CHALLENGES AND NEED OF TRANS-DISCIPLINARY RESEARCH FOR TECHNOLOGICAL INNOVATIONS IN COAL MINING – A LOOK FORWARD

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PREAMBLE

This keynote is aimed at creating awareness among mining community on the impetus of trans-disciplinary research and latest technological innovations applicable for mining industries. Latest Exploration and Survey techniques utilising GIS, light weight laser scanning systems etc including radar applications may be considered. Automation in underground mining machinery and innovations in heavy earth moving machinery for large scale open cast mining are also appears to be worthy of wide utilisation along with latest Information and Communication Technology (ICT) for mining as a drop in ocean of attempts for make in India concept a reality.

The mining industry is confronted with a number of well-known systemic challenges, including limited availability of qualified labour, remote and difficult work environments and the unending need to improve yields and reduce costs to meet competitive challenges in an industry where there is limited pricing differentiation. Mining companies has to understand their perspective on future industry trends and their expectations for autonomous equipment. Three areas in which autonomy could provide the most value were in improving overall mine performance, increasing safety and reducing the aggregate labour requirements. The mining industry typically operates in a cyclic fashion with periods of strong growth followed by inevitable downturns. The industry is currently in the throes of a downturn. In India, coal is the most important energy resource as also the main contributor to the basket of commercial energy of the country. India is the third largest coal producer in the world after China and USA. The biggest reserves of coal are in the USA, Russia, China and India. Suitable technologies suing expert systems are urgently required to techno-economically mine reserves in widely varying geo-mining conditions of 301.56 Billion tons of geological resources of Indian coal.

Associated with production of coal, mining industry also is a part of indirectly producing about 20 % of Coal as by-product of Thermal Power stations (about 0.67 Kg of coal for generating one unit –KWh of electric power). However, its utilization is nearly 50% of the production (2009-10), which is very less in comparison to the major fly ash producing countries like China, U.S.A. and Germany. Future generation of about 1000 MT of fly ash need to be properly utilised as a resource rather than waste material under the guidance of Centre for Fly Ash and research management CFARM Scheme of Government of India [2] (Table 1).

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Table 1: Generation and Utilisation of Fly Ash in India

Year	FA Generation (Million Tonne)	FA Utilization (Million Tonne)
1994	40	1
2008	160	80
2011-2012	220	110
2031-2032	1000	--

1. WHAT ARE ISSUES AND CHALLENGES OF MINNG?

Timely application of innovative practices in various aspects of mining; exploration, surveying, opencast and undrgorudn technologies are urgently required to improve productivity, getting more out of existing people, equipment and infrastructure. As owner-operators continue to slash Crores of Rupees of spending, shed jobs, divest underperforming mines, cut back on capital projects, and attempt to reign in wages, many

have begun to focus on long-term optimisation of operating costs and capital allocation as sustainable measures for mining industry with the recent set back of DE-allocation of coal blocks.

The Indian mining sector has been a success story in waiting for decades. Despite enjoying an endowment of the top 5 or 6 reserves globally across commodities such as thermal coal and iron ore, the mining industry has remained relatively small and stagnant. In fact over the last decade, the contribution of mining to India's GDP has fallen from 1.2 per cent to 1 per cent. If properly tapped, the mining industry could help propel growth for the country over the next decade. In fact, the performance of mining sector will be an important factor for India to achieve 7 per cent plus GDP growth. The mining industry has the potential to create 6 million additional total jobs by 2025, accounting for 12 per cent of the new non-farm job gap. At the same time, the mining industry could contribute an additional USD 125 billion to India's output and USD 47 billion to India's GDP by 2025. For this to happen, complete ecosystem centre, state and mining industry should work together to unlock India's potential in mining. Some of our issues of mining to be considered to keep pace with the present demand of minerals in India, with specific reference to coal mining are enumerated below:

1.1 Accident Statistics

Accident statistics since 1900 as shown in Fig 1 indicates drastically decreasing trend of fatalities since nationalisation of companies in 1970s (DGMS, 2015). However, there was no ostensible change in the trend over five decades signifying importance of new look and trans-disciplinary research to minimise the accidents in mines due to various reaons deleibereate din many conferences including National safety conferences conducted from time to time.

