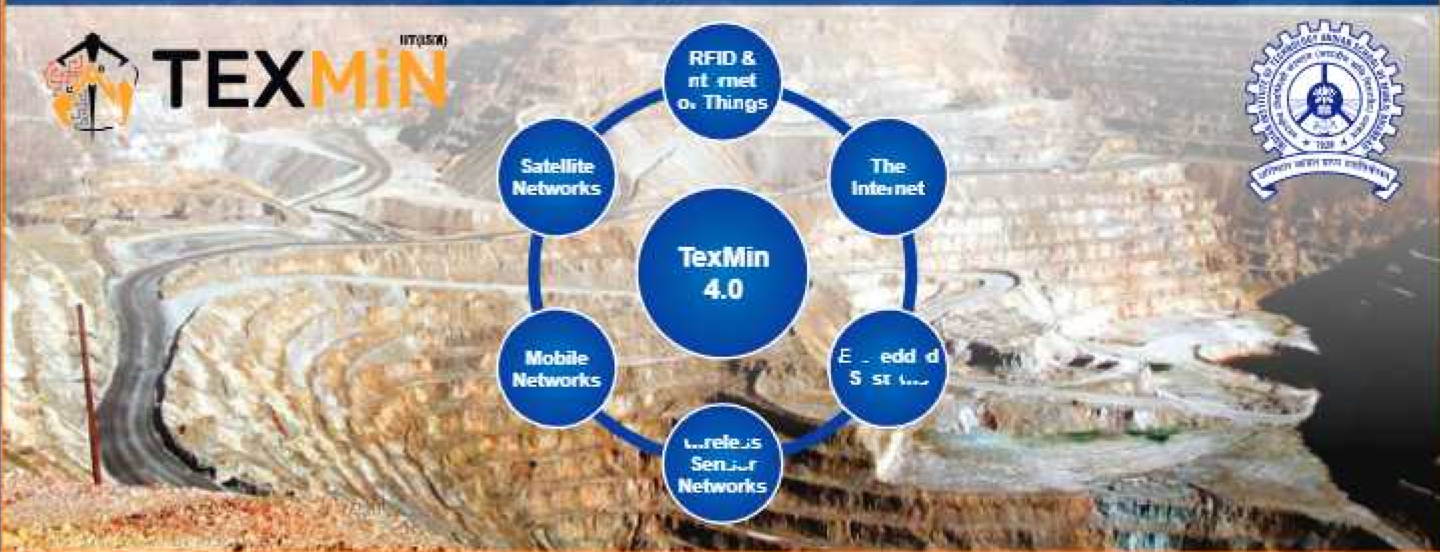
भारतीय प्रौद्योगिकी संस्थान (भारतीय खनि विद्यापीठ), धनबाद



DETAILED PROJECT REPORT (DPR)

Technology Innovation Hub in Exploration & Mining (TEXMiN)
National Mission on Interdisciplinary Cyber - Physical Systems (NM-ICPS)

Indian Institute of Technology (Indian School of Mines), Dhanbad
Dhanbad - 826004 (Jharkhand)

The present Detailed Project Report (DPR) is prepared for establishing the Technology Innovation Hub (TIH) in Mining Vertical under the framework of NM-ICPS, Department of Science & Technology, Govt. of India. The DPR contains several published information taken from the vision documents, annual reports, policy documents, white papers, recommendations, reports, online magazines, journals, mine portals and other literatures available online. The reference section contains a list of all such references. There might have been a few omissions. We sincerely acknowledge the contributions of all stakeholders, global consulting companies such as MoC, MoM, MoES, MoEF & CC, MoLE, MHRD, Coal India, GSI, DGMS, MECL, IBM, NMDC, Vedanta, Reliance, Adani, PwC, Deloitte, EY, KPMG, McKinsey, Accenture, Dassault, Sandvik, FIMI, CII, FICCI, FIMI, SCMS, IISD, IGF and other firms, multi-national professional servicing firms, publishing houses, mining consultants, policy and decision makers, regulatory bodies, print and electronic media, NGO etc. in presenting their views and concerns in shaping mining & mineral sectors for next generation. The feedbacks from stakeholders, published articles, policy documents, white papers, review papers etc. have been quite valuable in formulating aims, objectives, scopes, problem statements and deliverables of TIH in Mining Vertical under this DPR.

We are highly grateful to the empowered Committee and DST for considering Mining as one of the important verticals for implementation of CPS technologies and selecting IIT (ISM) for establishing the NM-ICPS mandated TIH in Mining Vertical. We are also grateful to various Ministries of Govt. of India and Departments for their visionary policy framing in getting the CPS implemented in Mining Industry at large leading towards USD 5 trillion economy.

Prof. Dheeraj Kumar
Dean (IIE) & Prof. In-charge
(Mine Surveying & Geomatics)

भारतीय प्रौद्योगिकी संस्थान (भारतीय खनि विद्यापीठ), धनबाद
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खनन अभियांत्रिकी विभाग । Department of Mining Engineering

CERTIFICATE

Name of the TIH: Technology Innovation in Exploration and Mining Foundation

Technology Vertical: Technologies for Mining

1. This is to certify that the Detailed Project Report (DPR) on the Technology Vertical Technologies for Mining is prepared and submitted to Mission Office, NM-ICPS, DST is as part of implementation of Technology Innovation Hub (TIH) at Indian Institute of Technology (Indian School of Mines) Dhanbad, Jharkhand - 826004 under National Mission on Interdisciplinary Cyber-Physical System (NM-ICPS).
2. This is to certify that this DPR has been checked for plagiarism and the contents are original and not copied/taken from any one or from any other sources. If some content was taken from certain sources, it is duly acknowledged and referenced accordingly.
3. The DPR will be implemented as per the Terms, Reference and Clauses stated in Tripartite Agreement signed on December 10, 2020 between Mission Office, DST, Indian Institute of Technology (Indian School of Mines), Dhanbad and Technology Innovation in Exploration & Mining Foundation .

Date: 26.09.2021

Place: Dhanbad

Technology Innovation in Exploration & Mining Foundation Dhanbad

(Dheeraj Kumar)
Project Director

प्रो. राजीव शेखर
निदेशक
Prof. Rajiv Shekhar
Director

भारतीय प्रौद्योगिकी संस्थान (भारतीय खनि विद्यापीठ), धनबाद
धनबाद–826004, झारखण्ड, भारत
Indian Institute of Technology (Indian School of Mines), Dhanbad
Dhanbad-826004, Jharkhand, India

Endorsement from the Head of the Institution

1. Certified that the Institute welcomes participation of Prof. Dheeraj Kumar as the Project Director for the Technology Innovation Hub (TIH) and that in the unforeseen event of discontinuance by the Project Director, the Indian Institute of technology (Indian School fo Mines), Dhanbad will identify and place a suitable faculty as Project Director for fruitful completion of the TIH activities.

2. Certified that the Host Institute shall provide basic facilities, faculty support and such other administrative facilities as per Terms and Conditions of the award of TIH, will be extended to TIH.

3. As per Tri-partite Agreement, the Host Institute (HI) shall play its role and fulfil its responsibilities for the success of TIH.

Date: 26.09.2021
Place: Dhanbad

(Rajiv Shekhar)

EXECUTIVE SUMMARY

Mining involves a complete life cycle from Exploration through Production to Eco-restoration. The Discovery of mineral resources (**Exploration**) and sustainable exploitation of such mineral resources (**Mining**) are two major economic activities contributing significantly to India's GDP.

Grand Problem 1

India has a mappable area of 3.146 million sq. km. and the Geological Survey of India (GSI) has covered 3.1189 million sq. km. (99.14%) on 1:50,000 scale till March 31, 2018. GSI has identified 0.571 million sq. km. as an Obvious Geological Potential (OGP) area for minerals. A major part of this OGP area is yet to be fully explored. With fast depletion of easily accessible and shallow or near-surface ore bodies and decline in the rate of locating new mineral deposits within shallow depths, **the challenge lies in identifying new areas for locating near-surface deposits and "deep-seated" and "concealed/ hidden" ore bodies through modern and sophisticated exploration methods/ techniques based on conceptual studies**.

