in shallow flat lying deposits)
- conduct stope surveying

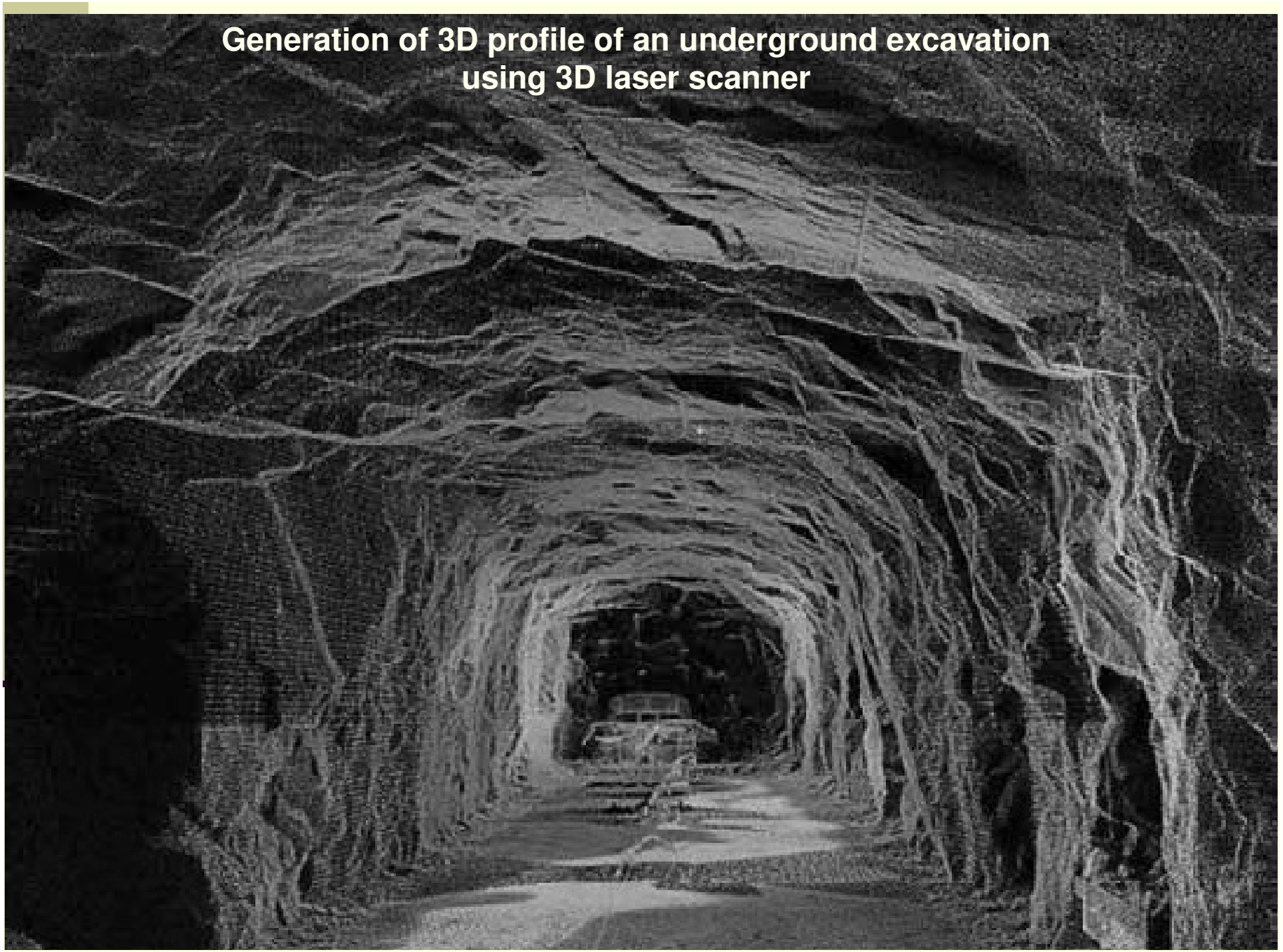

VZ-1000


Leica
LASER APERTURE
ScanStation

Generation of 3D profile of an underground excavation using 3D laser scanner

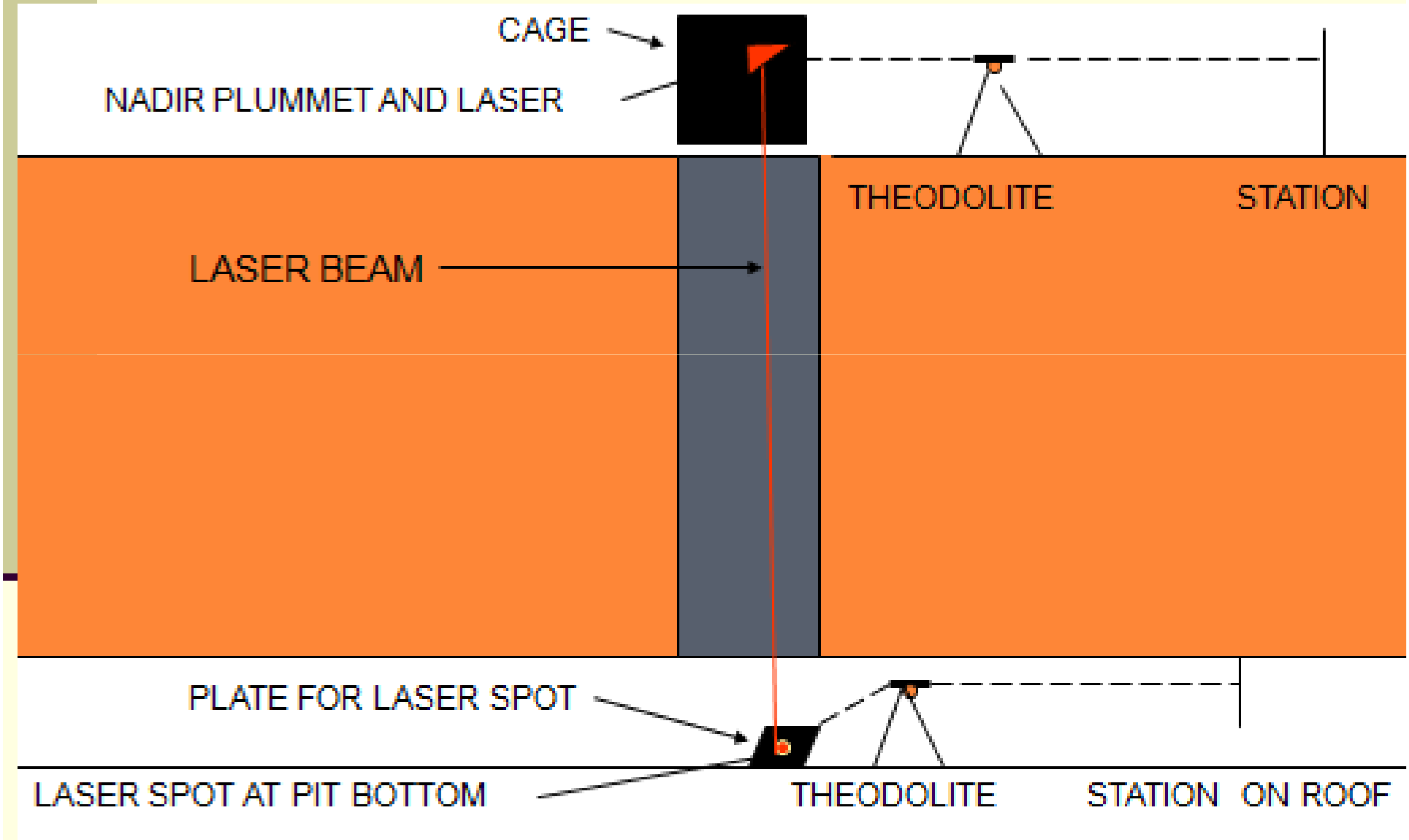


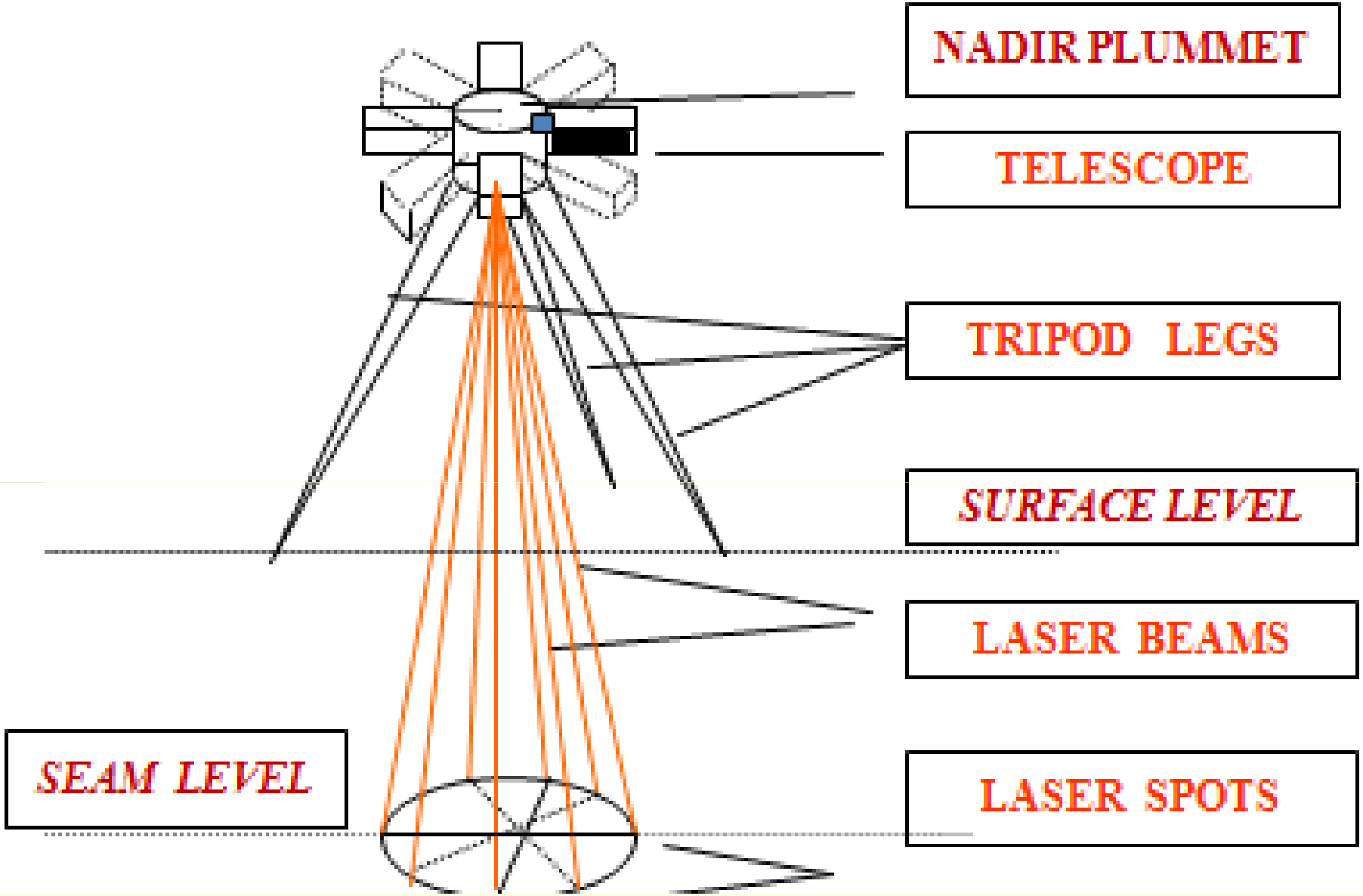
Generation of 3D profile of an underground excavation using 3D laser scanner