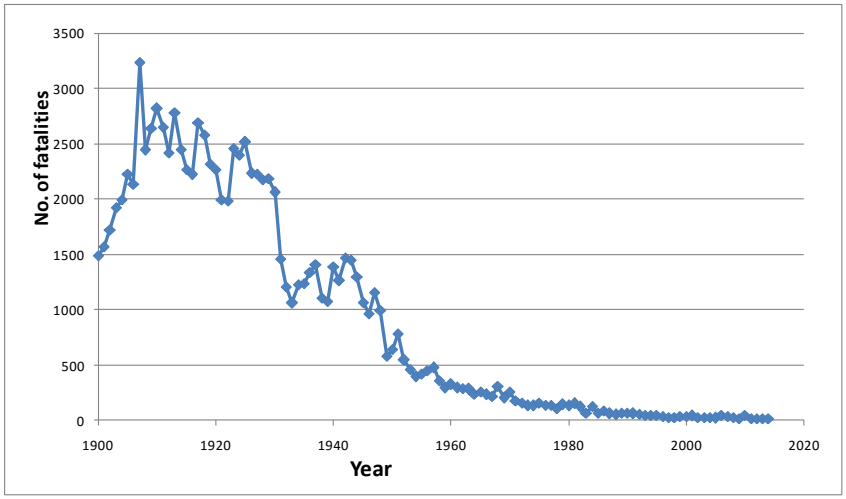

Fig 1 : Fatal accidents during years -1900 to 2014 in mines (DGMS, 2015)

1.2 Mine Resources That Are Difficult To Access

Deep seated resources (e.g., coal) or minerals located in eco-sensitive areas have not been consideredfor mining due to lack advanced and eco-sensitive technology. As an example, the Jharia coal block, which has large coking coal resources that can help meet steel industry coking coal demand, is un-utilized due to the ongoing fire. These resources can be accessed using advance underground mining technology and new mining techniques.

1.3 Power Quality Improvements In Mining

Deployment of large number of AC machinery and low cost variable speed drives in mines lead to poor power factor and in some cases severe harmonic current distortion. Some installations experience nuisance tripping of protection relays caused by harmonic currents, poor power factor (typically after upgrading motor drives and equipment). Networks can be overloaded due to harmonics (often undetected by

traditional 50 Hz analyses) and phase imbalances. Power utilities have already started penalising customers in an attempt to force a "voluntary" move in the right direction. Initiatives toward power quality compliance directly improve production capacity.

1.3. Low Investment In Exploration

The exploration of new minerals, particularly deep seated strategic minerals, the development of new technology, and the implementation of the best mining practices are critically neglected areas in the country's mining policy and investment budget.

1.4. The legacy of abandoned mines:

The number of abandoned mines, or mines without proper closure, is perilously high in India. Over the past decade, efforts have been made to strengthen regulations on mine rehabilitation and closure but the situation on the ground is still far from satisfactory.

2. RECENT INNOVATIONS AND POSSIBLE APPLICATION TO MINING INDUSTRY

With due credit to the recent advances in Electronics, computer science, electrical systems, communication and information technologies etc, it is the right time to initiate trans-disciplinary research activities in accelerated phase for harvesting the benefits of its utilisation for improvement of production levels, productivity, safety and conservation minerals. Some of the innovations in wireless systems, radar, IOT applications, real time slope stability monitoring through WSN General applications in mines, exploration technology, surface and underground mining technology are discussed below:

2.1 GENERAL APPLICATIONS TO MINING INDUSTRIES

Many innovations in other branches of engineering are worthy of immediate application to mining industry, in general, including office automation, security etc.