Improving resource discovery needs to be tackled by multi fold (a) to be precise with the target for drilling through deposit scale modeling and mineral discrimination, (b) defining a region to be a geologic province, (c) providing a detailed geological map, (d) Rare Earth Elements (REE) and Platinum Group Element (PGE) Exploration, and (e) developing drones and sensors for airborne hyperspectral surveying. There are examples whereby using only 4% data, and the prediction was accurate up to 86% in mineral exploration. Earth AI applied these tools to increase the resolution by 50X.

Grand Problem 2

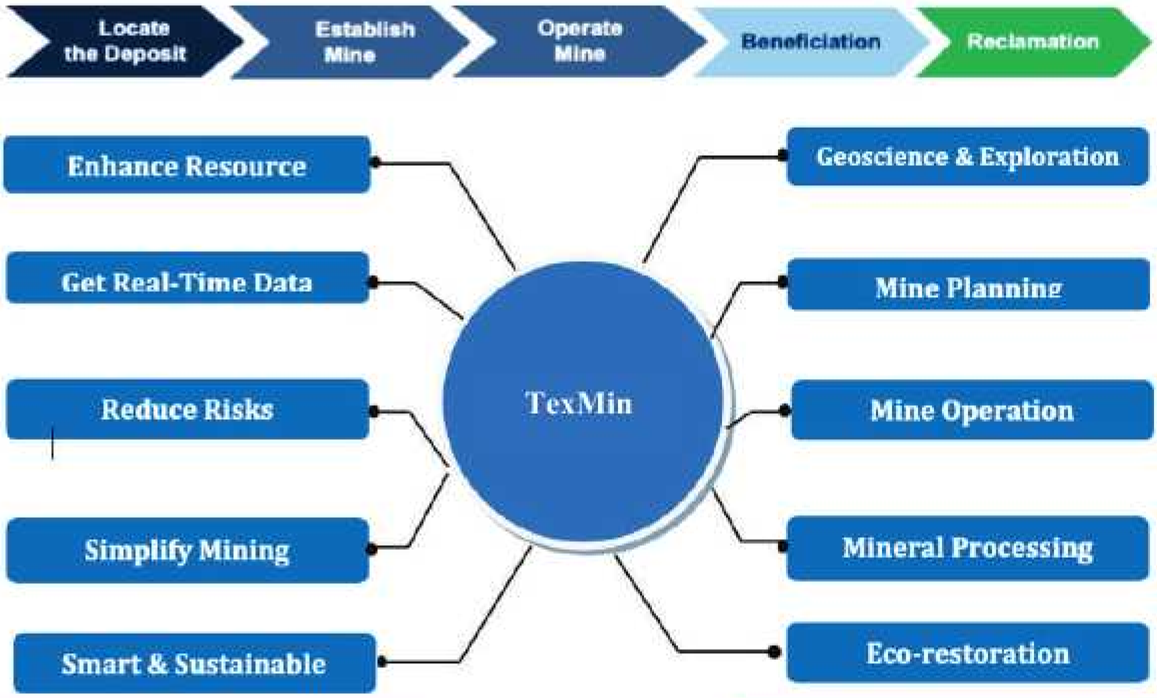
India is heavily dependent on coal-based power for its electricity needs, with Coal's contribution to electricity generation is 70%. Coal continues to be the most significant domestic source of energy supply and electricity generation. Despite having the world's fourth-largest coal reserves, India imported 235 million tonnes of coal at total spending of Rs.1,71,000 crores. **Demand is increasing, and there is a need to bridge the demand-supply gap by adopting frontier technologies**.

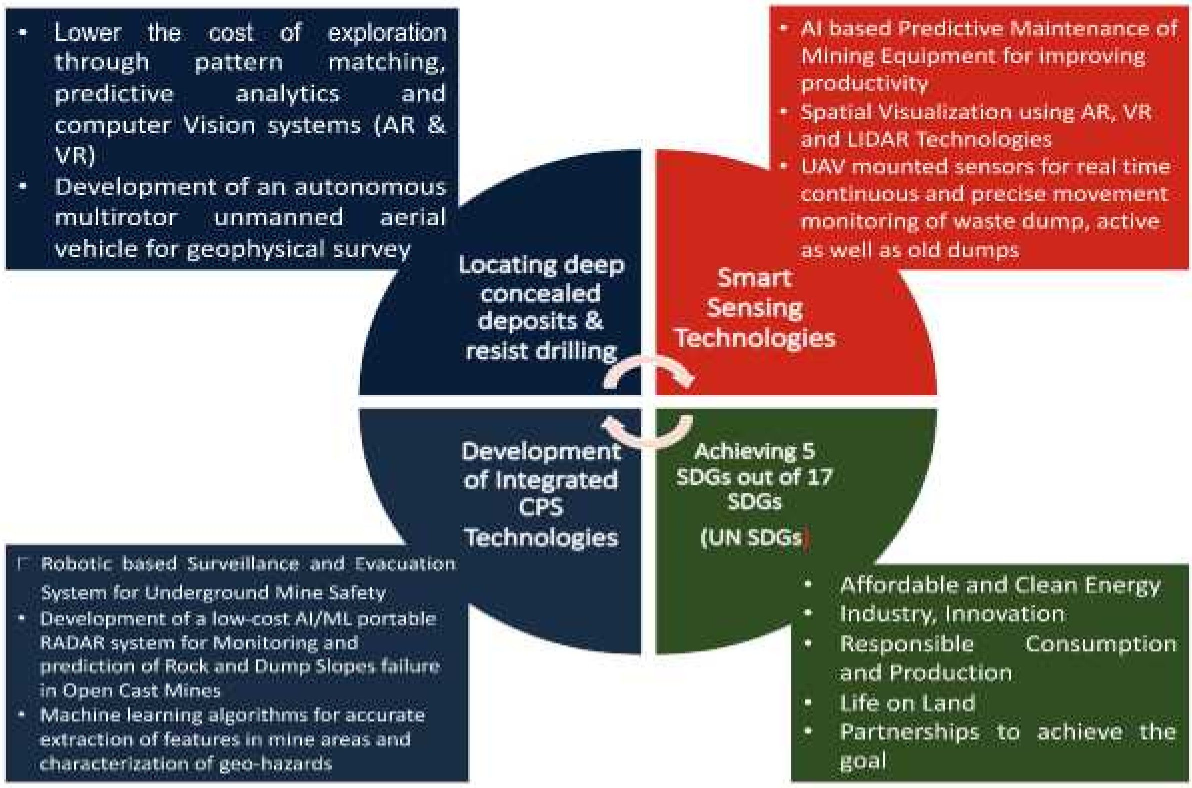
The Future of Mining has to be smarter, faster, safer, and more data-driven than ever. The World Economic Forum foresees a potential to add more than $315 billion of additional value to the mining industry. There is an urgent need to develop CPS-based innovative technologies in the mining industry to bring a step-change in productivity, safety, and sustainability in mining.

IIT (ISM) has been entrusted with establishing a technology innovation hub in the Mining vertical for the development and implementation of CPS base technologies in the Exploration and Exploitation of natural resources under the National Mission for Interdisciplinary Cyber-Physical Systems (NM-ICPS). As mandated under the framework of National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) by DST, Govt. of India, Technology Innovation Hub (TIH) at IIT (ISM) is aimed at becoming the nodal centre heading the CPS based innovation activities in **Exploration and Mining.**

In order to carry out the activities of TIH at IIT (ISM), a section 8 Special Purpose Vehicle (SPV) has been established in the name of Technology Innovation in Exploration & Mining Foundation

[**TexMin**]. The section 8 company is working as an umbrella body to nurture and promote the objectives and activities of the TIH as per the approved DPR within the framework of NM-ICPS, DST, GoI. The problem to be addressed across the mining value (from Exploration to Eco-restoration) and expected deliverables are shown in the charts below:





The total approved budget for the TIH is Rs. 110.00 Crores (Recurring: 78.38, Non-recurring: 31.62). The major academic and industry collaborators, such as C-DAC Kolkata, Coal India Limited, Sandvik, and Dassault Systems, have been consented to contribute significantly to the

TIH. The host institute has allocated 30,000 SQFT areas in a centrally air-conditioned building for the TexMin Foundation.