Alignment and Orientation Surveys

Alignment and Orientation Surveys

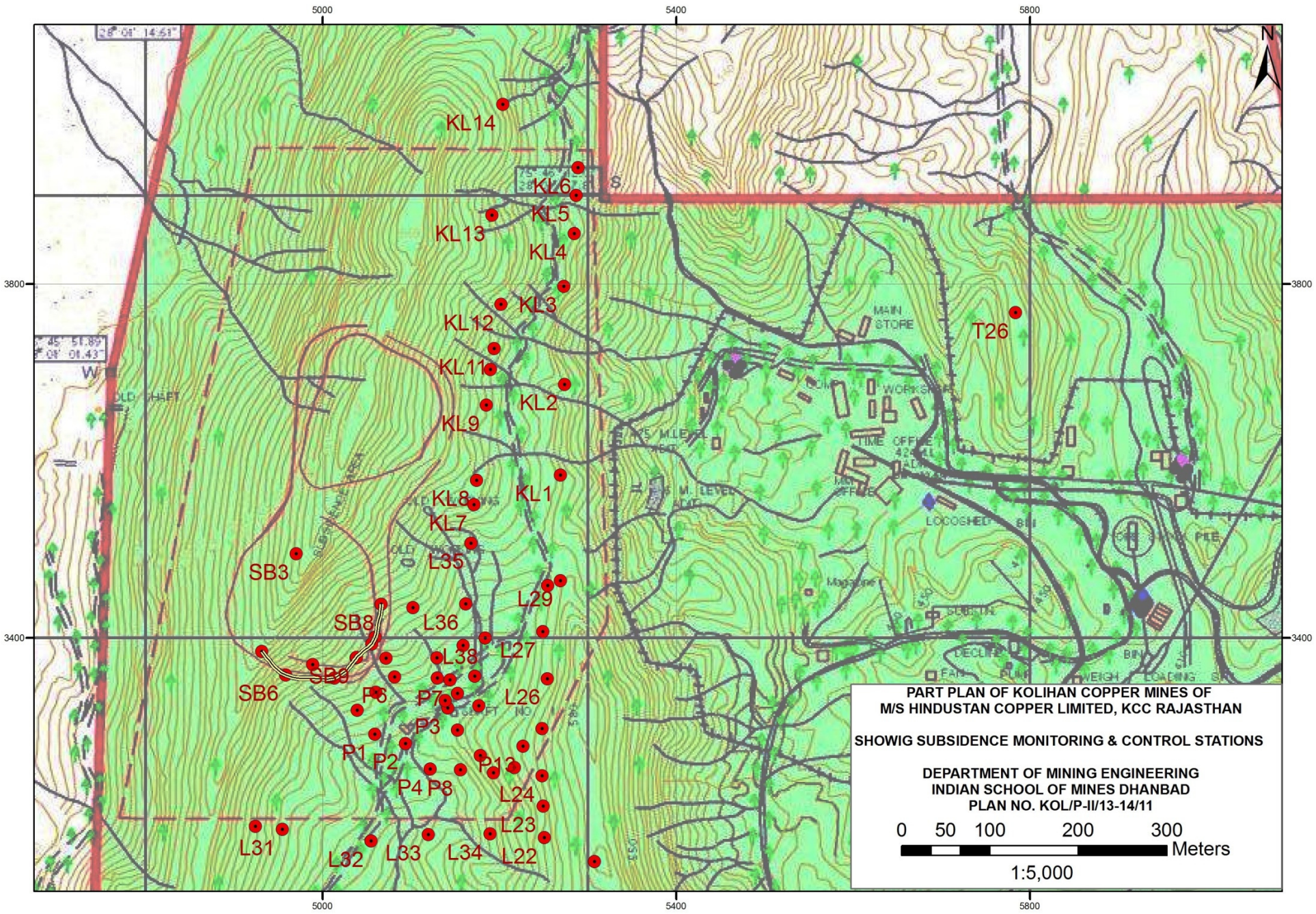



NADIR PLUMMET
TELESCOPE
TRIPOD LEGS
SURFACE LEVEL
LASER BEAMS
SEAM LEVEL
LASER SPOTS

Orientation Surveys by Gyromat 3000

Subsidence Monitoring

Monitoring of subsidence over the permanent subsidence monitoring station on hilltop using Prism monitoring (EDM) keeping total station on stable ground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MAIN STORE
WORKSHOP
TIME OFFICE
LOCOSHED
PART PLAN OF KOLIHAN COPPER MINES OF
M/S HINDUSTAN COPPER LIMITED, KCC RAJASTHAN
SHOWIG SUBSIDENCE MONITORING & CONTROL STATIONS
DEPARTMENT OF MINING ENGINEERING
INDIAN SCHOOL OF MINES DHANBAD
PLAN NO. KOL/P-II/13-14/11
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Meters
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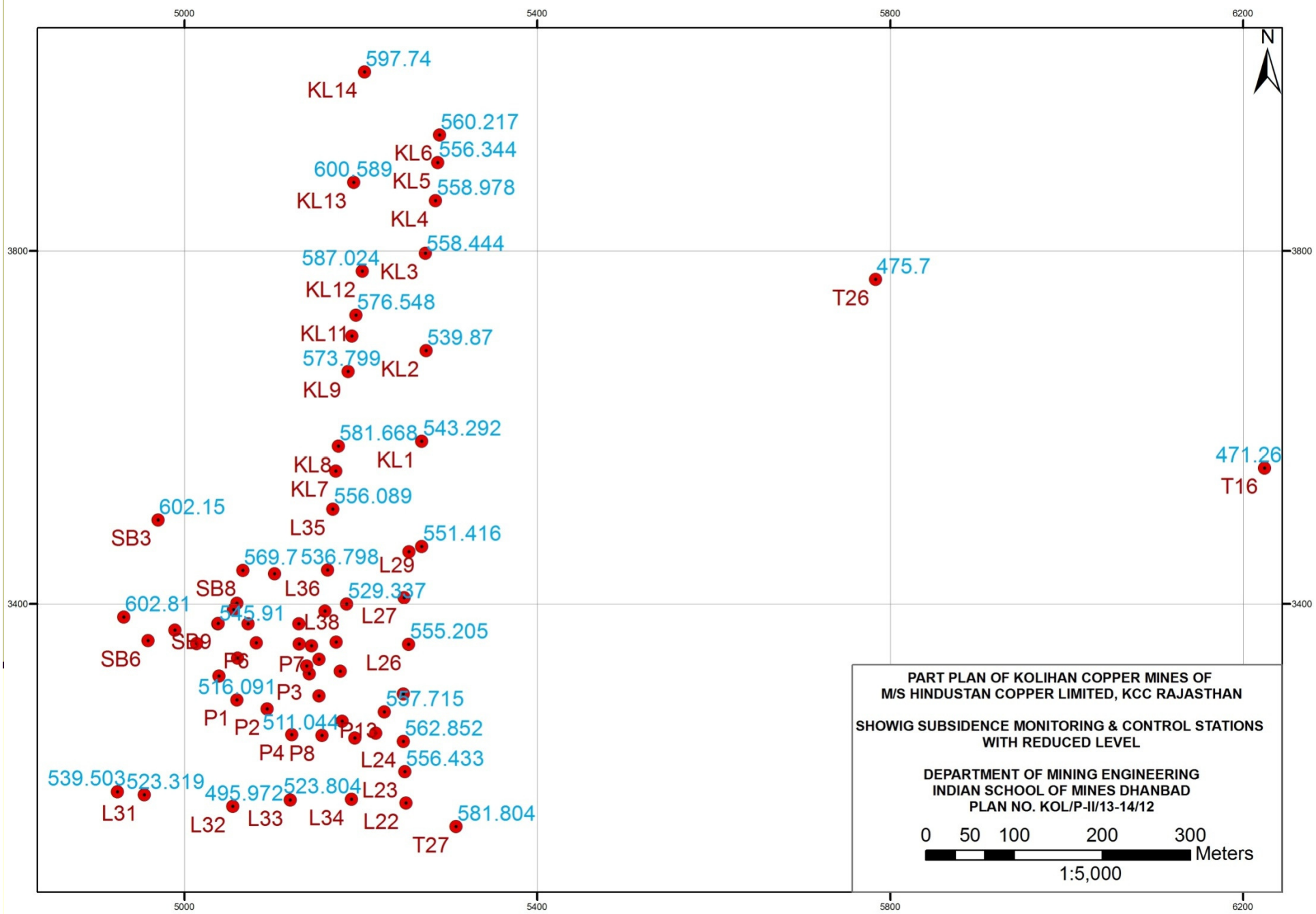
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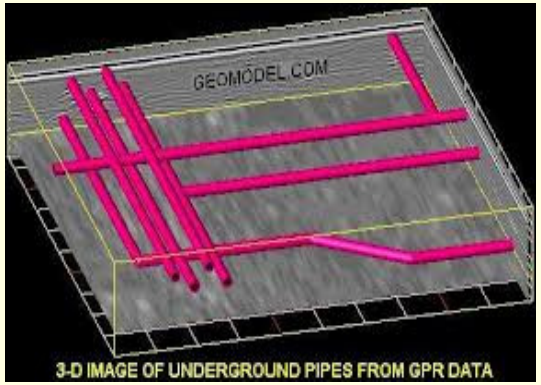
PART PLAN OF KOLIHAN COPPER MINES OF
M/S HINDUSTAN COPPER LIMITED, KCC RAJASTHAN
SHOWIG SUBSIDENCE MONITORING & CONTROL STATIONS
WITH REDUCED LEVEL
DEPARTMENT OF MINING ENGINEERING
INDIAN SCHOOL OF MINES DHANBAD
PLAN NO. KOL/P-II/13-14/12
0 50 100 200 300
Meters
1:5,000

Application of GPR in Mine surveying

- Determination of shape, size & extent of mineral deposits
- strata & Roof control.
- void, caved and stowing area exploration in past mining area.
- Evaluation of overburden thickness, U/G pipe line survey.



3-D IMAGE OF UNDERGROUND PIPES FROM GPR DATA

- India has largest coastline of **7500km** which play very important role for economic and defense.
- This coastal zone are dynamic zone with the interaction of air, land and water.
- Due to these reason the major change appearance in coastal zone by Coastal process ,Tsunami and other natural event.

Mapping of shallow subsurface details of costal area and Periodic growth Estimation of Sand bar using GPR will help in

- Buried items (like minerals ,Manmade or Natural features) detection.
- Estimation of thickness variation of strata layer.
- Identification of Moisture zone & sea water intrusion.
- Identification of location of palaeo beach.
- Estimation of Sand bar growth.

Why subsurface Surveying by GPR?

- This is fast method & gives continuous subsurface details information.
- Conventional method of subsurface surveying T**renching, Bore hole etc** are time consuming ,destructive and less Economical method. So GPR have used in this study.

A complete GPR system fitted on Survey wheel

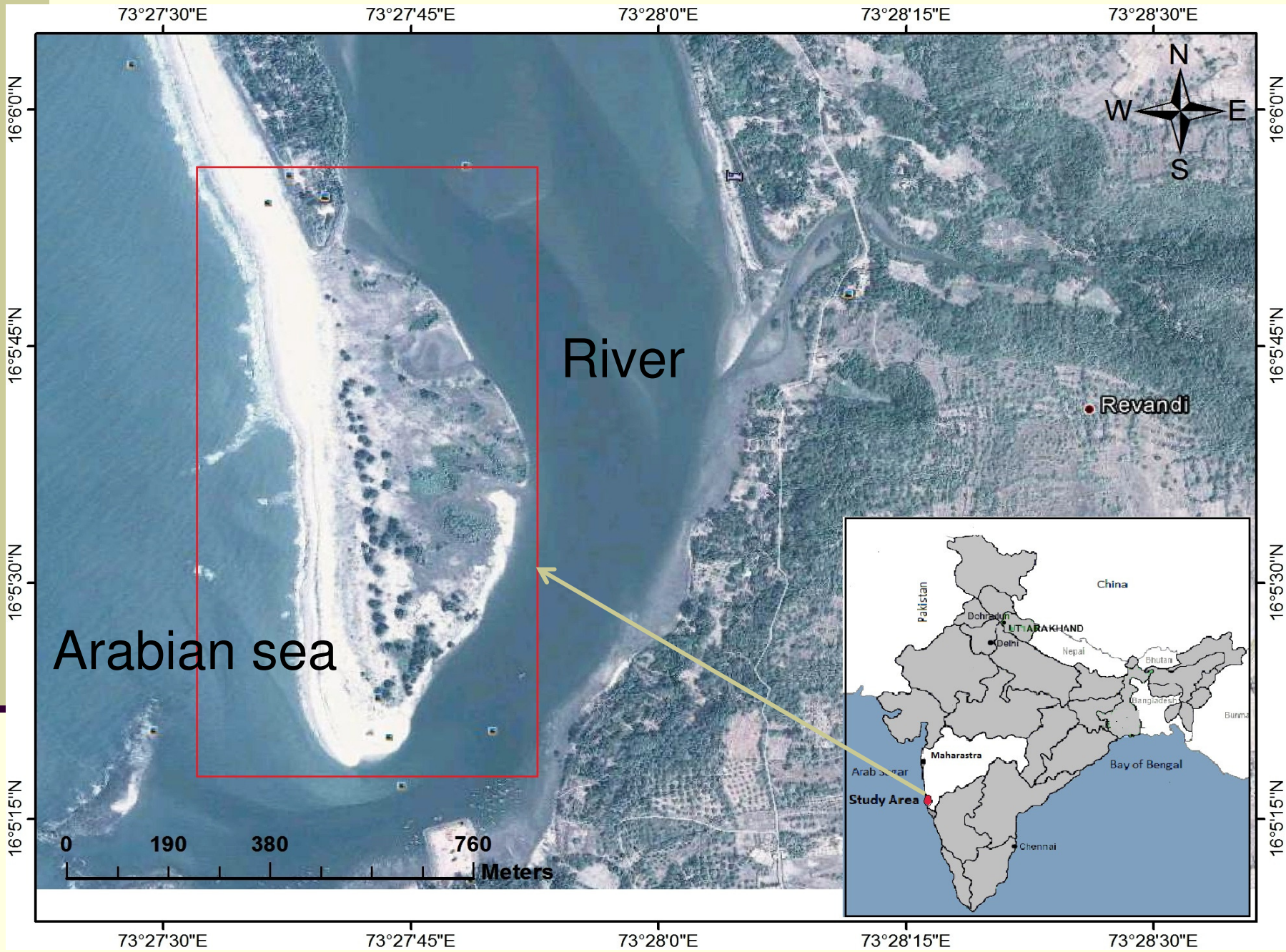
PARTS OF GPR

- Control unit
- Display system
- Transmitting & Receiving unit
- Power supply
- Control unit is heart of GPR system which regulate all function of system.