2.1.1 Wireless Systems

An advantage of using wireless systems and the Internet-based approach is that mines can remotely monitor their communications links and other systems within the mine. Some equipment vendors and third-party providers already offer services to monitor the systems, thus eliminating the burden of the mine operations personnel of monitoring and troubleshooting the networks. Because mining communications systems are for day-to-day routine use as well as for emergencies, when an emergency occurs, it is essential that a protocol exists to ensure that the dispatcher in the mine operations center immediately recognizes when the nature of the communication is an emergency. An emergency communication generally includes audio alarms for voice communications systems or visual alarms that display on the screen for text systems.

Video Surveillance over a wireless network provides a highly flexible way of monitoring outdoor areas such as campuses, parking areas, construction sites and industrial plants. Mobile broadband access allows in-field monitoring and distribution of live and record-ed video to mobile users. A metro-scale 802.11 wireless network can be deployed faster and can be setup tactically and then moved, with reduced deployment complexity and cost than alternatives. Key benefits of industrial video surveillance over an 802.11 wireless network. Resource multiplier: Provides extra 24x7 virtual eyes in the locations they are needed. Enables simultaneous centralized monitoring and recording of multiple areas and sites with minimum personnel. Mobile security patrols can monitor entire campus areas from one vehicle. Unattended security: Protection of critical equipment during downtime – collects evidence and acts as a theft deterrent. Improved operational communications: In-vehicle or man-carried cameras allow qualified, off-site personnel to see exactly what is going on, improving decision making and reaction times. Video monitoring of critical operations monitors compliance with safety procedures. Video recording provides visual evidence of accidents, improving operational procedures and reducing fraudulent claims. Improved

Remote monitoring of operating equipment or processes augments industrial instrumentation and provides an im-portant visual cross-check of operations in real-time.

2.1.2 Video Surveillance

Video surveillance helps reduce street crime and creates an environment where people of all ages can work and play in safety and security. Freed from the need for and cost of wired infrastructure, wireless broadband networks let you quickly and cost-effectively deploy CCTV cameras in commercial areas, transportation hubs (2), schools, sports stadiums and more. Wireless networks with video surveillance can also support Intelligent Traffic Systems (ITS), enabling cities to deploy bi-directional streaming, with upstream feeds from cameras to control centers and re-streamed to first responders and to traffic websites accessed by commuters.

2.2 EXPLORATION TECHNOLOGY

Recent innovations include geoscientific database for mineral prognostication in India. The geological Survey of India has built up a national geoscience database inthe form of 1:50,000/1:63,360 scale geological maps covering the entire country, using ground survey, aerial photographs and satellite imageries. In addition to the existing facility of aero geophysical survey by fixed wing aircraft for a faster coverage, procuring new set of equipment's and helicopter will strengthen the continuing program of multi-sensor aerial survey. [3]As more and more exploration data is collected, digitized, and stored, explorers are establishing a stronger focus on understanding the information for making it more easily accessible and preserving as digital data base it for future exploration.

INNOVATION comes in many forms. One such innovation embraced by industry is the adoption of digital data, including data-enabled equipment, operating/safety/ environmental sensors, and the growing acceptance of the use of laser scanning or point-cloud data. Digital data will increasingly be used to support real-time tracking, surveillance, traffic management, environmental monitoring, various automated routines (e.g. driverless trucks), improved maintenance and asset management, and production monitoring and reporting.

As data from these various sources becomes readily available to the broader enterprise, the mining industry needs to better leverage this digital data to target specific productivity challenges. This ability to successfully leverage digital data across an enterprise is often described as "information mobility. "Information mobility is a key to unlocking value across the entire lifecycle and without it, data languishes in 'islands' where it becomes stale and obsolete. As the mining industry transitions into this era of digital data and information mobility, there is growing recognition of the scale of digital data being created and the need to better manage, maintain, and disseminate this information across the entire enterprise to ensure the right information reaches the right people at the right time.

