Modernization of Indian coal mining industry: Vision 2025

S K Chaulya*, L K Bandyopadhyay and P K Mishra

Central Institute of Mining and Fuel Research (CIMFR), Dhanbad 826 001

In view of vision 2025, CIMFR, Dhanbad has developed a web-based information and decision support system for coal mining industry. Paper summaries scope of proposed IT based system by highlighting existing problems and proposed solutions under different modules, and briefly enumerates the methodology to develop the proposed system.

Keywords: Decision support system, Modules, Network, Sensors, Web-based information

Introduction

India is lacking in industrial based application of information technology (IT) in mining industry[1,2]. To achieve the future production target, coal mining industry has to improve its productivity and safety by enhancing mechanization[3], increasing on-line monitoring[4], implementing wireless communication systems in underground[5] and adopting appropriate application based IT system[6,7]. This paper presents a web based information and decision support system proposed for coal mining industry by Central Institute of Mining and Fuel Research (CIMFR), Dhanbad. The paper briefly describes the scope of IT application in Indian coalmines and methodology for development of IT based system.

Proposed Areas of IT Application in Coalmines

An effective IT system aims to provide increased productivity and profitability with an eye on the miner's safety working in the mines. An integrated IT system with different modules will be developed and implemented in a mining areas as follows:

Improving Production and Productivity

For effective mine management, managerial staff requires a complete knowledge of daily targets and achievements, output per man shift for piece rated, time rated and overall categories, and reasons for shortfall etc. The real time measurement of production using sensor and computer (on-line data feeding from dispatch conveyor or tippler where raw coal is dumped) can make

mine manager pro-active instead of doing production analysis and take decision at shift end or day after. Sensor as weight-o-meter will directly send data to computer. Analysis of breakdown reports obtained through feeding data from the Overman's (Supervisor's), Technician's, and Munshi's reports into computer, will clearly give breakup of total time lost and its item-wise cause. After going through web based reports generated by computer, it will be easy to identify gray areas and priorities can be set for allocation of scarce resources to improve production and productivity. Further, using machine status sensors, IT system can be used for monitoring machine operation period and calculation of production in shift-wise, day-wise, month-wise etc.

Shift and Personnel Management

IT will give new impetus to major functions, like (a) on-line monitoring of production, (b) day to day planning, (c) resource management and (d) face quality control. Employee personnel records can be effectively maintained at the mine level only, preventing delay in dealing with matters related to leave records, promotions, transfers and other matters. Preparation of payrolls can also be possible at the mine level only. Performance and attendance of individuals can also be ascertained by keeping separate records of performance of each person employed for improving productivity and discipline.

Reduction of Production Discrepancy

In most of the mines, there is coal production discrepancy (13-16%), which leads to Rs 250-300 loss per tonne of coal produced, considering the value of @ Rs 2000 per tonne. Main reason of discrepancy is coal

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*Author for correspondence
Telefax: 0326-2224277
E-mail: chaulyask@yahoo.co.in

tub, which miners fill in such a way that it looks as full, but tubs are partially loaded. Miners are paid in terms of number of tubs they fill. Using weight-o-meter, discrepancy will be reduced and mine will have to pay revenue as per their actual production in weight-o-meter. The production data will be recorded on-line in the system for record at different management levels.

Maintenance of Equipment

In mining industry, a number of equipments related to production and transportation are regularly maintained in order to avoid any failure or breakdown. Maintenance cost at mechanized mines (35% of operating cost of the system) goes as high as 50-60% when both direct and indirect costs are considered.

A computerized maintenance and management of equipment module will be developed to overcome existing problems. Materials/spares will be issued against predefined break down/preventive maintenance code. The module will be developed for: i) Routine condition monitoring of major equipments using on-line sensors; ii) Recording frequency and duration of all break down events; iii) Categorizing all events by required status codes; iv) Administering defect identification and quantification; v) Linking reliability to equipment performance and duty; vi) Automating work order generation and administration; vii) Tracking engine and wheel motor hours; viii) Automating generator of service schedule; ix) Tracking fuel consumption and allocation; x) Allocating maintenance resources and priority setting; xi) Coordination of production and maintenance function; xii) Management of tire inventory and performance; xiii) Major component tracking; and xiv) Correlating maintenance performance against equipment duty.