It is expected that the HUB will fulfil the national priories, namely, Sustainable Development Goal, Industry 4.0, Digital India, Society 5.0, Make in India, and Skill India & Stand-up India. Overall, the Technology Innovation Hub, **TexMin,** is aimed at improving resource discovery, mine productivity & safety, and minimize environmental impacts. **TexMin** Foundation will also significantly contribute to making the country a USD 5 Trillion economy.

Contents

1 INTRODUCTION

1.1 Context and Background

To harness the CPS system's potential and make India a leading player, the Union Cabinet approved the launch of the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) to be implemented by the Department of Science & Technology (DST) with a total outlay of Rs. 3660 Crore for five years. The NM-ICPS is a comprehensive mission addressing technology development, application development, human resource development & skill enhancement, entrepreneurship, and start-up development in CPS and associated technologies.

Cyber-physical systems integrate sensing, computation, control, and networking into physical objects and infrastructure, connecting them to the Internet and each other. CPS and its associated technologies, like Artificial Intelligence (AI), Internet of Things (IoT), Machine Learning (ML), Deep Learning (DP), Big Data Analytics, etc. have pervaded and is playing a transformative role in almost every field of human endeavour in all sectors. SERB, DST invited proposals from reputed Academic and R&D institutions to establish Technology Innovation Hubs (TIH). Within the academic institution, the TIH has been mandated to focus on the domain area of research.

1.1.1 Context

Department of Science and Technology, Government of India, has entrusted the Indian Institute of Technology (Indian School of Mines), Dhanbad, for the establishment of a Mining Technology (**Exploration & Mining**) Innovation Hub under the National Mission for Interdisciplinary Cyber-Physical Systems (NM-ICPS) based on the project proposal submitted to SERB followed by presentation and interaction with the expert committee. As mandated under the framework of NM-ICPS, Technology Innovation Hub (TIH) at IIT (ISM) aims to become the nodal center in heading the innovation activities in mining and allied domains with a financial support Rs. 110 Crores for five years.

With leading-edge knowledge, competency and facilities, the TIH will attract potential and harness expertise available nationwide, thus fostering research innovation, world-class technology, and product development. It shall coordinate across the country and build linkages with research institutes and labs in India and abroad. TIH will work in close collaboration with the mining industry to deliver industrial technology and products and create a vibrant innovation ecosystem by providing a reliable platform for technology-based start-ups and entrepreneurs. TIH at IIT (ISM) is a non-profit Special Purpose Vehicle (SPV) under Section 8 of the Companies Act in the name of Technology Innovation in Exploration & Mining Foundation [TexMin]. The Hub is governed by its Hub Governing Body (HGB) represented by the Host Institute (HI), Academic & Industry Partners, and DST.

1.1.2 Background

The mining process typically begins with finding the deposit (Exploration) and ends at eco-restoration. Mining processes are highly variable and uncertain. Mining operations often take place in extremely dynamic and changing planning and operating conditions resulting in issues related to productivity, increased cost, poor quality control of ore being mined out, and safety of mining operation. Minimizing uncertainty through the mining process through data analytics, reducing the cost, and adapting to change are some of the drivers causing mining companies to look for digital innovations.

In mining, exploration is the foundation of all value creation. It identifies new ore bodies for development, replenishes reserves depleted through production, and replaces those rendered uneconomic by falling commodity prices. Even companies that choose to grow by acquiring ore reserves rely on the exploration success of other companies. But with most of the world's surface mineral deposits already found, we need to be looking deeper to find the next generation of deposits. All the "easy" deposits at the surface have been found and mined out. In other words, the era of easy deposits is over.

As today's mineral explorers seek out increasingly difficult deposits, they are becoming reliant on expensive and invasive deep-drilling and data-heavy surveying; discovering new sources can be notoriously tricky but also very rewarding. The chance of finding an original deposit is around 0.5%, with odds improving to 5% if exploration takes place near a known resource (Goldspot, 2020). Table 1.1 presents an insight into the discovery performance by region.

Table 1.1: Measuring Discovery Performance by Region (2005 to 2014)

Region	Exploration Spend	Estimated Value of Discoveries	Value/Spend ratio
Australia	$13 billion	$13 billion	0.97
Canada	$25 billion	$19 billion	0.77
USA	$10 billion	$5 billion	0.48
Latin America	$33 billion	$19 billion	0.57
Pacific/SE Asia	$8 billion	$4 billion	0.49
Africa	$20 billion	$23 billion	1.19
Western Europe	$4 billion	$2 billion	0.42
Rest of World	$27 billion	$8 billion	0.32
Total	$140 billion	$93 billion	0.67

(Source: MinEx Consulting, March 2015)

On the whole, mineral exploration has not been a winning prospect if you compare the total dollar spend and the actual value of the resulting discoveries. Unless discovery rates increase soon, there could be a lack of resources. Rates of gold discovery and exploration spending have historically been tracked very closely - the more explorers have spent, the more gold they have found. However, during the last ten years, this close relationship between spending and discovery has diverged (Fig. 1.1).

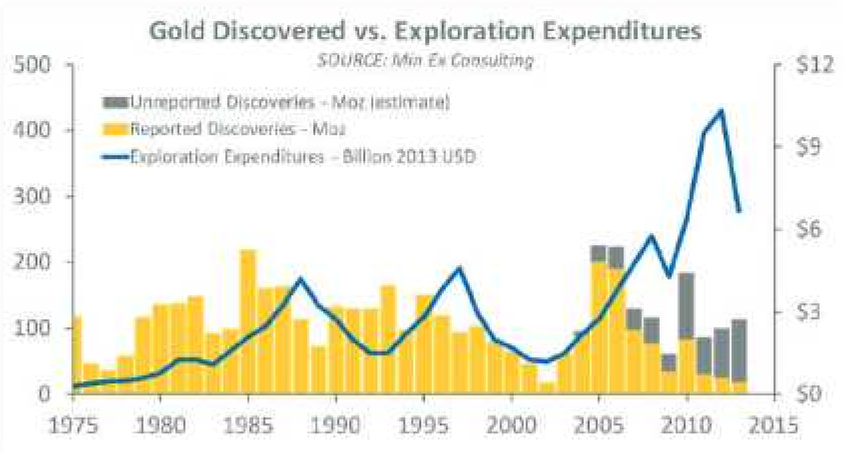


Fig. 1.1: Gold discovery vs. expenditure on exploration

Mining Industry needs a disrupting technology. It is time to treat exploration as a science, not an art (Goldspot, 2020). Machine learning links this 'reason' to available geoscience data to determine the relationship. Understanding this relationship means we can predict the likelihood of mineralization in new exploration areas.

The National Mineral Exploration Policy (2016) mentions that the "...the country is endowed with vast resources of various minerals and has favorable geological settings for many others. However, vast geographical areas are still to be explored to the desired levels. Detailed exploration to understand and uncover this potential is crucial for the growth of the Indian economy. This requires a sound and comprehensive mineral exploration policy/strategy to be implemented in a coordinated, systematic, and consistent manner...". India has a mappable area of 3.146 million sq. Km., and Geological Survey of India (GSI) has covered 3.11908 million sq. km. (99.14%) on 1:50,000 scale till March 31, 2018. GSI has identified 0.571 million sq. Km. as an Obvious Geological Potential (OGP) area for minerals. A major part of this OGP area is yet to be fully explored. With fast depletion of easy pickings – the world's outcropping and shallow or near-surface ore bodies and decline in the rate of locating new mineral deposits within shallow depths, the challenge lies in identifying a new area for locating near-surface deposits and "deep-seated" and "concealed/ hidden" ore bodies through modern and sophisticated exploration methods/ techniques based on conceptual studies.