2.3 MINE SURVEYING TECHNOLOGY

A mining operation needs to design and develop the necessary infrastructure prior to its operation. However, unlike many other infrastructure projects, once a mine site becomes operational the process of design, develop, and extract becomes an integrated and continuous loop, with this cycle remaining for the life of mine (LOM) which is often measured in years, if not decades. This continual cycle becomes the focal point of a mine's operation, with particular emphasis directed towards the results achieved throughout the extract phase.

Due to the innovations in survey technologies, traditional and historical surveying workflows are continuously being challenged. However, unlike other surveying disciplines, some aspects of mine surveying deal with unique circumstances. This is especially evident for underground operations, where surveying methods and techniques need to overcome the challenges of this environment. For this reason, traditional and historical survey workflows (i.e. tape and offset surveys) are still evident within industry today; however, there is an industry desire and need to promote innovative techniques to survey the

underground environment. Over the past 50 years, the survey industry has undergone massive changes due to technology advancements, including the introduction of electronic distance meters (EDMs), total stations, global navigation satellite systems (GNSS), and robotic total stations [6]. Today, point-cloud creation technologies are challenging those traditional mine surveying workflows, with surveyors now looking at solutions capable of quickly producing accurate point-cloud data of the mine's in-progress state. Technologies such as unmanned aerial vehicles (UAV) combined with photogrammetric processes are now used to create point-cloud data quickly, effectively, and safely.

More recently, advanced MLS techniques have been adopted for underground mining environments. Leveraging a simultaneous localisation and mapping (SLAM) technique that consists of a spinning 2D LiDAR unit and an industrial-grade mounted inertial measurement unit (IMU), the acquired scan data is processed through a series of steps to produce a dense and accurate geo-referenced 3D point cloud that can be collected quickly and efficiently, without disrupting mining operations. An extension of this SLAM technique has recently been successfully completed in South Africa using a handheld version of the vehicle-mounted SLAM technology. Regardless of the survey technology adopted, mine surveying still remains the technique and science of accurately determining the 3D spatial location of points and or features on or below the Earth's surface.

2.4 OPENCAST MINING TECHNOLOGY

Surface mining is the main pillar for meeting the rising demand of metals and minerals as the total production of limestone, dolomite, bauxite, and iron ore and lignite is to come from these mines for ever while nearly 90% of total coal production. With rising demand of the coal, estimated to cross 1000 million tons by 2024, this share is going to cross 95% limit and the working depth is going to cross 300 m and the mine size for the mission will cross on average 5 million tons per mine. Fig 2 shows backfilling wit*h* ***Fly ash in a typical opencast mine where scientific investigations were done for the first time in India*** on filed experimental trial of admixture of 25% of the fly ash with Overburden material. Heavy mechanization of the surface mining is therefore going to be the panacea of the mining sector [7].

There is need to amalgamate the latest IT modules in these machines, improve their efficiency, safety and economy in operation and maintenance. The conveyor system is found to be most economical in material transport in coal mines and needs perfection in fabrication, operational and energy efficiency. In addition, the machinery/ package demand will rise in coal mining sector during and be sustained over the next 50 years are In pit crusher conveyor package, Surface miner. Conveyor package, Dragline and auxiliary machines, High wall miner /conveyor package etc. Biggest causality with the surface mining is the land, environment, hydraulic regime and green cover, the basic need of the life to survive. The land of interim use for mining is the lifeline for the posterity, and the society realizing this fact has started resisting the mining so necessary for their own development. All effort should be made to make the surface mining eco-friendly , ensuring restoration of the land to the stake holders after it is of no use to the industry – forest land for forestation, agricultural land to the farmers for cultivation, dwelling land for the settlement of the displaced persons rather than making it water land for ever. These are possible only by clubbing these objectives to the mining practice, and undertake concurrent backfilling, reclamation and restoration to its prime stage. The in pit crusher – conveyor transport system should be hooked with the spreader like the one adopted with the bucket wheel excavator to reclaim the land for common use. Remote Control of equipment, Fleet management, Process management, and Proximity Detection are some of the areas requiring more research in application to the field conditions in opencast mines.