Management of Inventory

Computerized system will reduce the store cost of each mine. If the material list of all the stores of a company is in a web then any mine can draw material from any store of other mine (essentially from same company) so that non-moving item of one mine can be utilized by others. The system can have predetermined triggers so that dependence on individual decisions is minimized. Unique material code and nomenclature across the company stores will reduce inventory holdings. The study of obsolete/non-moving items may help companies to decide on write-off. This will reduce overall costing of the inventory and remove the duplicity of items by combining part number and vendors' specifications. Different type of reports can be generated easily as per the need of mine management.

Environment Monitoring

In Indian mines, generally portable devices (methanometer, CO meter, anemometer, thermometer etc.) are used for environmental monitoring and recording huge data in record book for future use. Such measurements are infrequent and subjective to human failures, causing lapse on safety precautions.

To overcome existing problems, on-line sensor based environmental monitoring system will be integrated with the proposed system for continuous monitoring of vital environmental parameters in normal condition [methane (CH_4), carbon monoxide (CO), oxygen (O_2), air velocity and temperature] and in case of sealed off area [temperature, CH_4, CO, O_2, nitrogen oxide (NO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), hydrogen sulphide (H_2S)]. The system provides on-line visual representation of trend of all monitored parameters and gives audio-visual warning signal when a particular parameter crosses respective threshold limit so that mine management can immediately take appropriate action. This would also help in enhancement of productivity and profitability of a mine, proper ventilation planning, early detection of fire, indicating occurrence of high concentration of gases, reducing response time and minimizing dependence on human errors.

History of Mine

Feeding mine details and updating it regularly in database will help in taking due course of actions in already mined areas. All historical information will be preserved in server and can easily be made available for future mine planning, preparation of environmental impact assessment and management plan reports, environmental compliance report, any R&D study in the mine, court of enquiry, statutory compliance, preparation of mine closure plan and other necessary purposes.

Disaster Forecasting and Mine Safety Management

Every year disasters occur in coalmines causing death of miners, and loss of coal and property. Underground pumps are often sited at remote locations, and their operation and maintenance is very difficult. On-line monitoring of pump operation and water level using sensors is highly essential for early detection of

Table 1—Techniques for disaster forecasting in underground coal mines

Category of disaster	Parameters to be monitored for forecasting	Sensor/technique
Explosion of flammable gas	Methane (CH4)	CH4 sensor
High concentration of toxic gas	Carbon monoxide (CO)	CO sensor
Mine fire due to self heating of coal	Temperature of coal strata	Temperature sensor
Roof fall	Movement of roof strata	Low frequency acoustic sensor
Inundation	Demarcation of water logged area, and maintaining safe distance between working area and water logged or old working area	Updating and analysis of day to day survey data by Ground Penetrating Radar (GPR)
Pump management	Running status of pump and early warning of increasing water level	Pump status sensor (ON/OFF mode) and water level indicator

fault in the pump. A microprocessor based multi-channel intrinsically safe real-time environmental monitoring system developed by CIMFR will be used for on-line continuous monitoring and providing early audio-visual warning signal to forecast different category of disasters using special sensors and techniques (Table 1). The system will also provide on-line visual representation of trend of all monitored parameters and give audio-visual warning signal when a particular parameter crosses respective threshold limit so that mine management can immediately take appropriate action.

Using computer database, all safety and rescue related data could be uploaded in the system for future use. Analysis of data can identify possible areas of weakness in mines safety system, and data can be used as a guideline for the decision making process to improve mine safety performance. On-line monitoring of exhaust fan speed and pressure development across fan will be done using tachometer and air pressure sensors, respectively for proper ventilation in underground coalmines.