Control & Display Unit

MODEL: SIR-20,
Company: GSSI (Geophysical survey system Inc.), USA
Antenna: 100, 200, 1400 MHZ

Transmitting & Receiving Unit


73°27'30"E
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16°5'30"N
16°5'15"N
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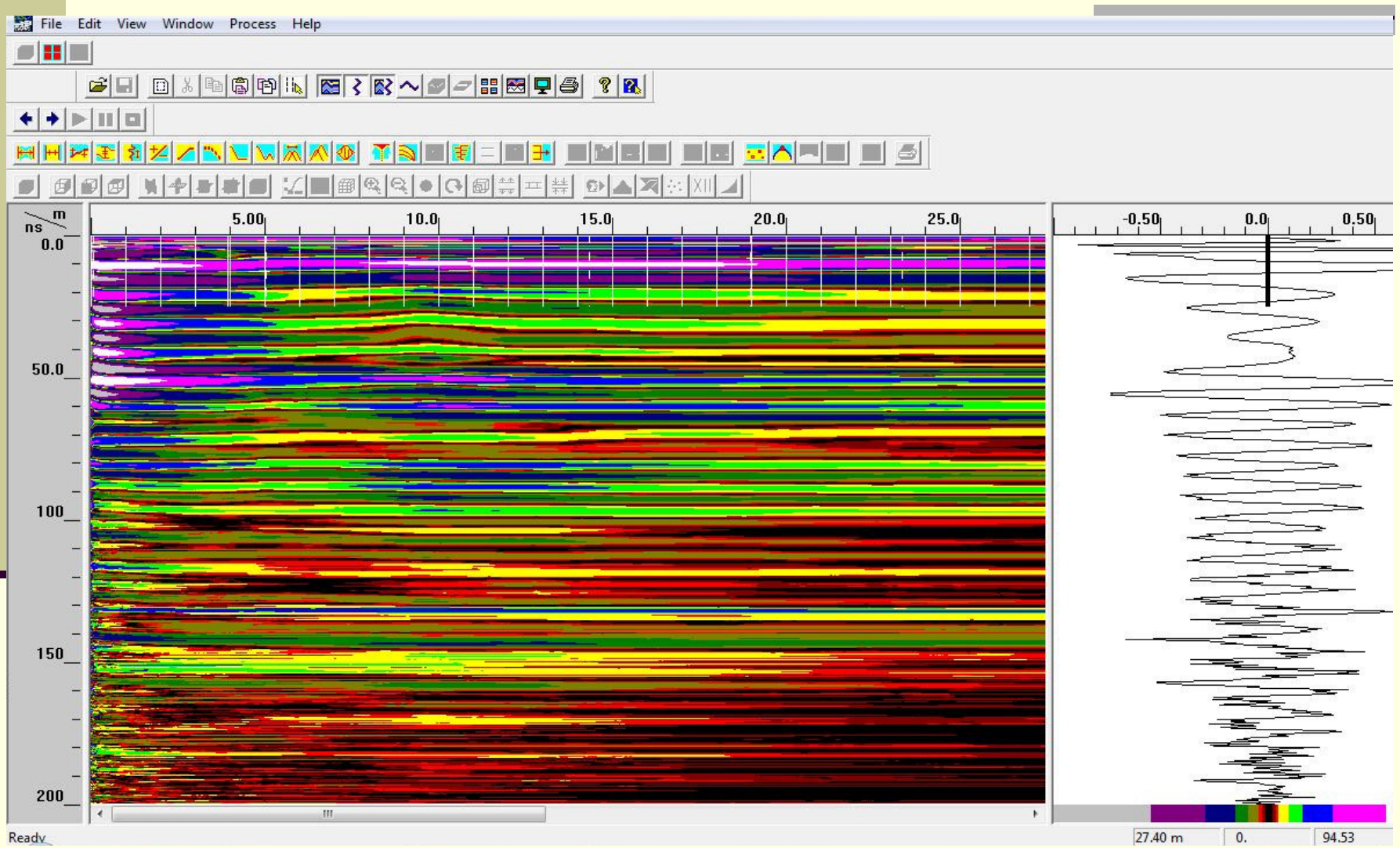
E
S
River
Arabian sea
Revandi
0
190
380
760
Meters
China
Pakistan
Dehradun
UTTARAKHAND
Delhi
Nepal
Bhutan
Bangladesh
Maharastra
Bay of Bengal
Study Area
Chennai

DATA AND SOFTWARE USED

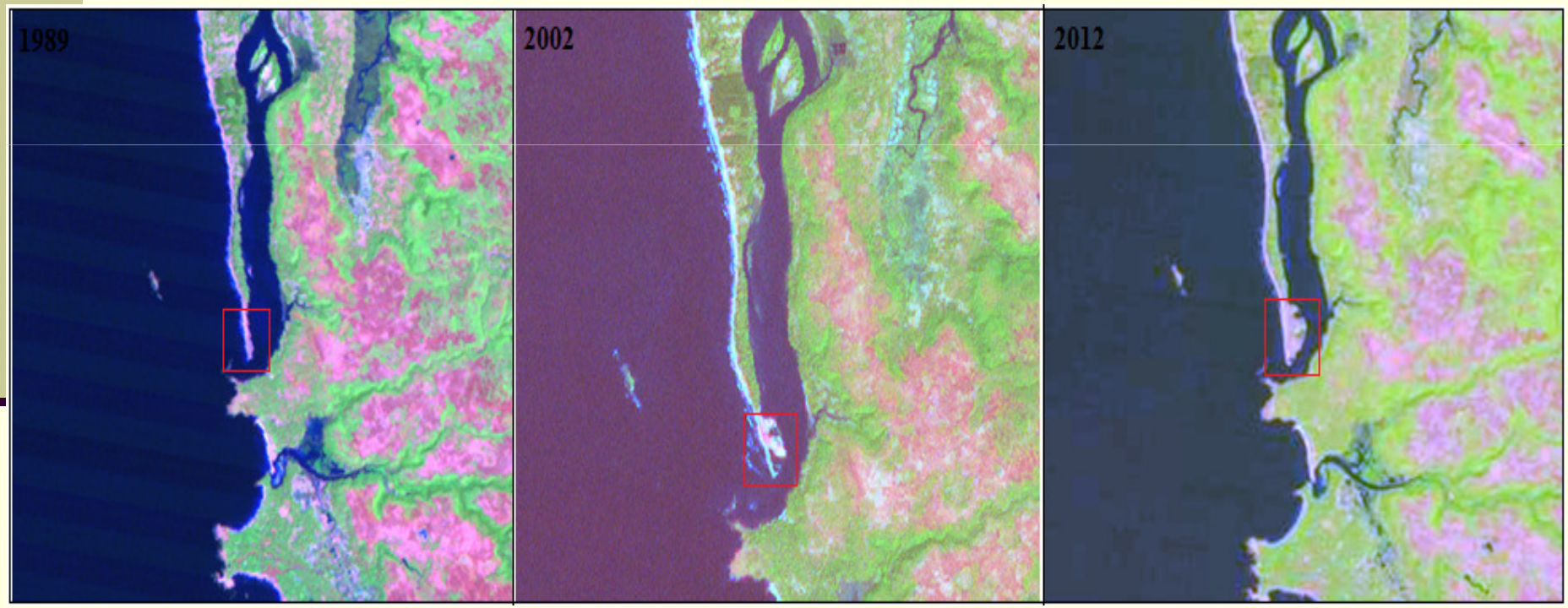
Data type	Source	Specification of data
GPR Raw data	Coastal placer Mining Department CIMFR Dhanbad	GPR SIR-20 **ANTENNA -200MHz** Total 16 GPR profiles
Profile leveling data		Taken by Total station for all 16 profiles
GPS data		Taken by Hand Hold GPS & corrected by GNSS
Satellite Image	www.usgs.gov	TM+, Pixel size 30m x 30m Data year 1989,2002,2012