2.4.1 Truck Dispatch System

Material transportation is one of the most important aspects of open-pit mine operations. The problem usually involves a truck dispatching system in which decisions on truck assignments and destinations are taken in real-time. Due to its significance, several decision systems for this problem have been developed in the last few years, improving productivity and reducing operating costs. According to the literature, material transportation represents 50 per cent of the operating costs for an open pit mine. Dynamic allocation of mining equipment (dumpers, shovels, etc.), thus minimizing the cycle time for open pit mine operations and improving mine productivity. Efficient queue management and monitoring of mobile

assets. Effective visualization throughout the operational boundaries within a mine. Trucks are used to haul overburden and ore from the pit to a dump site, stockpile or to the next stage of a mining process. Their use is scheduled in conjunction with other machinery, such as excavators, loaders and diggers, according to the site layout and production capacity. Monitoring of critical parameters of HEMMS and auxiliary equipment's for CBM and safety. Ability to integrate with mine surveys, mine planning and enterprise applications and can be configured with open standard hardware and software platforms such as Microsoft Windows or Linux. Monitoring of the performance of draglines with respect to the swing angle, overload, etc. to maximize operating efficiency.

2.4.2 The Proximity Detection System

The mine installed a Radio Frequency Identification (RFID) system to track vehicle movement. A RFID is commonly used for tracking objects such as cars on toll roads, public transport patrons and library books. RFID systems involve 'tags' which send out a vehicle identification (ID) in the form of electromagnetic waves that are interpreted by 'readers' showing the presence of an object. The system was primarily installed at the mine to improve the monitoring of production. However, there was an opportunity to add a proximity warning system to, hopefully, reduce the risk of collision between vehicles. 'Tags' were mounted on all vehicles. 'Readers' were mounted on heavy vehicles with large blind spots; haul trucks and the loaders. A visual display is provided to the drivers via a touch screen tablet computer. This is mounted on the right of the driver for both haul trucks and loaders. The system detects the presence of any vehicles in range, not just those that are determined dangerous or require action. The driver must still interpret the necessary course of action. The screen shows a text list of the vehicles currently being detected. Part of the text indicates the type of vehicle. A sound of alterable volume occurs on detection and the line with the vehicle ID flashes. Both continue until the screen is physically touched. When the vehicle is no longer detected, it is removed from the screen, regardless of whether the driver has acknowledged its presence by touching the screen.

2.4.3 Energy Analysis Of Truck Operations

There are several data sources that can be used as inputs to an energy efficiency analysis of haul trucks. Mining companies typically maintain records of total diesel use across the mining fleet. In some cases the fuel consumption of individual trucks is measured by recording the amount of fuel that is filled into each vehicle, while other operations simply measure total fuel dispensed to the fleet. Fortes cue was able to acquire data for fuel deliveries to each haul truck from their Fuel management system, and those of their con-tractors. Many mining vehicles have onboard data collection capabilities. Fortescue's fleet of Caterpillar 777 trucks used the onboard Vital Information Management System (VIMS) to capture information from sensors and controllers throughout the vehicle, enabling detailed analysis of vehicle performance and engine operating conditions. Fortescue worked closely with Caterpillar to develop a de-tailed understanding of relevant VIMS parameters. For many of the values recorded, it was important to understand how the VIMS system determined when each mode of the payload cycle started and stopped. In addition to the quantitative data available from fuel and vehicle systems, Fortescue found it useful to also gather qualitative information. Many factors affect the energy efficiency of the trucks, such as the diversity of routes; truck utilization patterns (which can increase the complexity of the analysis); historic information on mine development; site production; and other contextual details that enable a more comprehensive understanding of fuel records and truck utilization data.