Statutory Requirements

All statutory related data (acts, rules, regulations and standards) could be fed into computer for accessing required information as and when required. Compliance to the statutory requirement can be fulfilled easily and effectively with less manpower and cost.

Post-Disaster Management

Computerized system will be developed to provide accident analysis, accident prone areas, probable remedies, emergency response plan, list of first aid, rescue trained personnel along with their address, telephone numbers and place of duty during an emergency. Mobilization of manpower and resources can be done effectively to rescue the trapped miners without any delay. Sometimes during any mishap, there is misplacement of statute books, like Manager's diary, Overman's report, Mining Sardar's report etc., but if these reports are filled in web there is no chance of losing data/information. This information will help expediting the court of enquiry in case of accidents/or a disaster. A day-to-day action taken by safety managers can help in avoiding any causality and if any thing goes wrong then the logged data can help in rectifying the problem. It will also speed up actions in providing assistance and benefits to affected people. Computerized attendance of miners can be easily done and can be used during emergency.

Improvement in Working by On-line Record Keeping

In coalmines, lot of records are maintained manually for: (a) Explosive magazine report to prevent pilferage; (b) Cap-lamp maintenance report books to maintain lamp; (c) Fan record book to keep an online record of the mine resistance, pressure developed etc.; (d) Issue

registers of safety items, like safety lamps, methanometers, CO meters etc.; (e) Safety wears like helmets, safety boots etc.; and (f) Ventilation records, like air measurements at each stations, maintenance of fire stopping records, stone dust barriers, stone dust quality, inventory maintenance of ventilation department like cement, stone dust, water pipes, bricks etc. Even a Ventilation Officer has to maintain about 50 registers.

A computerized database for different purposes will be prepared. Technical persons can concentrate on his technical inspection to improve upon the actual mine condition near the workings in underground. Working culture of the mine will be improved with efficient management and improved productivity.

Wireless Communication in Underground Mine

A proper and reliable wireless communication system in underground mines will save machine break down time, and also help in immediate passing of message from the vicinity of underground working area to surface for speedy rescue operation. Different types of wireless communication systems are developed, namely, personnel emergency detector, mine tracking system, leaky feeder based system, induction based system, very high frequency (VHF)/ ultra high frequency (UHF) transceivers, trapped miner locator etc. and those systems will be integrated with the proposed IT system.

Decision Making

An appropriate audio-visual communication links will be established for effective, fast and instant decision-making at different management levels and keeping history of important decision in database for future reference. Audio-visual communication featured with integrated software would help to build a decision support system. It will also allow of storing important communication, which can be used as reference in taking the decision in similar circumstances. Important office circulars, orders and decisions can be scanned and upload in Intranet for wide and fast circulation and keeping history of such document.

Training

As there is a statutory provision of imparting training to at least 20% of the total strength in each year, a computerized list has to be maintained to cover all employees in 5 years. Computerization will help trainers for maintaining different forms like Form 1-9 of Schedule XII. Various training modules will be made

available in proposed IT system for implementation in the training programmes. Identification of the need for training will be easy through computerized database. With computerized training centre, technical trainers will be relieved of doing unproductive work. Training facility, imparted by HRD employees through audio-visual communication, would enhance employees' expertise and morale, and enable more participation with no incremental costs. The quality of training will be improved, to provide a technically sound, motivated, alert and safety conscious workforce.

Methodology

Proposed web based information and decision support system will be developed especially for connecting coalmines of different regions with their respective Area Office (AO) and Head Office (HO). The system will have appropriate software and database, middleware and hardware.

Software and Database

Separate database and module will be developed in each category as described. With the development of application software, networking software and specialized software, an integrated IT system will be made available to coal mining industry having following facilities: (i) Different modules for data entry, logging, on-line monitoring, processing, analysis, storing and transmitting; (ii) Web page for dissemination of mining information, information exchange, video conferencing and decision making utilities; (iii) Decision support system with mining data base; and (iv) Network architecture for connecting mining sites with area and head offices and providing communication strategies.