Trace windows of GPR data using during data processing

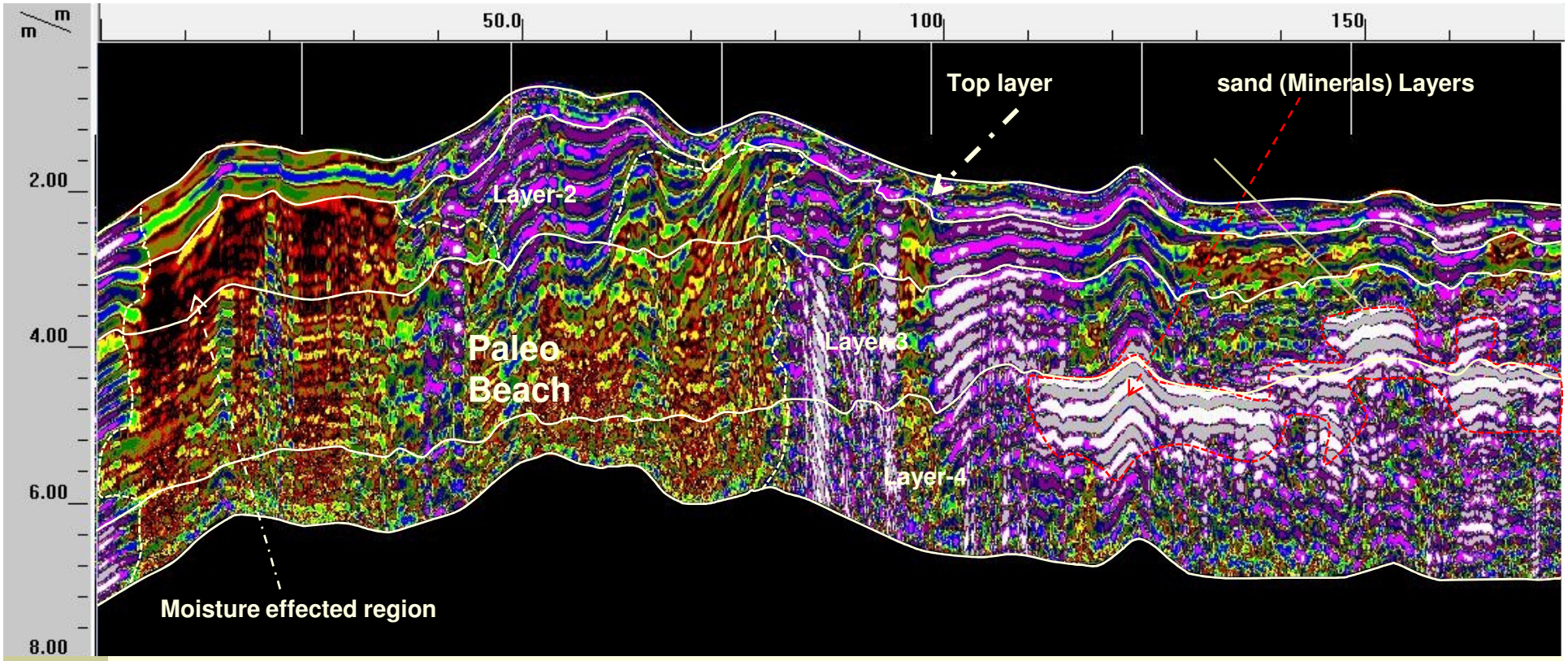


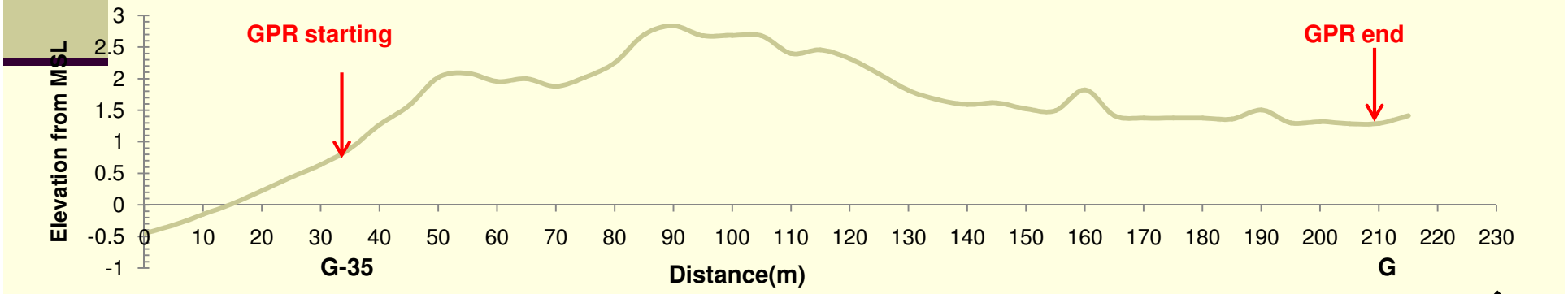
INTERPRETATION OF RESULT

Satellite Image analysis result & GPR Subsurface result



His. Img





Surface profile at Talashil Location. 11

- High resolution GPR surveying technique may helpful in development of coastal area.
- The GPR high resolution reflection technique could be give the accurate and details shallow subsurface information and hence can be widely used in subsurface surveying as a tool.

Mine Safety Technology

- Seismic monitoring is Potential technology for predicting ground movements.
- More applicable in hard rock mining, as part of a risk management program.
- Applying seismic monitoring at mines with a history of rock burst

ROBOTICS IN MINING

- for performing 3-D mapping and remote sensing in hazardous environments

- Robots will be doing jobs like laying
  - explosives,
  - going underground after blasting to stabilize a mine roof or mining in inaccessible areas

ROBOTICS IN MINING

Examples of the trend to mining automation include:

- **tele-operated and automated load-haul-dump trucks that self-navigate through tunnels, clearing the walls by centimeters**
- **a robot device for drilling and bolting mine roofs to stabilize them after blasting**
- **a pilotless burrowing machine for mining in flooded gravels and sands underground, where human operators cannot go**
- **a robotic drilling and blasting device for inducing controlled caving.**

Robotics :Mining Potentiality

- **Use of remote-controlled manipulators for mechanization of miner's actions**
- **Introduction of information robots or mine rescue robot in case of mine disasters**
- **Multifunctional technological robots**

Some case study related to robotics based mining

Groundhog

Robot having **An armed with an array of cameras,**
Gas sensor
Sink age sensors
Laser scanners
Gyroscope to help it surmount the obstacles it will encounter during its unprecedented journey.

- **Robot travels at a speed of 15 centimeters a second.**

Robot will be equipped with a wireless video system that will send back images from the first 500 feet into the mine

ROBOTICS IN MINING

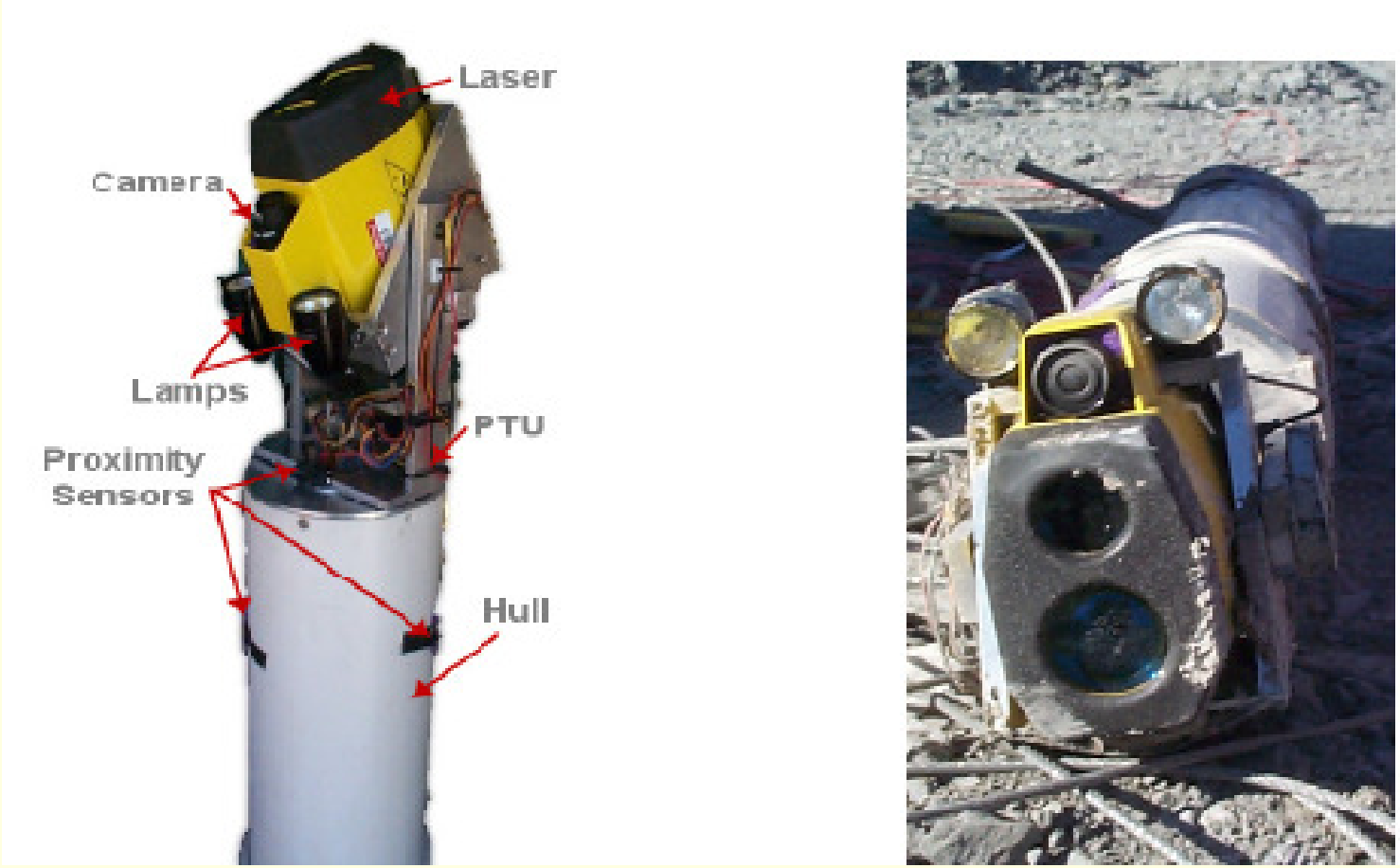
An autonomous, four-wheeled robot with heavy-duty tires

Ferret

- **To address the existence of subterranean void space belowground, a robotic tool has been developed that is capable of reaching a domeout via borehole access, acquiring the measurements necessary for void analysis, and relaying this information to the surface.**

- **Ferret provides quantitative information on cavity extent that is difficult or impossible to obtain using borehole camera systems**

Ferret



Remote Survey Vehicles

Remote Survey Vehicle with 3D laser Scanner mounted on the top
(Ambriefonline.com, 2011)

Internet and Information Superhighway

- Quickest and accurate information is vital to any decision-making process
- A number of websites offer update and relevant information on coal and mineral exploration and exploitation.
- Information Superhighway is the remote PC-based instrumentation system for continuous monitoring of a mining system/subsystem.
- It is like a highway where all the expertise is readily available for solving all kinds of mining related problems .

Communications and Tracking Technology

- In a crisis, any information, particularly accurate information, is fleeting and difficult to capture and to confirm
- There is an imperative need to not only manage communications but to fiercely guard the quality of the information communicated

Some of the recent applications of communication and tracking technology:

- **Mine Multimedia Communication System**
- **Close Proximity System (CPS)**
- **GPS based systems**
- **Radar / laser based systems**
- **Vision-based systems**
- **RFID based systems**

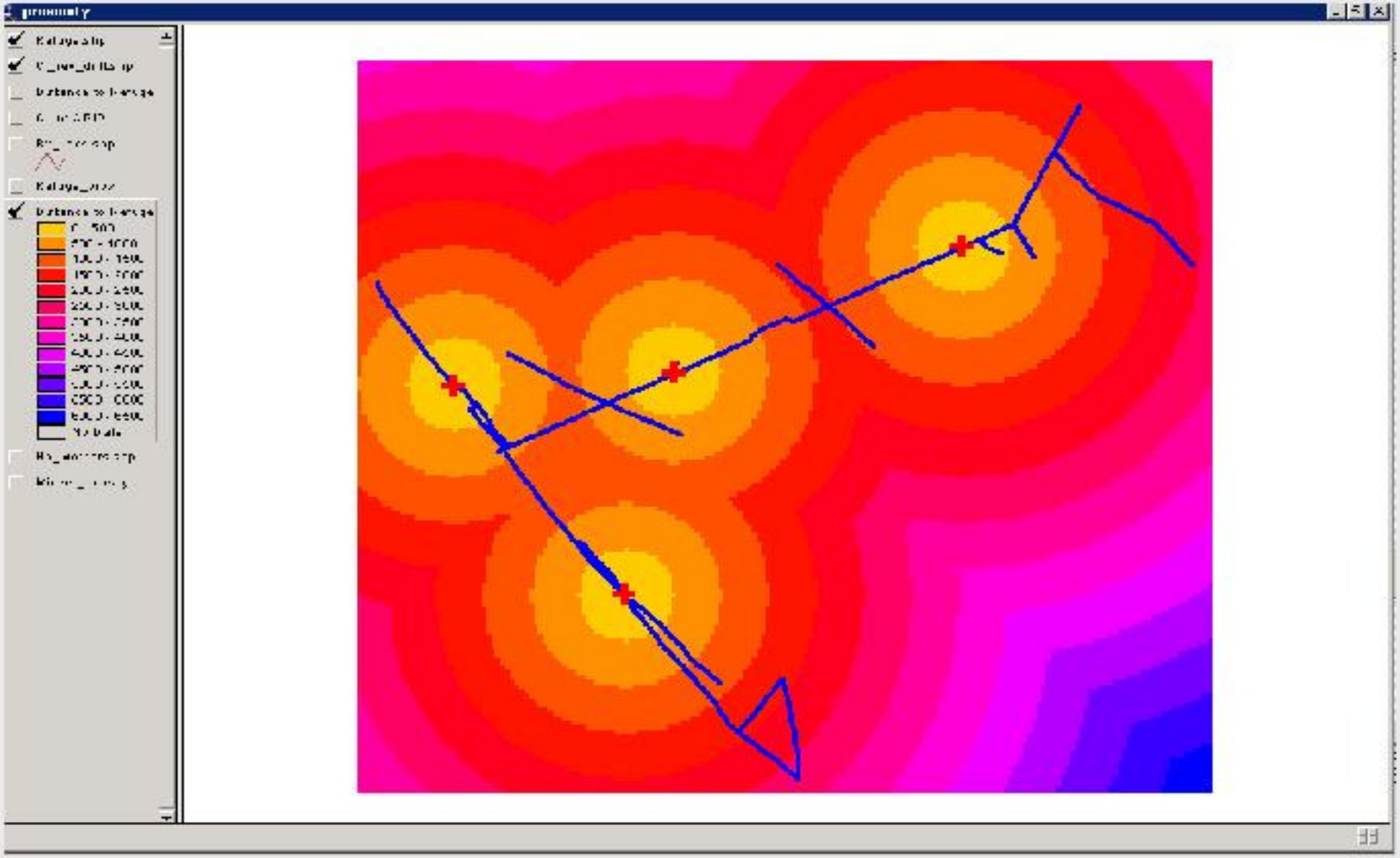
GIS & Remote Sensing

- GIS can contribute in providing a safe working environment in underground mining by performing network analysis and determine the appropriate sites for refuge chambers and facilitate the prompt evacuation of mine personnel