2.5 UNDERGROUND MINING TECHNOLOGY

Continued strong growth in the global demand for energy, driven by both developed and developing markets, has lead to the coal sector playing a major role in meeting current demand and in raising production to meet annual planned increases. The most important of these markets for coal is the Asian Pacific area with consumption at over 3.3 billion tonnes last year, or over half the world's consumption. China is the most important coal-consuming country by far with its energy sector growing at between 7 to 9% per year. With this booming growth, underground coal owners and operators are looking at ever more productive and powerful equipment. Man riding systems for underground mines are very much required to

cut down the time for reaching to work place and efficiently utilise the equipment. Fig 3 shows the man riding facility at a typical underground mine.

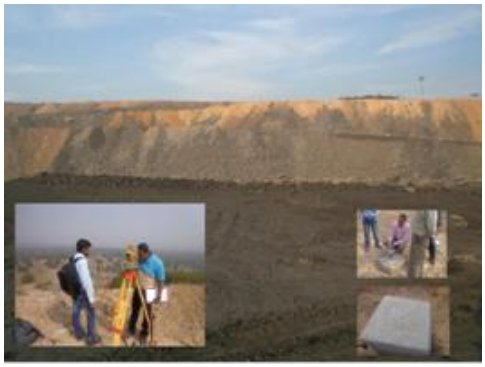

Fig 2: OB dump and Backfilling with Fly ash in a opencast mine

Fig 3: Man riding facility in a typical mine

Particular emphasis is made on the high capacity Chinese, Australian and the US markets where high productivity is coupled with maximising the extraction of coal reserves in both very thick seams and in thin high quality seams where premium prices can be commanded. As a result of this demand for increased production, manufacturers have made significant advances in thin seam and ultra-high seam extraction equipment.

Roof Support Electronicsusing the FACEBOSS electronic control system Integrating the long wall and mine-wide system to enable automatic control of the long wall operation, including fully automatic shearer and roof support gate turn rounds appears to be a better choice for future long wall equipment for better performance.ComPak Valve System for controlling modern automatically operated longwall roof supports and facility for online and continuous monitoring of health of equipment, and stability of workings with appropriate sensors may be explored using Wire Less sensor networks, wherever feasible.

Major portion of this reserve will come from underground mines, to be worked by Long wall method of mining. First requirement for this will be the sinking of deep shafts, may be through backfilled loose burden. The mining will be possible only by fully mechanized long wall package, with high capacity double telescopic power support (600-800 tons) and high shearers. The fast advancing long wall faces will need advanced preparation of the panels that will need 3 heading drivage pattern, possible only by continuous miner conveyor combination with self-advancing bolting machines. It is therefore, necessary that instead of multisource shopping of package of different specifications, the country should select, fabricate and modify the most trusted package with the latest IT modules by the time this stage comes, The present long walling in different pockets may be used to derive conclusive guideline for such in house development . As per the mining condition of India and the past experiences, some of the machine/ equipment which will be the most befitting mechanization for deep working which should be developed at home to meet the future requirement include Sophisticated shield support of 600-1000t capacity for thin to thick seams, Shearer for seams of different thickness and compatible panzer conveyor, Continuous miner shuttle car/ conveyor package, Self advancing bolter etc.

2.6 UNDERGROUND COAL GASIFICATION (UCG) TECHNOLOGY

India has total resources of 301.56 billion tonnes of coal and about 43.22 billion tonnes of lignite resources. The coals in Kaitha and Thesgoda 'C' blocks are at greater than 300m depth with more than 150 MT coal resource. Conventional mining is not suitable for these blocks. To utilize this unmined coal reserve underground coal gasification is one of the most suitable technologies which is economically viable and environmental friendly.