Many data base software are available for data storing and maintaining, namely Oracle, SQL server, MS-access, MS-excel, DB2, MySQL, D2K and others. Oracle database will be used for data storage, as it is more compatible and secure than other available database. Initially, database will be designed on the basis of collected information. Manager/concerned authority will recognize specific data/information related to safety, productivity, maintenance of equipment, statutory requirement, environmental monitoring and other information of a mine. The collected information of a mine will be categorized as: i) production, ii) mine operational, iii) geological, iv) geotechnical, v) technological, vi) mining and environmental standards, vii) environmental status, viii) mine-planning and design,

ix) store inventory, x) equipment maintenance, xi) finance and accounting, xii) store and purchase, xiii) R&D, xiv) policy and decision, xv) legal, (xvi) sales, xvii) procurement status, xviii) safety, xix) medical, xx) attendance, xxi) accident, xxii) lease, xxiii) HRD, xxiv) training, and xxv) pay role and other information.

Information will be collected on-line using sensors on i) CH_4, ii) CO, iii) air velocity, iv) temperature, v) strata movement, vi) water level indicator, vii) machine status, viii) load, ix) vibration, x) oil temperature, xi) bearing temperature, xii) pressure and other sensors. The data will be received from sensors using sensor-reader software/driver, such as Data Acquisition Software (DAS), which is already developed by CIMFR, Dhanbad. In this software, files can be opened for viewing graphical simulation of data in different channels. Various statistical analysis operations like maximum, minimum, average, moving average, standard deviation etc. are also incorporated. There are alarm and warning messages when a data cross its safe limit and helps in taking precautionary measures. The second way of getting data will be use of on-line web camera and headphones. Other ways of getting data will be directly feeding of data by using keyboards, scanners, digitizers etc.

All collected information will be stored in a master database having different modules. All modules will be internally connected to each other with foreign, reference and composite keys, and program codes. These modules will be managed with front-end program code and back end tools having advanced functions, procedures, view, cursors and triggers. These functions, keys and tools will be used to manipulate, relate, displayed data with security and remove data redundancy. Stored information will be accessed though web. The data will be displayed in tabular, pictorial, chart, graphical, 3D formats etc., using SQL query/commands. Retrieve will filter and display information as per the desired format of user with the help of front-end software, back end database, web server's software and support networking.

Middleware

All computer terminals placed at different places will allow access to data/information available in the database. The terminals will also be updated with new data/information placed at mine sites.

Proposed web based information system will have a number of stations (mines) equipped with computer terminals having web camera, modem, and head phone,

telephone etc. facilities connected with each other using switch and all computers are connected with a common server. Specially developed software will store all data at central location at AO. Web-camera facility in each station - for situation assessment purposes - which has the ability of connecting directly to any other computer in the network, will send data both in audio and video format (speed, of 100 Mbps). On each station number of computers will be placed with web camera and headphone and all these computers will be connected with a switch. All the servers will be kept at central location at AO. Basically, two types of servers will operate: (i) To keep entire database server; and (ii) To work as application server. At HO, a computer will be connected with AO with dial-up connectivity and other computers will be connected with the said computer. Server at AO will also be configured as Remote Access Server (RAS) so that connection can be established from HO through dial-up using modem and existing infrastructure of telephone line.

For data manipulating and storing, all the data of each mining site will be stored in the server. Web server will be responsible for collection, processing and storage of data from all stations via a commercial program. Oracle database server will do the data storage and batch processing. The processed data will be sent through web page after, execution of a code written in Visual Studio NET, which would produce a file with desired information from any station. Consecutively, a program written in Visual Basic NET will be executed, that will read experimental data and produce desired report at any location. For comparison, desired previous day information/decisions will be available to authorized user based on the requirement through database server. Any query can be executed from any client using the application developed in Visual Basic NET, which will be made available from Application server.