- GIS and remote sensing assist the planners in identifying natural hazards such as potential landslides, floods, and earthquakes prior to the construction of production and housing installations

- GIS can be also used for the selection of a housing site that meets safety, scenic, and recreational requirement within reasonable proximity to the mining operation

Safety – Grid: Distance to Refuge Chambers



GIS and Remote Sensing

Other applications :

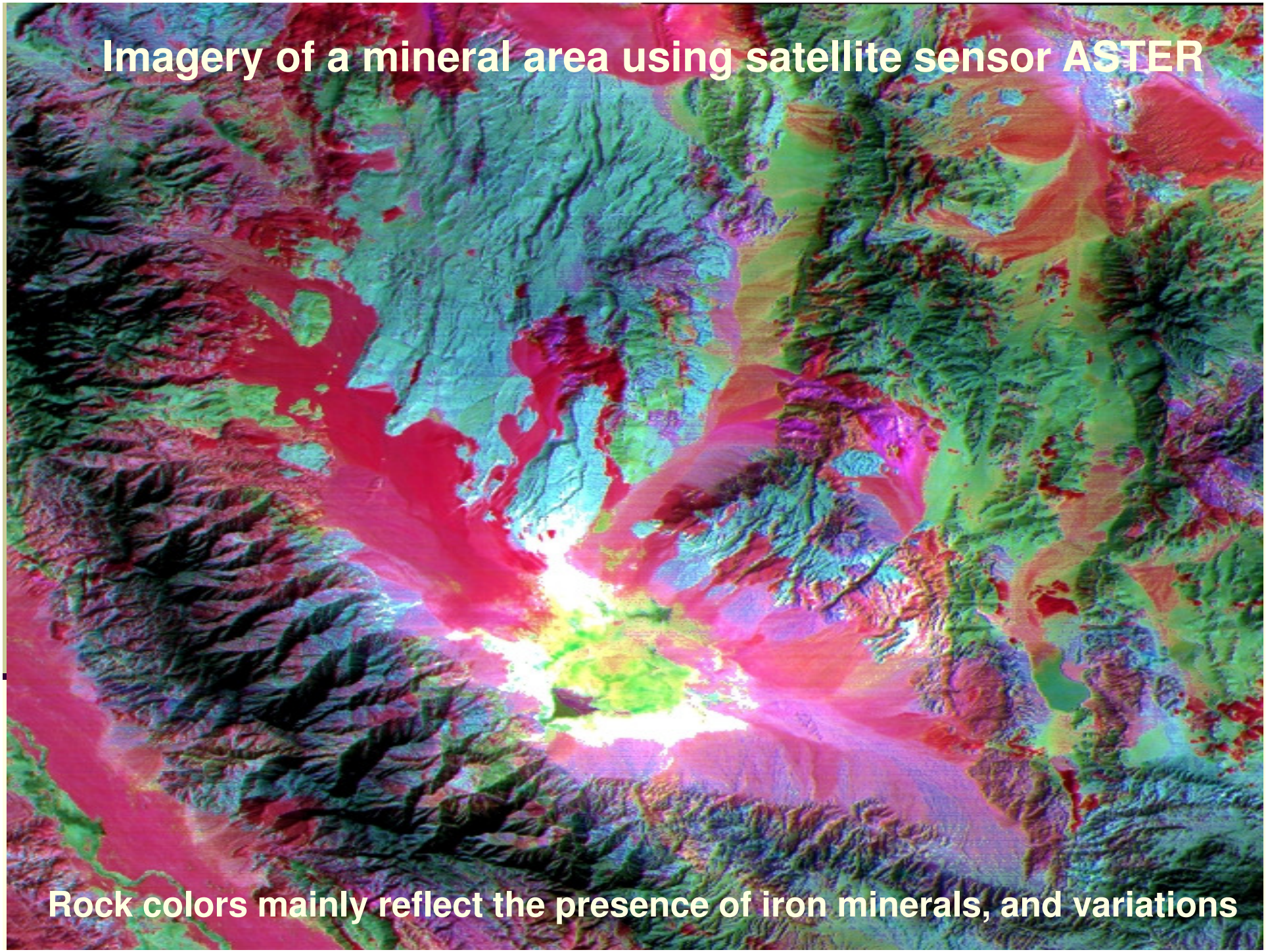
- Land ownership and mineral claims
- Exploration management
- Siting of ore pass, draw points, ramps, shaft, winze, raises, haulways that are within a certain distance of production centers (stopes) and meeting production criteria.
- Querying the production stopes affected by unstable ground conditions, hazardous gas, refractory ore, etc.
- In mine development, GIS can assist the planners in establishing the optimal location for exploration drifts, crosscuts, sublevels, man ways, ventilation shafts

- The use of satellite imagery in mineral exploration, generally a combination of panchromatic and multispectral image information has been used in mineral and petroleum industries over the final decade.

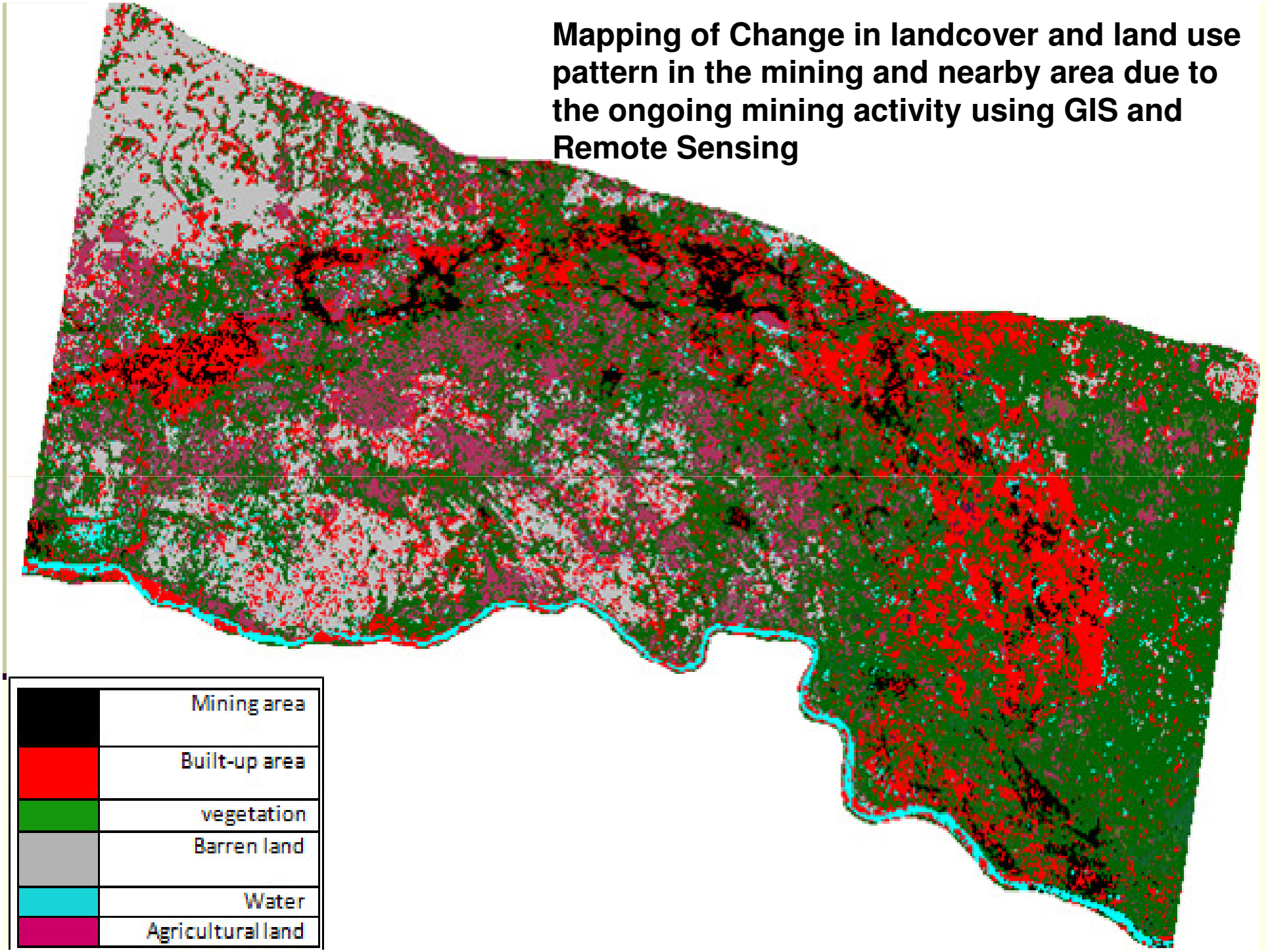
- Imagery from satellite sensors such as ASTER, LANDSAT 7 +ETM, GeoEye-1 and WorldView-2 apiece supplying panchromatic and multispectral total color imagery have benefited geologists, scientists and exploration managers in earth sciences due to the sensor containing multiple band colors

major applications of remote sensing in mines

- mineral exploration and delineation of ore reserves
- assessment of temporal and spatial lands cover (vegetation) change distribution using remotely sensed imagery;
- quantifying land-cover changes in terms of percentage of area affected due to mining activity and rates of change;
- understanding the possible causes of the change and the impact of coal mining on vegetation
- planning for rehabilitation and land reclamation
- mine closure planning
- Detailed mapping of structural geology of an area
- Mapping and evaluation of mining waste anomalies


Imagery of a mineral area using satellite sensor ASTER
Rock colors mainly reflect the presence of iron minerals, and variations

Mapping of Change in landcover and land use pattern in the mining and nearby area due to the ongoing mining activity using GIS and Remote Sensing



Radar images captured by satellite

↓

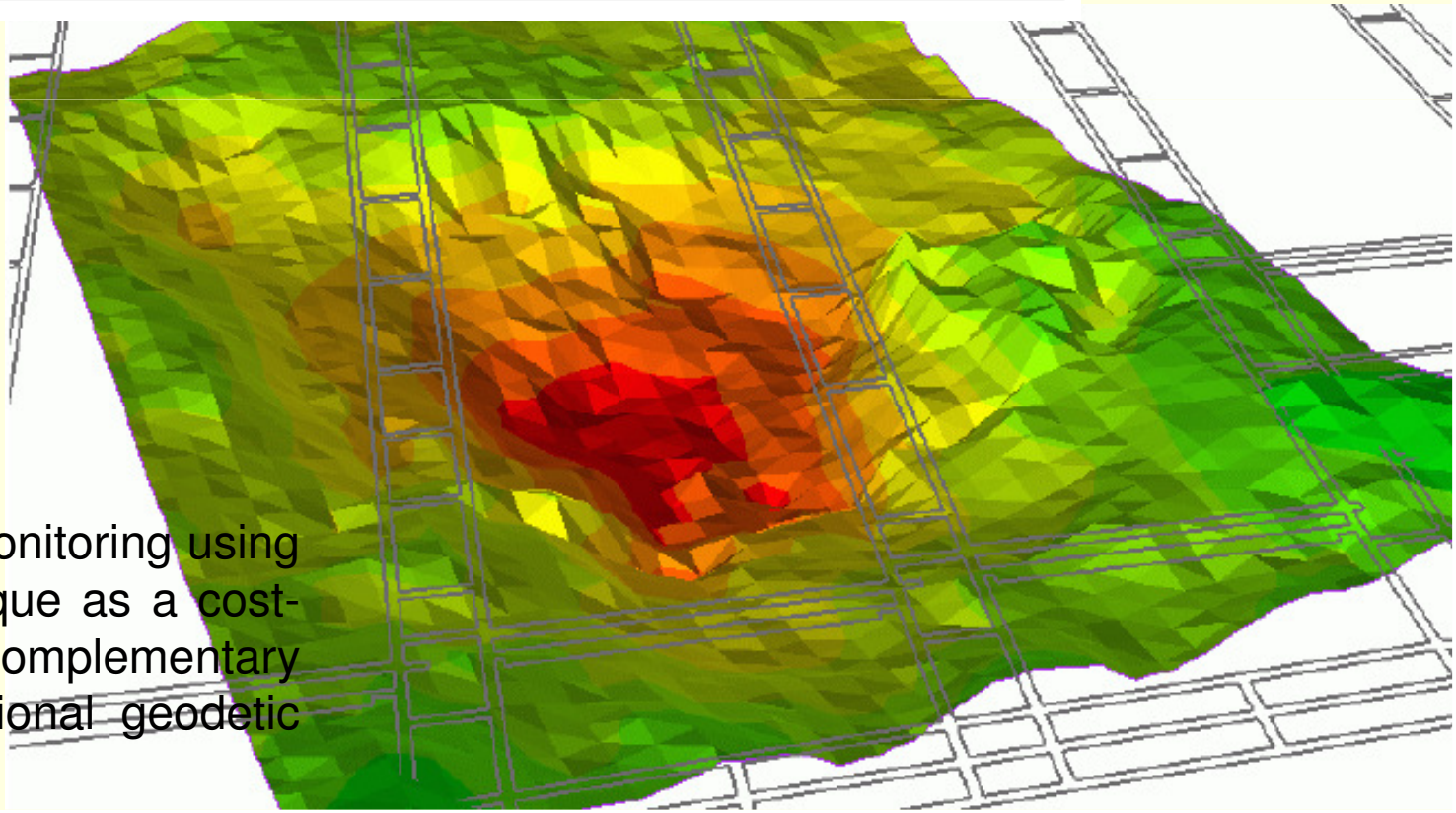
Generate ground deformation with InSAR image processing software