Successful exploration requires bringing together the best of knowledge and experience, state-of-the-art technology, a highly trained workforce, and enormous financial resources on an open, collaborative, and inter-disciplinary platform.

India has a significant quantity of mineral resources, which the country needs to mine efficiently. India is a leading global producer of many minerals. The country has been ranked as the world's fifth-largest iron ore, second-largest coal, and third-largest chromium producer. Still, the mining industry's contribution to India's GDP was 1.53% in FY2017-18, while the GDP grew by 7%. Compared with other resource-rich nations, India trails significantly in the mining sector's contribution to the economy. In South Africa, mining has a 7.5% share of the GDP. Australia, another major repertoire of bulk minerals, beats India hands down, with mining accounting for 6.99% of its GDP. Even Brazil ranks ahead, with the mining sector's share of GDP at 2.0% in 2017-18. This indicates that the sector has not grown at the rate befitting its potential. The policy emphasizes scientific and efficient exploration and exploitation of mineral resources with due care to the environment and society around.

Throughout history, the mining industry's success has always remained in the evolution of mining technology. Implementing novel systems and adopting improvised equipment in mines help mining companies in two crucial ways: enhanced mine productivity and improved worker safety. Safety is one of the key factors driving the trend to automation. Efficiency is imperative if a mine is to survive, and digitalization can play a significant role. By developing and commercializing automated mining technologies for continuous mining equipment, the productivity of each mining machine improves, and the operators can run the machine from a safe distance, which reduces associated costs for worker exposure, health benefits, and liability. With the advent of new autonomous equipment used in the mine, the inefficiencies are reduced by limiting human inconsistencies and error. The desired increase in productivity at a mine can sometimes be achieved by changing only a few simple variables.

The Future of Mining is more intelligent, faster, safer, and more data-driven than ever. The World Economic Forum has classified mining technologies into four main categories viz., (i) automation, robotics, and operational hardware, (ii) digital-enabled workforce, (iii) integrated enterprise, platforms, and ecosystems, and (iv) next-generation analytics and decision support and. These areas can add more than $315 billion of additional value to the mining industry (Fig. 1.2).

There is an urgent need for transformation in the mining sector. There are several drivers of modernization in the mining sector. The mining companies must increase the efficiency of deposit discovery; strengthen their mineral recovery rates; improve the productivity of their assets; reduce their operational risks; recover metals and minerals of higher quality; and drive their growth.

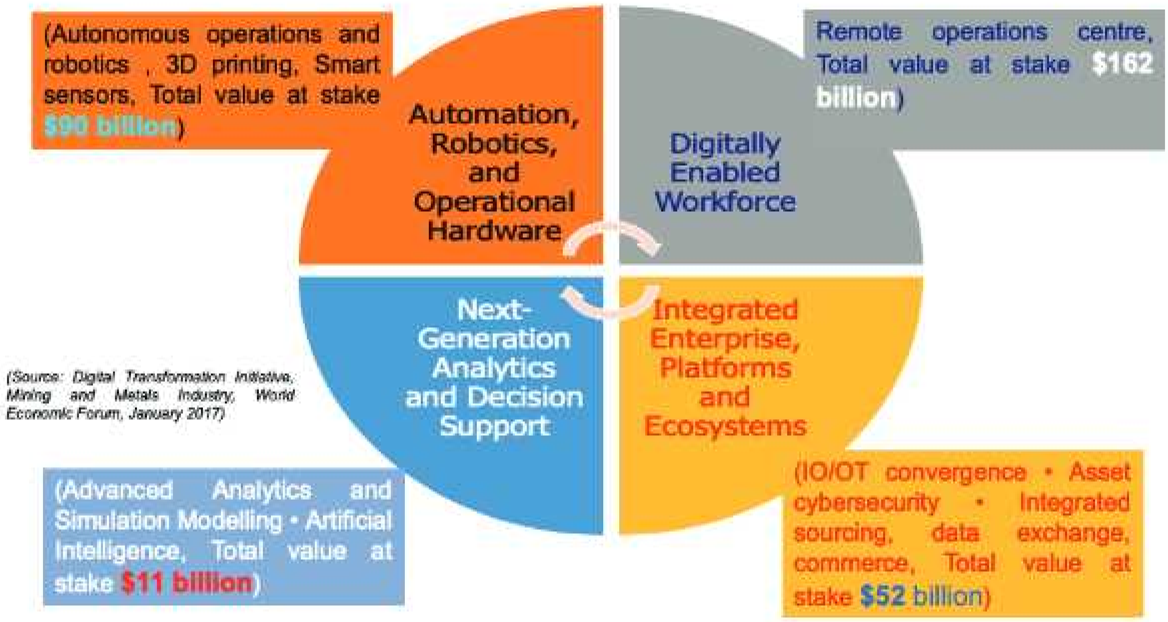


Fig. 1.2: Potential of investments in Innovative Mining Technologies

More than 60% of mining companies view innovation as crucial to their long-term business strategies. A statistic of possible innovation needs is presented in Table 1.2.

Table 1.2: A statistics of possible innovation needs to be envisaged by different companies

Embracing Data, Analytics & AI	Value from Risk & Cost Reduction	Innovation spend is set to increase	Transforming the way we do business
55% of companies are focused on driving innovations in data, precisely innovations in Artificial Intelligence and Analytics	44% of companies view risk reduction as their primary source of innovation. 67% of companies see cost reduction as a critical area technology can create value	Almost half of companies are planning to increase innovation budgets in future years. 76% of companies are looking to lead or be a fast follower of industry innovations	Traditional decision making underscored with data-driven insights is the key to staying relevant and dealing with market pressures

(Source: The State of Play Mining 2019 Survey Data Pack, State of Play, July 2019)

The World Economic Forum (WEF) estimates that autonomous machines will be common place by 2025, and that having these machines operating 24 hours a day, every day, at high levels of productivity and with lower personnel costs, could add USD 56 billion in value to the industry (WEF, 2017). In the same study, WEF estimates that intelligent sensors could create USD 34 billion in value for the mining industry by facilitating predictive maintenance, improving equipment utilization, reducing downtimes and equipment failures, and lowering the frequency of health and safety incidents (WEF, 2017). In India, an average of 0.21 individuals has lost their lives per thousand persons employed during 2011-2018 [DGMS]. Through improved health and safety, Digitization could save an estimated 1,000 lives and avoid 44,000 injuries (WEF, 2017). The mining industry has typically lagged behind other industrial sectors in adopting digital technologies such as AI/ML, sensors, IoT, Block Chain, etc.

Large amounts of data generated across the mining processes need to be captured and leveraged on close to real-time basis to accurately predict the variability in the mining processes to bring consistency in operation. Complex mining tasks such as geological modeling and mine planning, production planning and scheduling, equipment maintenance and spare parts management, and continuous monitoring and capturing of operation data can now be brought under the domain of statistical and optimization algorithms of CPS technologies. IDC's FutureScape 'Worldwide Mining 2018 Predictions' report claims that "companies that prioritize digital transformation at the execution level by 2019 will deliver productivity, efficiency and revenue gains of up to 20%.

There is growing consensus in the Indian mining industry that technology and innovations will bring a step-change in productivity, safety, and sustainability in mining. Results and initial estimates have shown that the use of advanced digital technology solutions in mining processes has resulted in a productivity gain of up to 15 - 20% with enhanced safety and sustainability. The benefits of becoming a 'digital champion' would be significant. A 2018 study by PwC's Global Digital Impact Centre found that companies who achieve digital technology mastery earn higher revenues and lower their costs consistently over time.