3. ACTION PLAN FOR FUTURE - THRUST AREAS

Considering some of the above emerging areas of trans-disciplinary research, many governmental and non-governmental organisations indentified thrust areas to make a quantum jump towards sustainability in mining activities. Following are the thrust areas identified for further research by interested institutions for industry oriented projects with special reference to Indian mines:

a. Minimum safe barrier for recovery of coal in fire area with special reference to Rajapur OCP, BCCL
b. Extraction of locked standing pillars below surface structures
c. Underground Stowing using crushed OB
d. Extraction of coal seam having less than 3m parting with special reference to Behraband U/G mine, SECL
e. Standardization of safe barrier between river/nalla and opencast workings from inundation point of view
f. Dry fill technology in SECL mines
g. Slope stability of Dumps and Benches in opencast mine workings in steep seams
h. Effect of underground fires on surface features and mining of thick seams under shallow cover with special reference to Chirimiri coalfield, SECL
i. Dust suppression techniques using mist in combination with suitable chemicals
j. Development of Drill bits suitable for the different formation of strata
k. Blending of coking coal with the coal having slightly more than 35% of ash content for use in metallurgical industry
l. Removal of fluoride in drinking water by using cost effective treatment methodologies
m. Determination of impact of different cations present in pyrite band causing AMD, on treatment methodology of AMD
n. Determination of Emission factor for coal mines under Indian environment conditions for air modelling
o. Cost effective modifications in exiting sedimentation tank design to enhance efficiency for treatment of coal mine water discharge
p. Extraction Technology For Thick Coal Seams
q. Mining Methods for Extraction of Thick and Steep Coal Seams
r. Water Jet Cutting Technology for Coal Seams on Fire
s. Long wall Mining with Stowing
t. Hard Roof Management
u. Warning Device to Indicate Impending Roof Failure
v. Development of Portable Drilling Machine
w. Biological Debris Detection of Buried Body under Overburden Dumps

4. A LOOK FORWARD

With the above note, summarily i look forward for the cross fertilisation of ideas and information sharing among the participants of the National seminar on “recent practices and innovations in mning industry, with specific reference to the following:

a. The recent Information and Communication systems (ICT) along with WSN systems for all aspects of mining industry can be widely implemented in opencast and underground mines for reliable monitoring of stability of workings and location of men and machinery in conjunction with audio-visual alarming systems for warning of impending ground failures in right time for taking proper control measures as per the requirement.

b. coal mining sector will need heavy mechanization; giant size shovel dumpers, draglines, in pit crushers surface miners and High wall miners for different situations and along with ancillary equipments like spreaders, reclaimers etc . There is need for the mining industry to come out of the cell, invite engineers and technologists of different allied streams for the joint effort to cope up to the demand. But before that, the mining engineers have to have clear perception, dedication and commitment to customize the options and inculcate confidence in the manufacturing units to come forward for the investment and resources to make in India mission a success.

c. For the underground mining, modern high capacity power support, panzer conveyor and shearer suitable for high to moderately thick and thin seam will be required in large number in days to come. The Industry on date is depending upon the foreign sources for most these machines/ equipments while the nation has capability to develop them at own.
d. Underground coal gasification should be widely practiced with due regard to identification of proper blocks unsuitable for mining but most suitable for UCG.
e. Wireless technology enables continuous online planning and real time monitoring of the geological and production activities throughout the operation. Wireless communications can significantly enhance the efficiency, productivity, safety with increased automation of mining operations, Lower maintenance costs with improved condition-based monitoring , Lower labor costs with the reduction in repetitive tasks with automation etc..
f. Joint effort of the engineers and the technologists is highly solicited to put in their expertise in deciding the package characteristic most likely suitable for deep seated coal seams under hard roof formation. Once, the decision is finalized, the MAKE IN INDIA exercise should start with the cooperation of different R&D agencies and the manufacturing units in translating the technology.

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