↓ Corrections from GPS

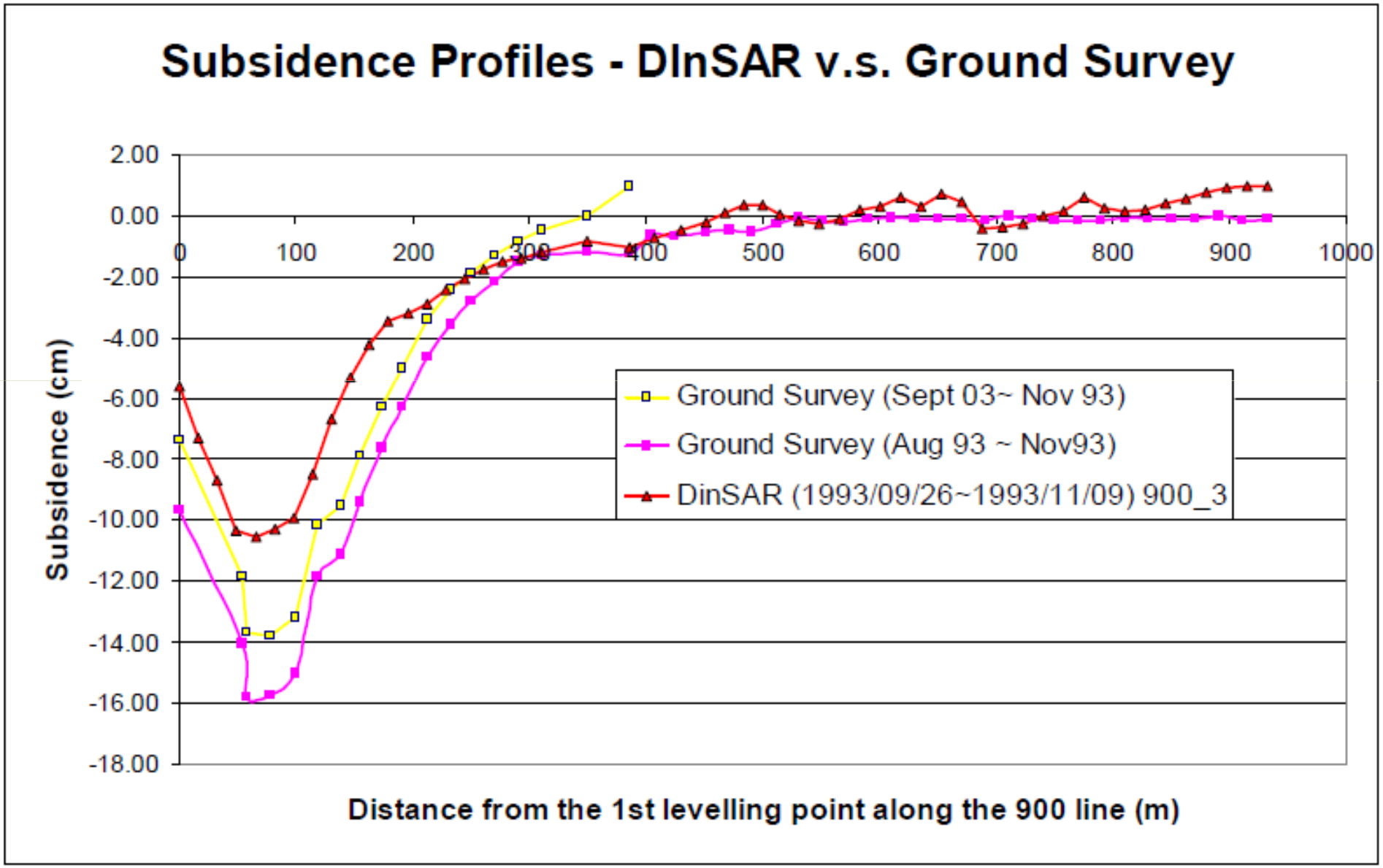
Import image into GIS

↓

Spatial analysis, presentation & report



Mine subsidence monitoring using the DInSAR technique as a cost-effective and complementary method to conventional geodetic techniques


Subsidence Profiles - DInSAR v.s. Ground Survey
2.00
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-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
-16.00
-18.00
0
100
200
300
400
500
600
700
800
900
1000
Subsidence (cm)
Ground Survey (Sept 03~ Nov 93)
Ground Survey (Aug 93 ~ Nov93)
DinSAR (1993/09/26~1993/11/09) 900_3
Distance from the 1st levelling point along the 900 line (m)

Virtual Reality in Mineral Industry

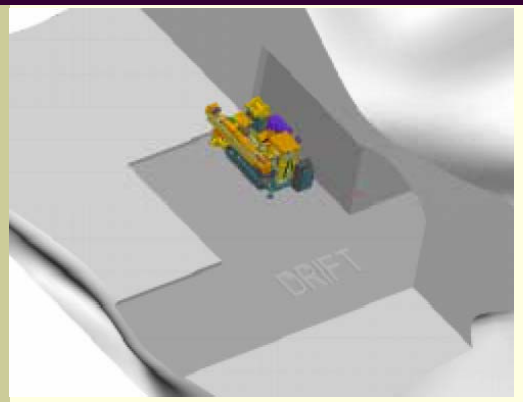
Virtual Reality in Mineral Industry

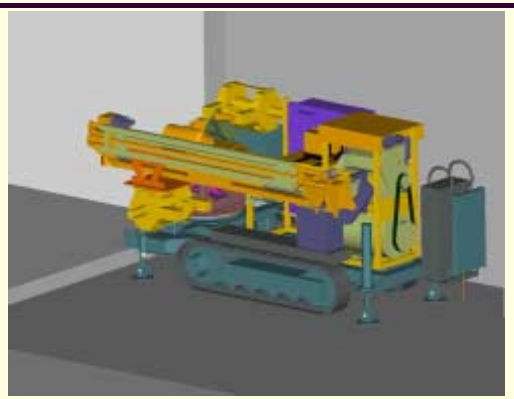
It helps mine planners and designers through a strong capability to visualize overall impact of various factors in a complex mining environment.

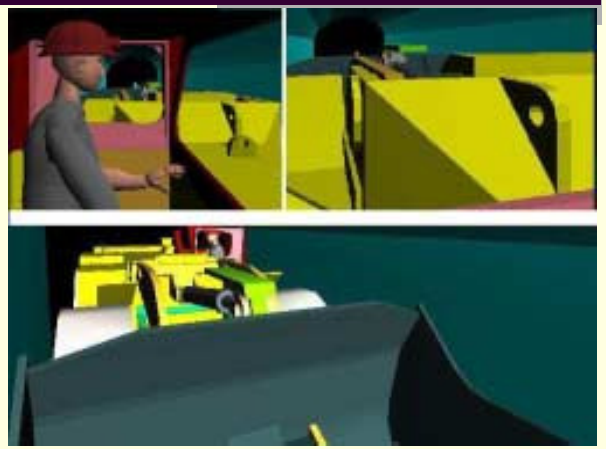
Virtual Reality in Mineral Industry

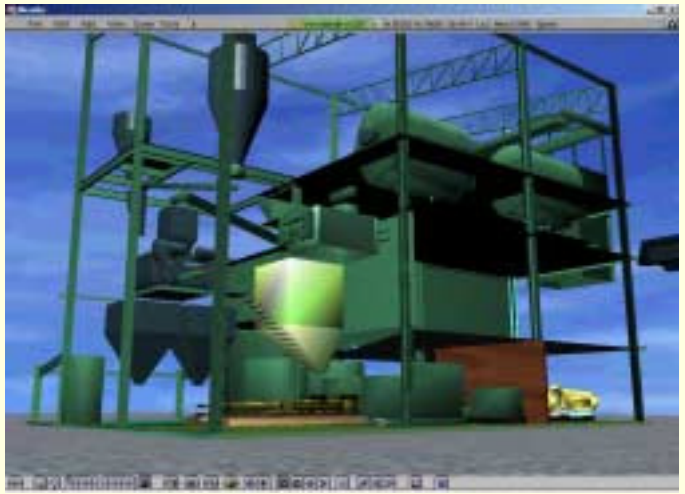
- Mining Equipment Concept development
- Design Review, Operator Input, Maintenance Procedure Review and Simulations
- Development of a simulation / animation model for mine planning
- Presentation of Mining Concepts to an Approving Authority