The establishment of the Technology Innovation Hub (TIH) for CPS-based Mining Technologies at IIT (ISM) will prove to be a milestone for giving a new direction to the mining industry of India.

1.2 Aims, Objectives, and Scopes

The mining process typically begins with finding the deposit and ends at closing the mines with due care to the environment and society during and post mine operations. TexMin is the need of this hour towards unlocking the mining potential, putting India on the growth path. Implementation of CPS is the key to Exploration and Mining.

1.2.1 Aims

The following are significant aims of the TexMin Hub:

(i) Make India a leading player in CPS technologies in Exploration & Mining.

(ii) Achieve translation of CPS technologies in Exploration & Mining for socio-economic growth and commercial use, nurture start-ups, and increase the job market.

(iii) Produce next-generation technocrats for developing CPS technologies in Exploration & Mining and its implementation to make Indian mines more innovative, safe and sustainable.

1.2.2 Objectives

The objectives of TexMin Hub are as follows:

(i) To develop CPS-based technologies & promote translational research in **Exploration and Mining**.

A. Exploration

a. Identifying new and potentially viable areas to mine: Locating deep concealed deposits and resist drilling

b. Lower the cost of exploration through pattern matching, predictive analytics, and computer Vision systems (AR & VR)

c. Development of an autonomous multirotor unmanned aerial vehicle for geophysical survey

B. Mining

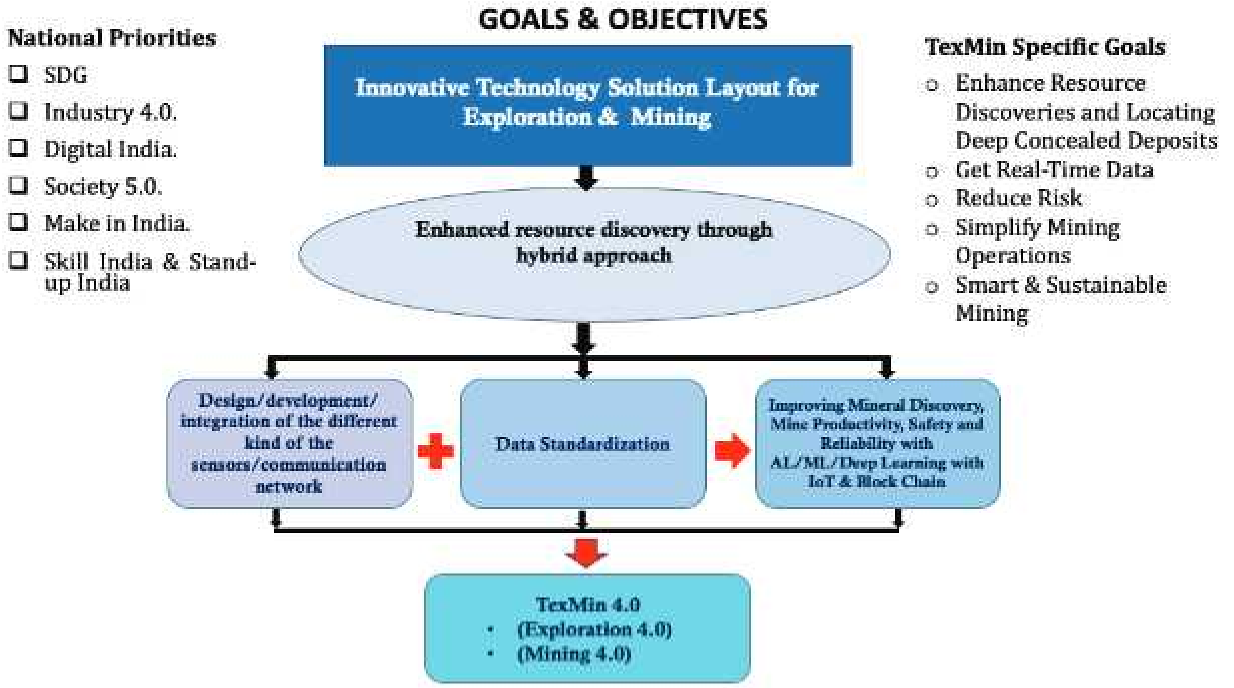
a. Robotic based Surveillance and Evacuation System for Underground Mine Safety

b. Low-cost Integrated monitoring systems to predict and prevent displacements (Dump slope and Subsidence)

c. Machine learning algorithms for accurate extraction of features in mine areas and characterization of geo-hazards

d. Decision Support Systems for significant improvements in equipment productivity and reduced maintenance costs

(ii) To enhance high-end researchers base, Human Resource Development (HRD) and skill-sets in the emerging areas of TexMin.
(iii) To enhance core competencies, capacity building, and training to nurture innovation and start-up ecosystem for TexMin.
(iv) To establish and strengthen the international collaborative research for cross-fertilization of ideas.
(v) To set up a world-class interdisciplinary center of excellence under TIH in Exploration & Mining



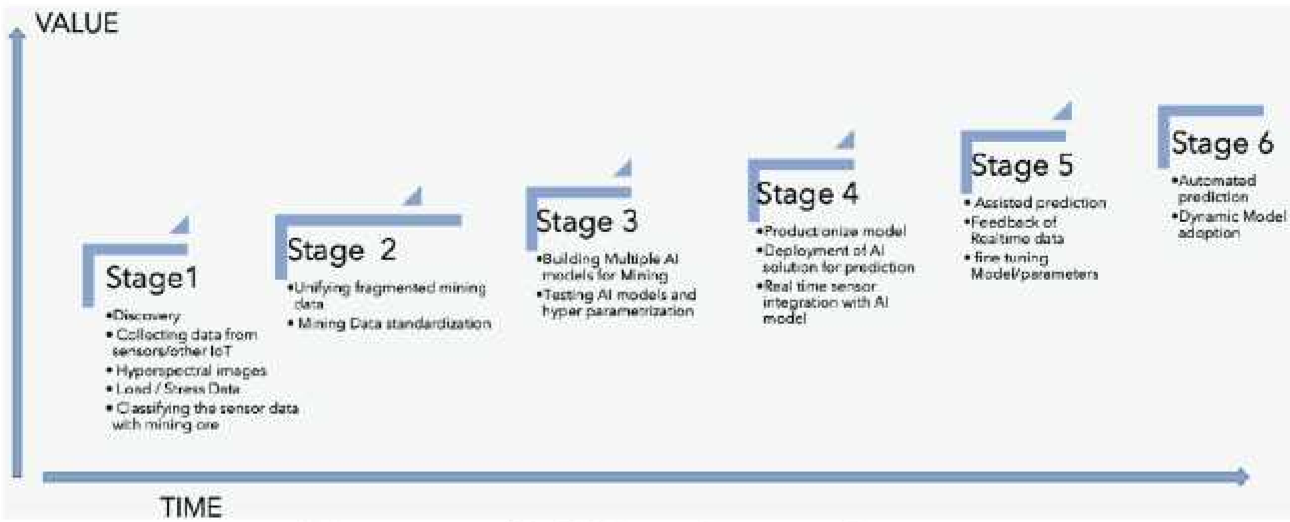


Fig. 1.3 Maturity Model of CPS in Exploration and Mining

The above objectives of TexMin Hub are consistent with the goals of NM-ICPS.