Complete networking system (Fig. 1) indicates placement of computer terminals and bi-directional feature of flow of data/information. Computers at one location will be connected with a switch using twisted pair, cat 6 cables. Switches of all stations will be connected with optic fibre cable. AO will be connected with HO through dial-up. For this, one server at AO will be configured as RAS and one modem with telephone line will be attached with it. System kept at HO will be having one modem attached with it along with telephone line. Any time the computer at HO can dial into the servers at AO and get the required information.
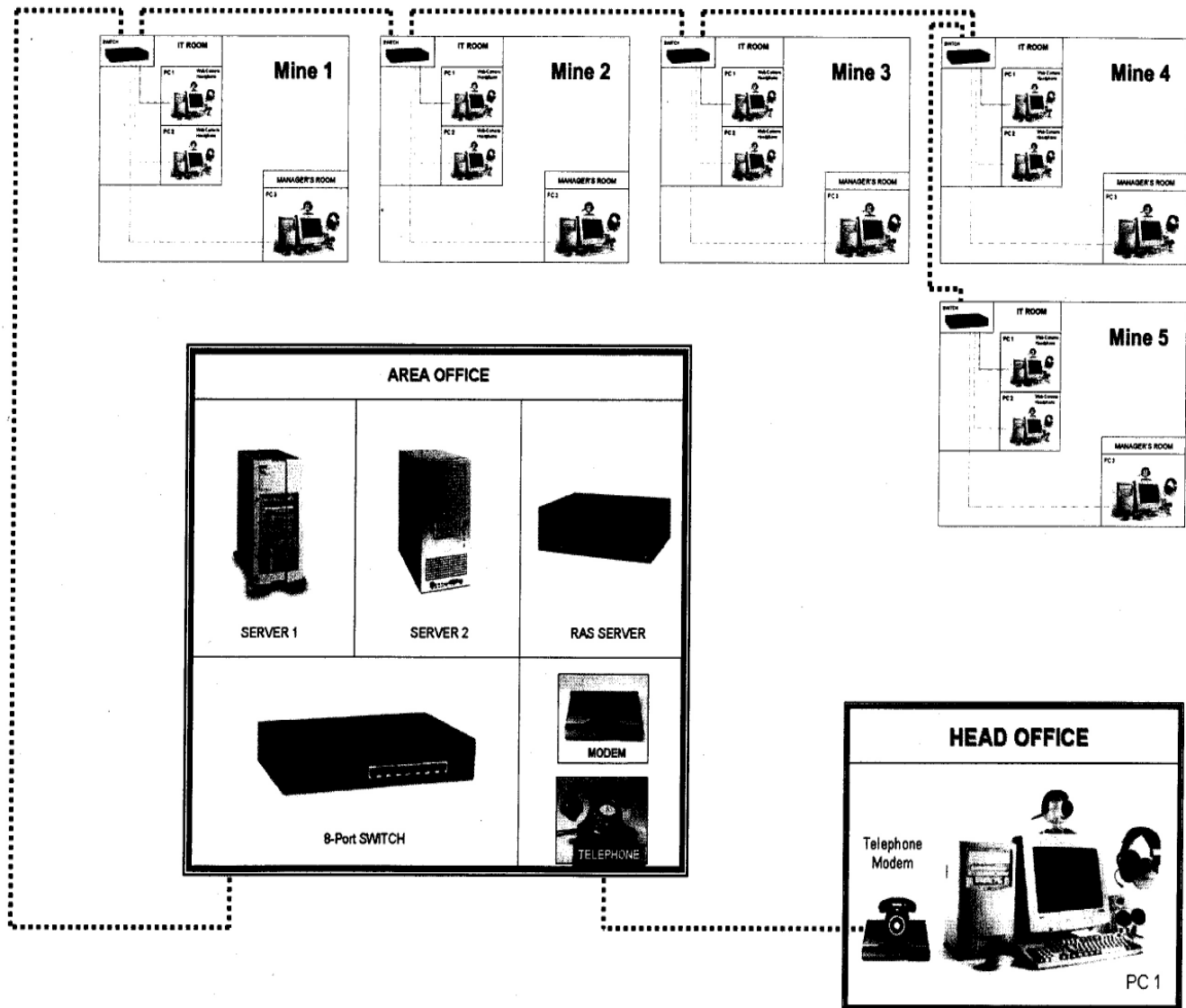
Fig. 1—Setup for the complete network system