Virtual Reality in Mineral Industry

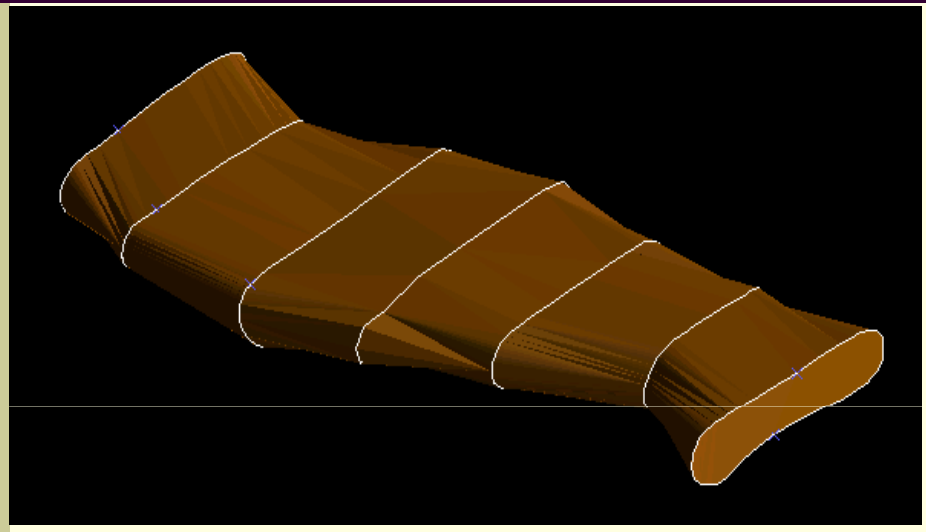




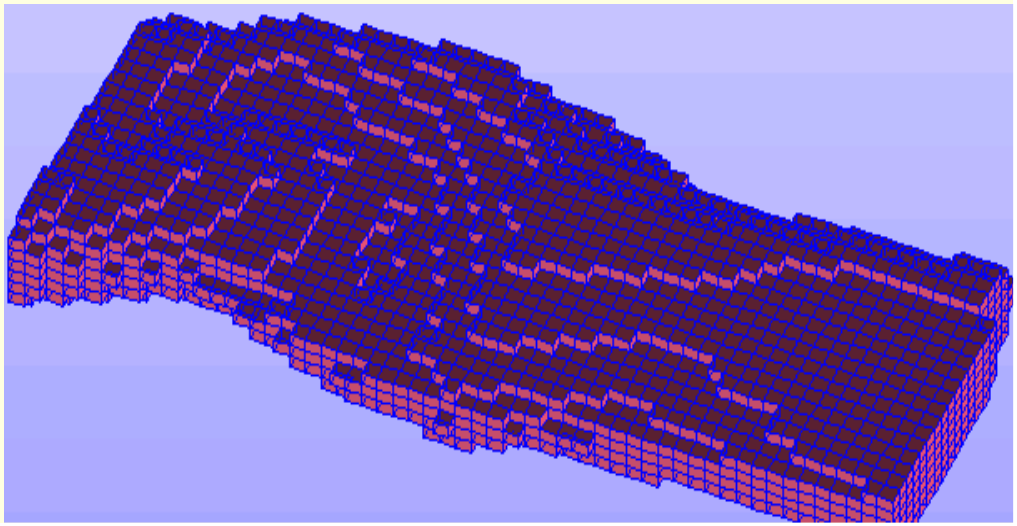


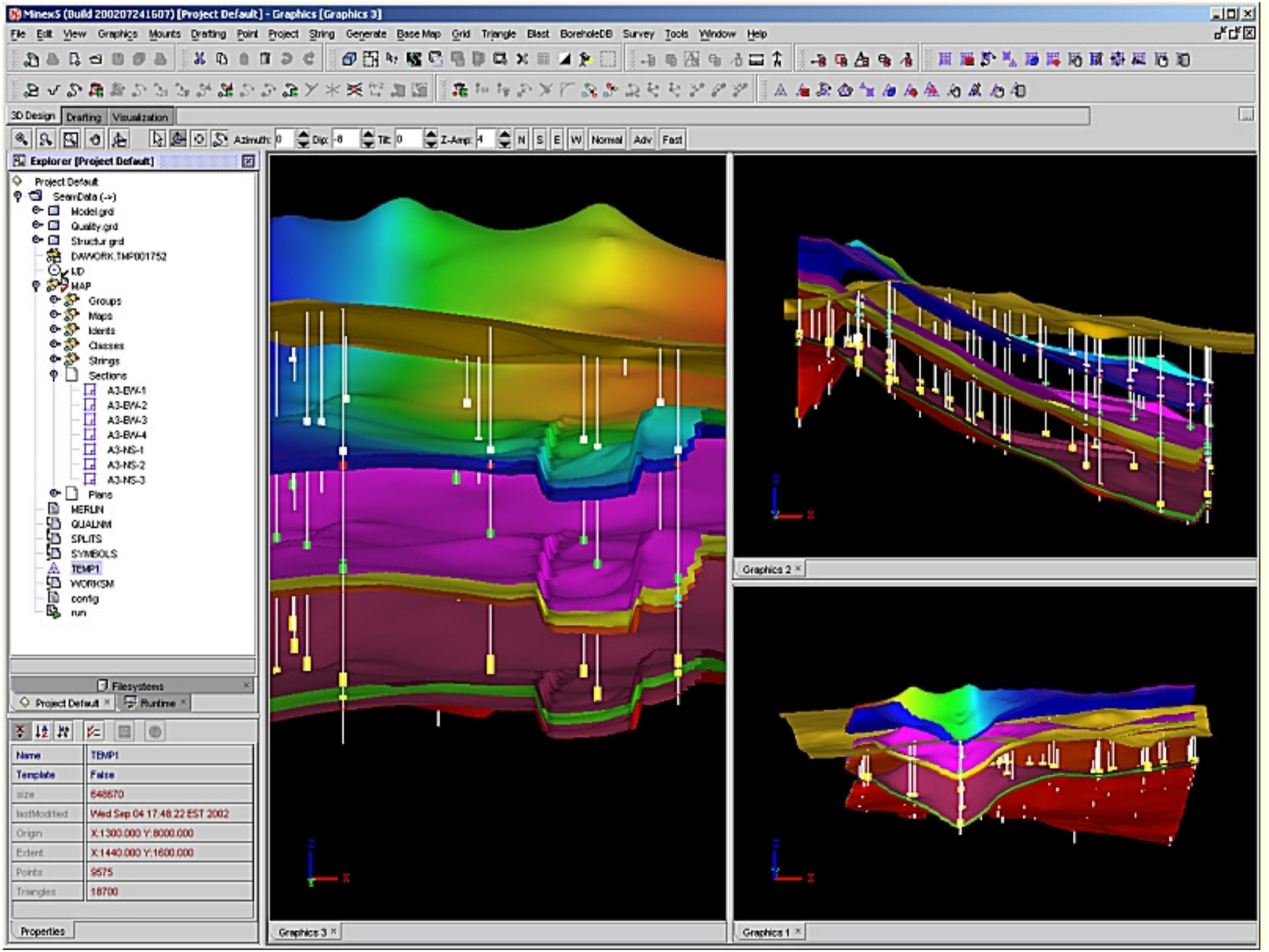


Computer Aided Mine Plan and design



Solid modeling & block modeling of an iron ore deposit using SURPAC




MinexS (Build 200207241607) [Project Default] - Graphics [Graphics 3]
File Edit View Graphics Mounts Drafting Point Project String Generate Base Map Grid Triangle Blast BoreholeDB Survey Tools Window Help
3D Design Drafting Visualization
Azimuth: Dip: Tilt: Z-Amp: N S E W Normal Adv Fast
Explorer [Project Default]
Project Default
SeamData (--)
Model.grd
Quality.grd
Structur.grd
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UD
MAP
Groups
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Classes
Strings
Sections
A3-EW-1
A3-EW-2
A3-EW-3
A3-EW-4
A3-NS-1
A3-NS-2
A3-NS-3
Plans
MERLIN
QUALNM
SPLITS
SYMBOLS
TEMP1
WORKSM
config
run
Filesystems
Project Default
Runtime
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Template False
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lastModified Wed Sep 04 17:48:22 EST 2002
Origin X:1300.000 Y:8000.000
Extent X:1440.000 Y:1600.000
Points 9575
Triangles 18700
Properties
Graphics 2
Graphics 3
Graphics 1

Computer Aided Mine Plan and design

- **Use of CAD methods for mine design, geological databases and resource estimates, block modeling techniques, blast pattern designs, 3D orebody modeling and 3D open-pit and underground mine layout.**
- **Development of software for strategic open pit planning based on object-oriented stochastic simulation.**

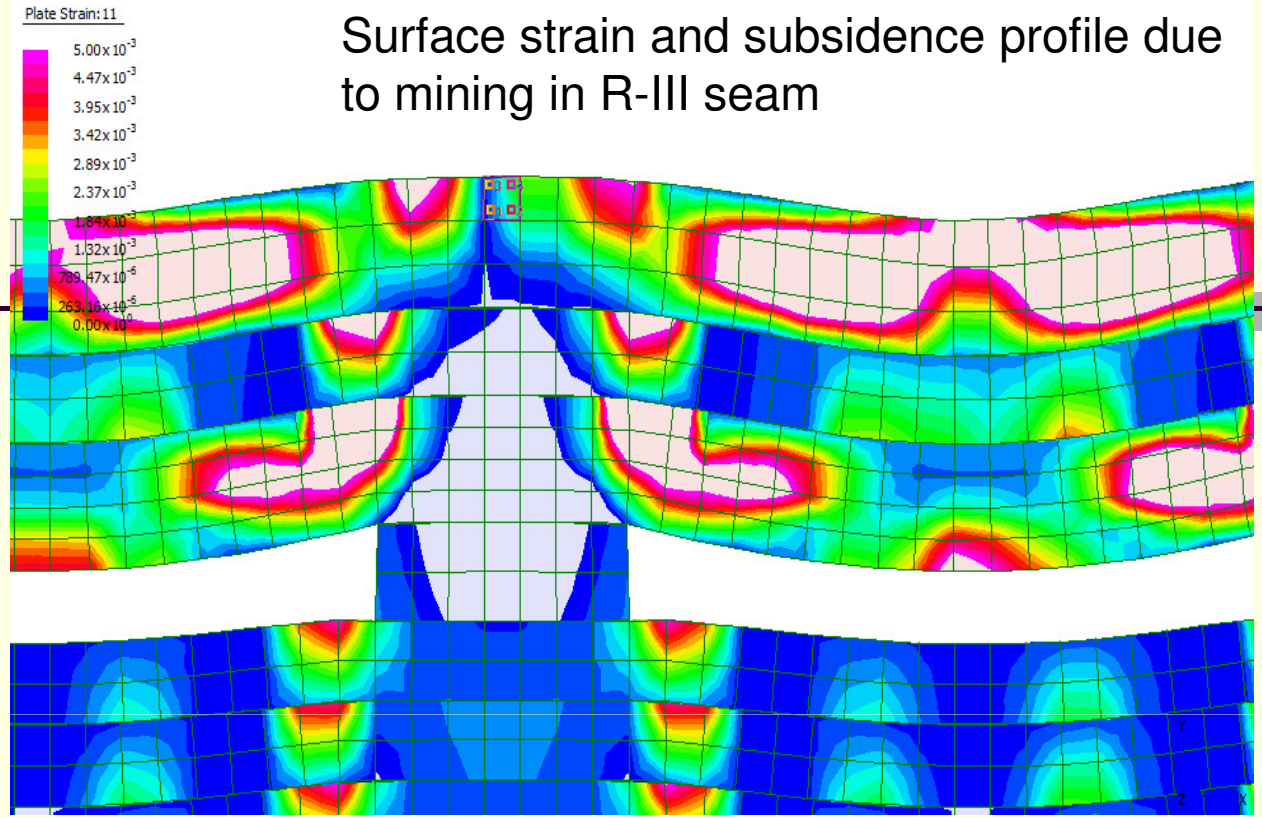
Computer Aided Mine Planning and Design

- **Development of a simulation / animation model for open pit mine planning**
- **Computer Modeling for Performance Estimation and Optimization of Mechanical Excavators**
- **Computer Simulation of Gravity Flow of Ore in Ore Passes by the Discrete Element Method.**
- **Project Scheduling and Costing for major Mining Projects using CPM & PERT software packages viz. Microsoft Project, Visio etc.**

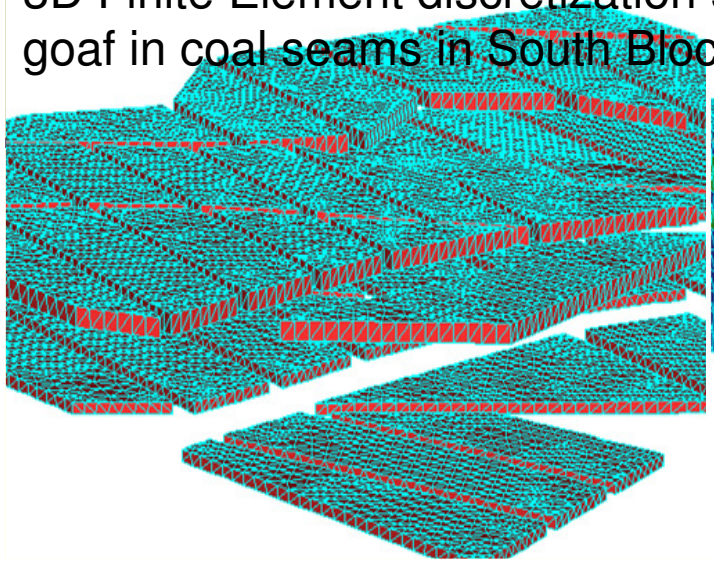
Computer Aided Mine Planning and Design

- **Numerical modeling software (ITASCA):** UDEC, 3DEC, FLAC, FLAC 3D, PFC 2D, PFC 3D. These are essentially for stability analysis and mine design.
- **MICROMINE:** This software is meant for exploration and mining.
- **SURPAC:** This software is applied in Geological modeling and mine planning.
- **TECHBASE:** The features available in this package are Database generation, Statistical modeling, Graphics etc.
- **GEMCOM:** This is for Geological exploration and evaluation apart from surface underground mine design, environmental engineering and hydrological engineering.
- **MINEX 3D:** This software is meant geological modeling and mine planning systems.
- **MINEX UG :** Interactive underground mine planning
- **O.P.MINE:** Open pit mining simulation for designing mining sequences, mining methods and equipment.