1.2.3 Scope

The scope of TexMin Hub includes the following:

- AI and ML: Use of AI and ML in Discovery of Mineral Resources and decision-making process in mines.
- Augmented Reality: Integrating information from digital systems to the physical workplace. A real-time problem-solving system such that problems and solutions can be shared and visualized in real-time.
- Virtual Reality: Hardware and Software based simulation and training on real-life mining situations such as simulating mine fire, roof failure, dump slope, etc., Operation and maintenance practices for Heavy Earth Moving Machines, etc.
- Smart Sensors and Miner's Tracking Systems: Development of wearable sensors and underground positioning systems (UPS) akin to GPS systems.
- Smart and Intelligent Sensing System: Heavy Earth Moving Machineries (HEMM) Real-time condition monitoring & health prediction to improve Overall Equipment Efficiency (OEE), Intelligent personal assistance system for miners for interfacing with machines, computers/PDAs and other information system. At present RFID based systems are in place for communicating with smartphones and other personal devices for reporting purposes.
- Robotic Miners System: Robotic based systems and their integration for performing hazardous and repetitive operations in mines such as drilling robots, rescue robots, robotic Loading and Hauling machines, Robotic roof bolters and dressers etc.
- Enterprise-based Decision Support Systems: Introduction of a robust underground hybrid communication system (WIFI/TTE/5G) for interaction between the miners in operations and decision-makers with IoT in place.
- Mine Data Analytics: Use of Big Data and other related tools for valuable information discovery and prediction of various unforeseen events in mines such as prediction of roof fall, dump failure, unsafe mine environment, etc.

1.3 Activities

To achieve the stated objectives of TIH and the mandates of NM-ICPS, the following significant programmes (TIH verticals) are proposed to be undertaken:

1. Technology Development

- Generation of new knowledge through basic and applied research in CPS with a specific focus on Mining Domain.
- Expert-driven focused research for specific requirements of the Mining Industry, Government and R&D organizations, and International Collaborative Research Programmes.

2. Centre of Excellence

- Dedicated Centre for Mine Automation and Data Analytics in PPP mode. This center would be a National Facility to carry out domain-specific translational research, training and capacity building, product and prototype development, promoting and implementing technologies in mining sectors, etc.

3. HRD and Skill Development

- Development of highly knowledgeable human resource with top-order skills including Graduate Internships, Postgraduate Fellowships, Doctoral Fellowships, Faculty Fellowships, and, Chair Professorships.
- Skilling workforce of the future with a focus on lower pyramid of skill development aiming towards Mining 4.0.

4. Innovation, Entrepreneurship, and Start-up Ecosystem

- Enhance competencies, capacity building, and training to nurture innovation and start-ups.
- Support young and aspiring entrepreneurs for enabling translation of idea to prototype.
- Inspire the best talents to be entrepreneurs by providing support through fellowship, guidance, and co-working spaces to develop their ideas into products.
- Initial funding assistance for student start-ups.
- Create linkages with TBI at IIT (ISM) under the TIH.

5. International Collaboration

- Leveraging international alliances for carrying out CPS-based research and development activities in the mining domain at par with international standards.
- Connecting Indian research with global efforts in the mine domain.
- Participating in international projects and advanced facilities.

The mining industry's contribution (excluding petroleum and natural gas) to India's GDP is 1.63% (2018-2019), sharply contrasting India's true potential, being a geologically rich country. This is against the backdrop of the fact that eight core sectors of the Indian economy – coal, fertilizer, electricity, steel, and cement – were dependent on mining. A significantly higher contribution to GDP will go a long way in achieving India's dream of becoming a USD 5 trillion economy, as demonstrated across economies like South Africa, where mining contributed 7.5% to GDP and Australia, where it is 6.99% to GDP.

2 TECHNOLOGY OVERVIEW IN THE MINING & EXPLORATION INDUSTRY

India produces as many as ninety-five minerals, including four fuels, ten metallics, twenty-three non-metallic, three atomic, and fifty-five minor minerals (including building stones and other materials). The mining and quarrying sector's contribution (at current price) to Gross Value Added (GVA) accounted for about 2.38% for 2018-19. The Indian mining industry is characterized by a large number of small operational mines. The number of mines which reported mineral production (excluding atomic, fuel, and minor minerals) in India was 1405 in 2018-19. India's ranking in 2016 as compared to world production was 3rd in steel (crude), 4th in chromite, iron ore, aluminium (primary) & zinc (slab), 5th in bauxite, and 6th in manganese ore and copper (refined).

More than 90% of the world's total proved coal reserves are located in just ten countries. The US tops the list holding more than one-fifth of the total proven coal reserves, while China, which ranks third, is the biggest producer and consumer of coal. Mining Technology profiles the ten countries with the most significant coal reserves, based on total proved reserves. India's proven coal reserves as of December 2018 accounted for more than 9% of the world's total. The primary hard coal deposits of the country are located in the eastern states of Jharkhand, Chhattisgarh, Orissa, and West Bengal, which account for more than 70% of the country's coal reserves.

Coal is the most essential and abundant fossil fuel in India. It accounts for 55% of the country's energy needs. The country's industrial heritage was built upon indigenous coal. Indian coal offers a unique eco-friendly fuel source to the domestic energy market for the next century and beyond. Hard coal deposits spread over 27 major coalfields are mainly confined to eastern and south-central parts of the country. The lignite reserves stand at around 36 billion tonnes, of which 90 % occur in the southern State of Tamil Nadu. As a result of exploration carried out up to the maximum depth of 1200m by the GSI, CMPDI, SCCL, and MECL, etc., a cumulative total of 319.02 Billion tonnes of Geological Resources of Coal have so far been estimated in the country as on 1.4.2018.

Overall coal demand is estimated to be 900–1,000 MTPA by 2020 and 1,300–1,900 MTPA by 2030. The demand scenario is influenced by economic growth, energy efficiency, and the emergence of alternate coal uses. By 2030, of the overall coal demand, thermal coal demand is estimated to be 1,150–1,750 MTPA, and the balance is coking coal demand.

The all India Production of coal during APR-MAR 2018-19 were 728.72 MT (Provisional) with positive growth was 7.89%.

The production and growth targets of Fuel, Metallic and Non-Metallic Minerals are listed in Table 4.1.

Coal India Limited (CIL), an organized state-owned coal mining organization incorporated with a modest production of 79 million tons, is the single largest coal producer globally. Operating through 82 mining areas with seven wholly-owned coal-making subsidiaries, CIL crossed the threshold of half a billion tons in 2016, both in coal off-take and production.

Table 2.1: The production and growth target of Fuel, Metallic and Non-Metallic Minerals

Mineral		2012-13	2013-14	2014-15	2015-16	2016-17	2017-18 (P)	2021-22 (P)
Fuel	Coal	556.4	565.77	610.21	639.02	670	700	900
	Lignite (MT)	46.45	44.27	48.29	44.01	44	45.404	55
Metallic	Bauxite (MT)	16.61	22.32	22.49	28.13	25	29.69	38.72
	Chromite (MT)	2.8	2.87	2.16	2.89	3.36	3.15	3.61
	Copper Conc. (MT)	0.12	0.14	0.11	0.14	0.12	0.14	0.14
	Iron ore (MT)	136.62	152.18	129.32	156	190.5	186	231
	Manganese ore (MT)	2.34	2.63	2.37	2.15	2.29	2.8	4.2
	Zinc conc. (MT)	1.49	1.49	1.49	1.47	1.46	1.49	1.49
	Gold (Kg)	1588	1564	1441	1323	1531	1600	2500
Non-Metallic	Limestone (MT)	285.03	280.86	293.27	303.82	309	315	344

(Source: Production data during 2012-16, Annual Report 2016-17, Ministry of Mines, Govt. of India; Production data 2016-17, Monthly Statistics of Mineral Production, Indian Bureau of Mines, Gov. of India, February 2017, Vol 49, No. 02).

Coal India Limited (CIL) and its subsidiaries accounted for 567.36 million tonnes during 2017-18 as against a production of 554.14 million tonnes in 2016-17 , showing a growth of 2.4%. CIL production of coal during APR-MAR 2019 was 606.89 MT (Provisional) with a positive growth of 6.97%.

Singareni Collieries Company Limited (SCCL) is the primary source of coal supply to the southern region. The company produced 62.01 million tonnes of coal during 2017-18 as against 61.34 million tonnes during the corresponding period last year. SCCL's coal production during APR-MAR 2018-19 was 64.40 MT (Provisional) with a positive growth of 3.85%. Small quantities of coal are also produced by TISCO, IISCO, DVC, and others.