Hardware

Schematic diagram (Fig. 2) of a mine indicates location of sensors, computer and other peripherals. Different sensors will be connected to a computer in IT room using underground remote station, armored cable, junction boxes, FLP power supply, intrinsically safe UPS and other accessories. Various parameters will be continuously monitored on-line using different sensors. Each mine will have one IT room and manager room, where proposed system will have connections. IT room will be equipped with computers, web-cameras, head phones, UPS, laser printer, scanner, plotter, digitizer, mobile handset and other accessories for calibration, testing and maintenance. Manager room will be equipped with a computer, UPS, headphone, web-camera, scanner, laser printer and mobile handsets.

Concluding Remarks

Adaptation of IT based management strategy in coal mining industry will allow officials to quickly access, integrate and display critical information for making better tactical decision and at the same time to provide long-term information that senior management require for taking strategic decisions. Further, IT system will provide access to mining personnel on world wide development related to mining technology, which will help them to adopt best technology for their site specific
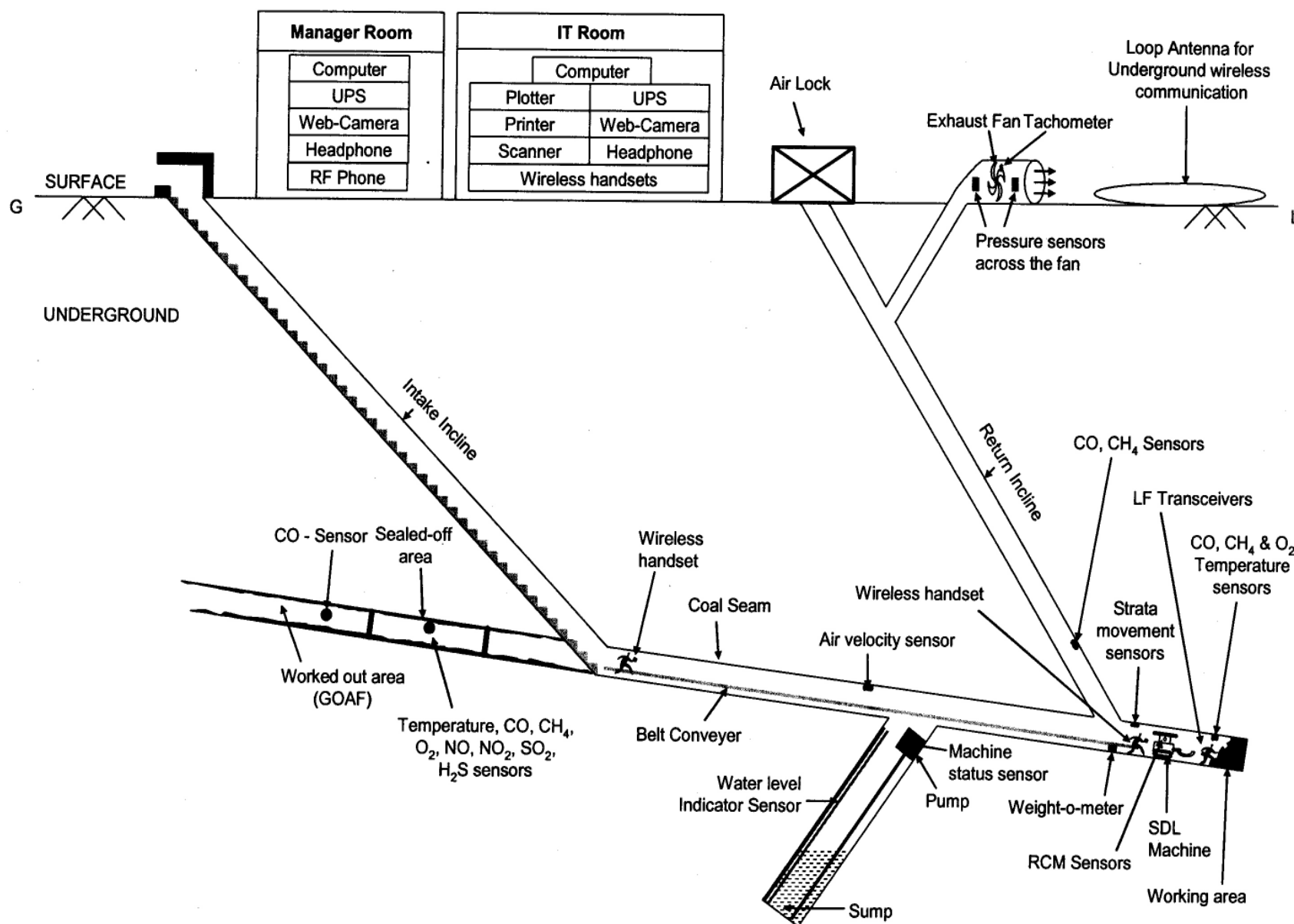
Fig. 2–Schematic diagram of a mine showing location of sensors and other accessories