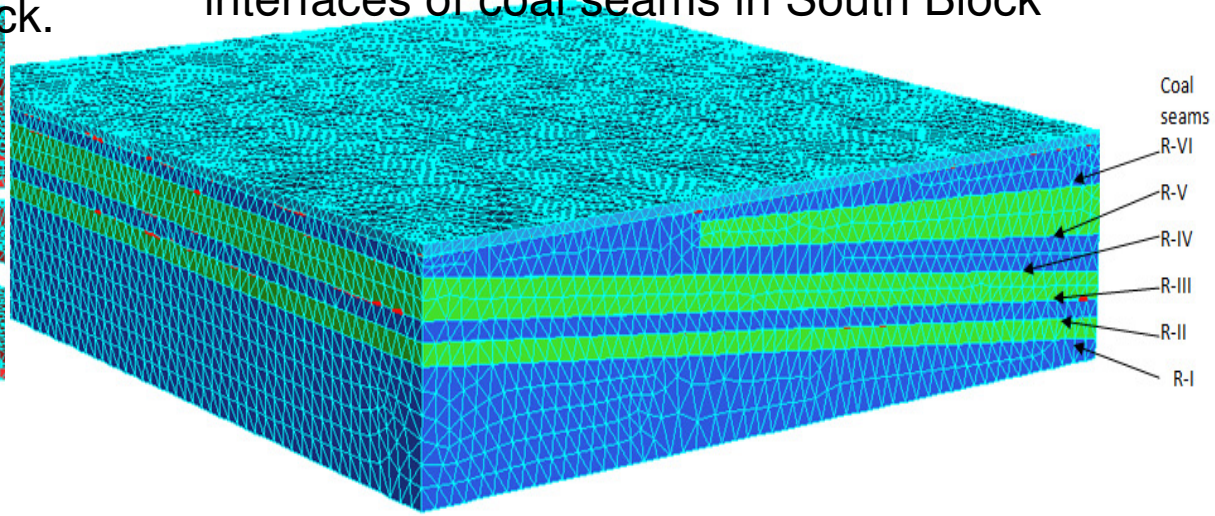
Surface strain and subsidence profile due to mining in R-III seam



3D Finite Element discretization showing goaf in coal seams in South Block.



3D Finite Element discretization showing interfaces of coal seams in South Block



Armchair Mining

The backbones of ARMCHAIR MINING are:

- **Robust communication system in the mine, capable of handling data, voice, and video signals**
- **'Smart' mining equipment, outfitted with on-board computers and a host of sensor**

Armchair Mining

- **Stereovision and 3D Modeling for Remote Operation of Mining Equipment**
- **Develop advanced sensing and control techniques**
- **Allow migration of miner from on-board manual operation to a mode of remote supervision**
- **Improve the miner's health and safety, and improve their working conditions**

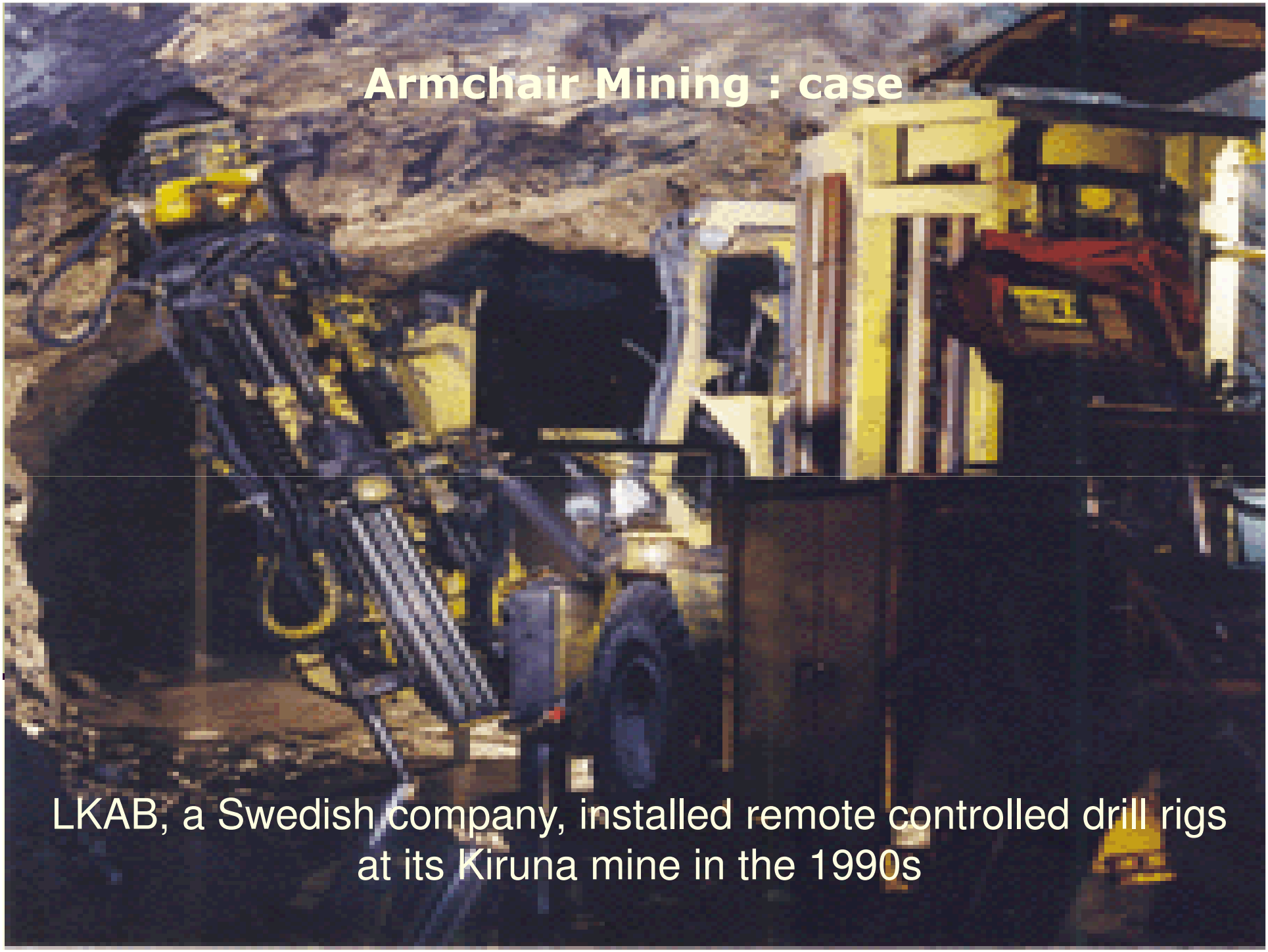
Armchair Mining : case

- With an ore body 4 km long, 80 m thick and reaching a depth of 2km, LKAB's Kiruna iron ore mine, Sweden is the world's largest, most modern underground iron ore
- Since mining began here over 100 years ago, LKAB has produced over 950 Mt of ore.
- Very few people work underground.
- The seams are drilled by remote operated drills.
- Huge Finish-built driverless wheel loaders follow computer-controlled routes and only stop at piles of broken rock to collect the ore

Armchair Mining : case

- At this point an operator sitting in front of a TV screen on the surface loads the ore and carries it to shaft where it is dropped to the 1,045 m level.
- The ore is crushed here and then hoisted to the surface to be processed.
- Electric-powered, remote-controlled drilling and ore handling equipment supplied by Atlas Copco and Tamrock is widely used here.
- After blasting, load-haul-dump machines (some of which are fully automated) carry the run-of-mine ore to the nearest ore pass, from which it is loaded automatically on to one of the trains operating on the 1,045 m level

Armchair Mining : case



LKAB, a Swedish company, installed remote controlled drill rigs at its Kiruna mine in the 1990s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A load-haul-dump vehicle in LKAB's iron ore mine in Sweden scoops rock with the help of a teleoperator working off-site; the vehicle does hauling and dumping automatically


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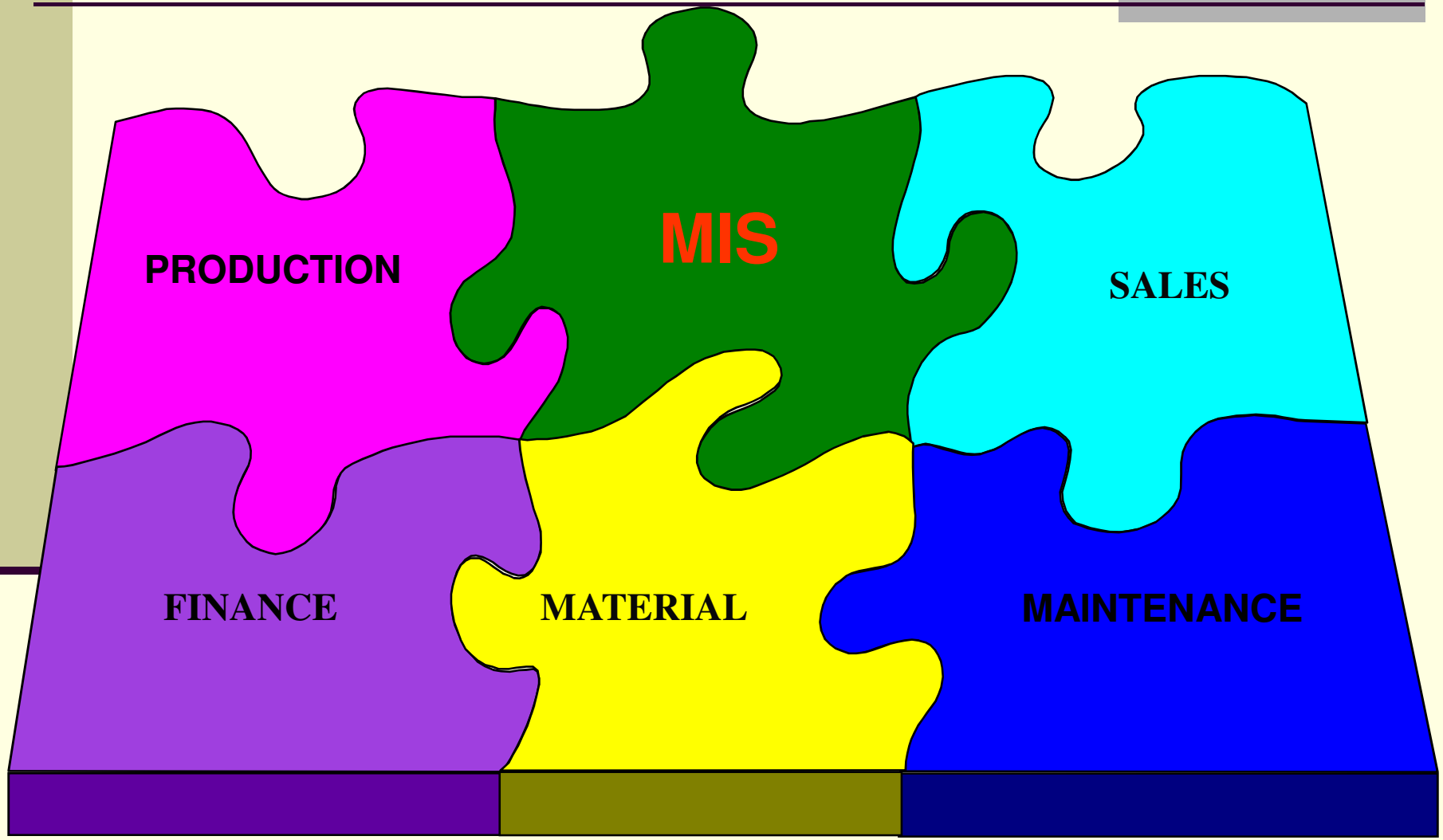
ASEA

Enterprise Resource Planning in Mining Sector

Integrated Business Solution (IBS) : for Mining Companies



Conclusion

- There is a substantial need of adoption of state of the art automation technologies in the mines to ensure the safety and to protect health of mineworkers.
- The paper has highlighted some of the recent innovations in the mine automations that could be deployed in Indian mines for safe mining operations and for avoiding any unforeseen mine disaster.
- Significant developments have been made in the areas of surface and underground communication, robotics, smart sensors, tracking systems, mine gas monitoring systems and ground movements etc

Conclusion

semi-automated / automated mining technologies backboned with information technologies is need of the day

This will satisfy the two most important goals of any mining operation: improved productivity and safer working conditions.