2.1 Technology

Mining involves a complete life cycle from exploration through production to closure with provisions for potential postmining land use. There are two main mining techniques used worldwide – surface/opencast and underground mining. Surface mining is commonly used to produce most of the metallic ores and minerals (excluding petroleum and natural gas) in India. In contrast, underground mining is limited to specific minerals by few prominent mining companies, specifically the coal industry. This is mainly due to a combination of factors, including the need for huge initial capital, high labour costs, long gestation periods, and limited or non-availability of local equipment.

2.1.1 Exploration

Modern mineral exploration is primarily technology-driven. Many mineral discoveries since the 1950s can be attributed to geophysical and geochemical technologies. To get systematic views of geology, mineral exploration at depth is vital. This requires physical property studies, geological studies, 2D and 3D surveys, and downhole measurements. In this preliminary stage, the mass move towards mechanized drilling technologies has already begun in India. Capacity enhancing technologies like 2D and 3D seismic surveys are being accepted widely in India. Further research in geological sciences, geophysical and geochemical methods, and drilling technologies could increase the effectiveness and productivity of mineral exploration.

Exploration in India is mainly limited to 50–100 m, compared to 300 m in Australia. Another issue that requires attention is the underutilization of funds collected under the National Mineral Exploration Trust (NMET). As of March 2018, INR 1,184 crore was collected under the NMET, but only INR 79.95 crore has been spent so far. The unavailability of high-tech equipment for exploration also remains an issue. In India, most of the current expenditure on exploration is on coal, iron ore, and surficial minerals. By contrast, the most significant proportion of global exploration is gold, base metals (such as copper, lead, and zinc), and diamonds.

Technology Development Challenges in Exploration

Although India's geological resource base can sustain much higher levels of mineral development, India lags behind other mining countries across all stages of mining, geoscience, exploration, development, production, and reclamation. Some of the challenges and R&D needs in exploration are as follows:

1. Geoscience (the search for ore bodies): The generation of baseline data to promote exploration activity, led by the Geological Survey of India (GSI), is yet to be completed. Aeromagnetic surveys have covered only 18 percent of India's total area to date, compared to 90 percent of Australia's total area covered since 1990. Australia has made all its digital maps online, whereas India follows hardcopy maps with restricted access. While India does have geological data covering 98 percent of the country's total area, at a scale of 1:50,000, the country lacks geophysical and geochemical data (only two to four percent coverage, compared to 90–100 percent coverage in Australia). Some of the most crucial shortcomings are the lack of geophysical and geochemical data and the shortage of high-precision equipment (e.g. gravimeter and total field magnetometer). The GSI should focus on baseline data generation to encourage exploration activity by large mining companies and juniors. Traditionally India's exploration spend has been low compared to other mining economies. India accounts for only 0.4 percent of the world exploration budget.
2. Exploration (defining the extent and value of ores): The Mines and Minerals (Development and Regulation) (Amendment) Act, 2015, ushered in a regime of the transparent and nondiscretionary grant of concessions. However, it also resulted in the nationalization of the exploration regime. Traditionally, most mining countries have adopted the 'first-come-first-served' principle to grant exploration rights and make provisions for automatic transfer from prospecting to a mining lease. Reconnaissance-cum-prospecting cum- mining

licenses should be issued on a 'first-come-first-served' basis through a transparent online system for deep-seated, concealed, or rare-earth minerals. Surficial, bulk, and stratified minerals areas for exploration may be allocated on exploration-cum-mining rights through an auction process. This will boost private and foreign participation in exploration.

According to the Ministry of Mines, 100 percent of the OGP area has been mapped for surficial minerals, while for deep-seated minerals, only 22 percent had been mapped as of March 2018. In contrast, other mineral-rich countries with similar geology, such as Australia, have almost 95 percent of their OGP fully mapped.

To attract private and foreign investors to mine in India, it is essential to complete all the surveys—geophysical, geochemical, aero-geophysical and marine—and make the basic data available in the public domain. India can also introduce a robust and transparent 'public-exploration reporting mechanism', compliant with the 16 JORC code or equivalent in the statute.

Australian METS companies have a competitive edge in advanced technology and systems. On the Australian UNCOVER project lines, the GSI is partnering with Australian counterparts to unlock India's mineral potential. The initiatives include characterizing India's geological cover, investigating India's lithospheric architecture, resolving 4D geodynamic and metallogenic evolution, and detecting and characterizing the distal footprints of ore deposits. Geoscience Australia is the national agency for geoscience research and geospatial information.

As part of Project Uncover (India), deep seismic reflection surveys (DSRS) will be carried out to interpret the lithospheric architecture of the earth. The idea is to look for potential mineral deposits up to a depth of 1,000–2,000 m. Experts also tap into the domain of magnetotellurics, i.e., studying the earth's crust to analyze its conductivity.

3. Critical Minerals: Technological change has driven the global demand for a new group of metals, non-metals, and mineral elements, considered necessary for the economic well-being of the world's foremost and emerging economies. The importance of rare earth elements and other critical minerals stems from their unique catalytic, metallurgical, nuclear, electrical, magnetic, and luminescent properties. The growing significance of these minerals is demonstrated in their use in the manufacture of mobile phones and computers, flat-screen monitors, wind turbines, electric cars, solar panels, rechargeable batteries, defense-industry technology, and products, etc. The growing demand for critical minerals creates significant economic opportunities for Australia and India to collaborate.

2.1.2 Mining

Mining involves breaking apart in-situ materials and hauling the broken materials out of the mine while ensuring the health and safety of miners and the economic viability of the operation. A relentless search has been under way since the early 1900s for new and innovative mining technologies that would improve health and safety and increase productivity. In recent decades another driver has been a growing awareness of the adverse environmental and ecological impacts.

A. Surface Mining

Opencast or surface mining consist of three different methods: strip mining, open-pit mining, and mountain top blasting. The soil on the surface is broken up, and rocks are broken down using explosives and then removing debris until the coal seams are exposed. Drills and other equipment are then necessary to extract the coal. As previously mentioned, this allows for more complete extraction. The use of surface miners is gaining widespread acceptance in opencast mines of India.

In India, open-pit coal mines contribute around 94% of coal production as the seams are closely located to the surface. Some of the open-pit mines in India are producing huge quantities of coal, to the tune of 35 to 45 MTPA, which is comparable with the large mines around the globe. For example, mines of SECL like Gevra, Deepika, and Kusmunda produced 42.2 MTPA, 35 MTPA, and 40 MTPA, respectively, in the year 2019-20. These mines mainly use 10 m^3, 15 m^3, and 42 m^3 shovels with 100 te, 115 te, and 240 te dumpers. The draglines are mostly 24 m^3 bucket capacity and 96 m boom length. However, the significant differences between these large mines of India and the large mines of the world are mainly in applying state-of-the-art technologies in terms of equipment capacity and intelligent mining techniques. For example, most of these mines use 42 m^3 bucket capacity Shovels, 400 to 500 te payload capacity of dump trucks and Draglines of 65 to 122 m^3 bucket capacity, and a boom length of 100 to 130 m.

In hard rock mines, some of the Indian mines have reached a depth range of 300 to 600 meters, like the Rampura Agucha Mine of HZL worked up to a depth limit of around 350m. In contrast, the deepest open-pit mine in India is the Malanjkhand Copper Project, which worked up to a depth limit of 550m. Both the mines have been converted into Underground mine as the depth of the pits have reached ultimate pit depth for many geo-technical and economic factors.