mining conditions. With the development and implementation of proposed web based information and decision support system, Indian coal mining industry will become technologically sound, economically viable, profitable and safer.

References

1 Das S K, Application of information technology in the mining industry, in *Proc Third Conf on Computer Application in Mineral Industry*, edited by C Bandyopadhyay & P R Sheorey (Oxford & IBH Publisher, New Delhi) 2001, 35-48.

2 Kumar V V & Guha R, Computerisation of Indian mining industry – quo Vadis?, in *Proc Third Conf on Computer Application in Mineral Industry*, edited by C Bandyopadhyay & P R Sheorey (Oxford & IBH Publisher, New Delhi) 2001, 15-22.

3 Sen S K, Current status of mechanization and automation in mineral industry – Indian scenario, in *Proc Int Conf on Mechanization and Automation – The Future of Mineral Industry* (Mining, Geological and Metallurgical Institute of India, Kolkata) 2001, 7-11.

4 Bandyopadhyay L K, Chaulya S K, Dutta M K, Narayan A & Kumar M, Development of an environmental monitoring system for underground coal mines, in *Proc Int Sem on Coal Science and Technology – Emerging Global Dimensions*, edited by A K Singh & K Sen (Allied Publishers, New Delhi) 2005, 629-635.

5 Bandyopadhyay L K, Kumar, S, Mishra, P K, Narayan, A & Sinha, M K, Studies on wireless communication systems for underground coal mines, in *Proc Int Sem on Coal Science and Technology – Emerging Global Dimensions*, edited by A K Singh & K Sen (Allied Publishers, New Delhi) 2005, 56-64.

6 Prasad S B, IT strategy for mineral industry, in *Proc Nat Sem on Information Technology in Mineral Industry, Organized by the Mining* (Geological and Metallurgical Institute of India, Kolkata) 1997, 185-192.

7 Chandramouli V & Singh J K, Application of information technology for sustainable development of mining industry, in *Proc Nat Sem on Role of IT in the Present Scenario of Globalisation*, edited by J K Singh, R Lolarak, V K Kalyani & L Kumar (Central Mining Research Institute, Dhanbad and Computer Society of India, Dhanbad) 2003, 295-304.