Global Overview of Mining Technology

<u>HEMM for Surface Mining</u>

Dragline

Joy Global's P&H 9020XPC walking dragline has a considerable bucket capacity of $85m^3$ to $122m^3$ ($110yd^3$ to $160yd^3$), making it the biggest dragline available in the market. The digital AC drive control dragline comes in different configurations, with the boom length ranging from 100m to 130m (325ft to 425ft)

Caterpillar's Cat 8750 series draglines have a bucket capacity ranging from $76m^3$ to $116m^3$ ($100yd^3$ to $152yd^3$) and 5,800t to 7,500t of working weight. The Cat 8750 is equipped with the world's most extended boom measuring up to 132.5m (435ft) and has a suspended load capacity of up to 383,286kg.

The ESH 100.125 and ESH 100.100 draglines produced by Russian heavy engineering company OMZ (Uralmash-Izhora Group) are equipped with the world's third-biggest bucket capacity of $100m^3$. Boom lengths of these walking draglines are 125m and 100m, respectively

OMZ's ESH 65.100 dragline comes with a $65m^3$ capacity bucket and 100m-long boom

Shovel

The Bucyrus RH400, owned by Caterpillar, is the world's most giant hydraulic excavator. The Bucyrus RH400 is a front-shovel excavator that can hold 45m^3 of rock in a single scoop.

The Hitachi EX8000-6, launched by Hitachi Construction Machinery in 2012, is currently the second-largest hydraulic excavator. The excavator has a bucket capacity of 45m^3 and a shovel capacity of 40m^3.

The excavator in third place is the Liebherr R9800. Liebherr built it at its Colmar factory in France in 2008. Both the backhoe bucket capacity and the shovel capacity are 42m^3.

Dump Trucks

Belaz 75710, with a payload capacity of 496t, is the biggest mining dump truck globally. The Belarusian Company Belaz launched the ultra-heavy dump truck in October 2013 under an order from a Russian mining company. Sales of Belaz 75710 trucks were scheduled to start in 2014.

The truck is 20.6m-long, 8.16m-high, and 9.87m-wide. The empty weight of the vehicle is 360t. Belaz 75710 features eight large-size Michelin tubeless pneumatic tyres and two 16-cylinder turbocharged diesel engines. The power output of each engine is 2,300HP. The vehicle uses an electromechanical transmission powered by alternating current. The top speed of the truck is 64km/h.

Caterpillar 797F, the latest model of 797 class dump trucks manufactured and developed by Caterpillar, is the second-biggest mining dump truck in the world. The truck has been in service since 2009. It can carry 400t of payload compared to its predecessor models 797B and the first generation 797, with payload capacities of 380t and 360t, respectively.

The dump truck has a gross operating weight of 687.5t and measures 14.8m in length, 6.52m in height, and 9.75m in width. It is equipped with six Michelin XDR or Bridgestone VRDP radial tyres and Cat C175-20 four-stroke turbocharged diesel engine. The single block, 20-cylinder engine offers a gross power output of up to 4,00HP. The truck uses a hydraulic torque converter transmission and runs at a top speed of 68km/h.

Komatsu 980E-4, introduced by Komatsu American Corporation in September 2016, has a payload capacity of 400t. It is the biggest electric drive rear dump truck from Komatsu. Fitted with big bucket shovels with a capacity of up to 76m^3, the Komatsu 980E-4 is suitable for large-scale mining operations.

The gross operating weight of the truck is 625t, while its loading height and widths are 7.09m and 10.01m, respectively. The vehicle is powered by a four-cycle diesel-fired 3,500HP Komatsu SSDA18V170 engine with 18 V-type cylinders. It uses GE dual insulated-gate bipolar transistor IGBT) AC electric drive system and can run at speeds of up to 61km/h.

Global mining companies are adopting unmanned vehicle fleets to increase safety and boost efficiency while moving large volumes of materials. In November 2018, the Komatsu Front Runner autonomous haulage system (AHS), which allows the unmanned operation of ultra-class mining trucks, achieved a milestone: moving more than two billion tonnes of surface material in the copper, iron ore, and oil sands industries.

Mining companies worldwide – particularly those in Chile, Australia, and Canada – are transitioning from manned to unmanned truck fleets. Autonomous haul trucks are operated by a supervisory system and a central controller instead of a driver. They use pre-defined GPS courses to navigate haul roads and intersections and determine the locations, speeds, and directions of other vehicles. Implementing autonomous haulage means more material can be moved efficiently and safely, creating an immediate increase in productivity.

Underground Mining Technology

The share of underground mines in other major coal-producing countries other than India, such as China, the United States, and Australia, is 95 percent, 30 percent, and 25 percent, respectively. In India, efforts are under way to step up production from underground mines by introducing mass production techniques like Longwall/Highwall/Shortwall mining as these techniques have greater mineral extraction capacity than surface mining. In India, Longwall and continuous miner technologies are being seen as important technology for coal extraction. Longwall mining involves the complete extraction of coal from a section of the seam or face using mechanical shearers. The coal face can vary in length from 100 meters to 350 meters. Self-advancing and hydraulic-powered supports hold the roof temporarily while the coal is extracted. When the coal has been fully extracted from the area, the roof is allowed to cave in.

Indian coal mining sector is still beset with relatively small scale mining with limited mechanization/scale of equipment. About 50 percent of CIL's total production comes from 15 mines (all opencast), having a total production of 279MTPA. The remaining 452 mines produce only 274MTPA, approximately 0.60MTPA per mine. Similarly, in SCCL, 83 percent of the total output comes from only 14 mines; the remaining 48 mines produce only 11MTPA. Small-scale mining constrained the extent of mechanization. Technology adoption in underground mining is even more limited. Approximately 87 percent of the underground coal mines of CIL are either semi-mechanized or non-mechanized (manual).

There is a significant gap in productivity norms of a similar class of equipment in mines in India and those worldwide. For instance, a similar type of shovel in international mines is operated 40–50 percent more hours annually than at CIL. Equipment utilization rates at mines operated contractually have been better than those operated departmentally by CIL. This requires a much greater focus on operational excellence and asset management practices in the Indian coal mining sector.

The key functions and the corresponding goals for the overall growth of the coal sector in India as per the Vision Doc 2030 of CIL are presented below. Subsequently, some of the specific action items are presented. This is the broader framework for the evolution of coal sector to a sustainable future.

The fundamental five core elements of the coal mining sectors and corresponding goals for 2030 for CIL is shown in Figure 4.1. The critical additional five elements and the corresponding goals of CIL for 2030 is shown in Figure 4.2. Table 4.2 shows some of the specific action items as per the Vision 2030 of CIL.

Fig. 2.1: Core elements of the coal mining sectors and corresponding goals of CIL for 2030

Fig. 2.2: Ancillary functional elements of the coal mining sectors and corresponding goals of CIL for 2030

Table 2.2: Some of the specific action items as per the Vision 2030 of CIL

Layers	Key Activities
Digital in governance	IT Platform for submission of applications for various approvals, clearances, supporting documents, clarifications, surveillance, progress monitoring, and roadblocks. The platform may be gradually expanded to include operational monitoring of mines including DGMS and coal regulator/ CCO related activities
Collaborate to minimize the impact of coal consumption (power sector)	Increase ash utilization in coal mine filling; collaborate and develop necessary frameworks, infrastructure and cost sharing mechanisms
Development exploration	Mandate development exploration and revision of Geological models for all critical operating mines in India

Technology deployment in exploration	Increase adoption of remote sensing, core open drilling and geophysical and geochemical logging (as against dominant core hole drilling), 2D and 3D seismic survey
Renewable energy in mining	Define RPO obligations for coal mines in India
Zero water discharge	Enforce zero water discharge guidelines for all coal mines in India
Sustainable Development Framework	Extend SDF to all coal mines in India
Star rating of mines	Extend star rating system to all coal mines in India
Phase-out small, unviable mines	Plan for progressively phasing out small and unviable mines in India
Skill upgradation	Develop skills up-gradation roadmap in line with technological developments and up-gradation such as remote operations, particularly for UG mines, a higher degree of mechanization in all mines, continuous R&D regarding automation, and increased use of digital mining Increased focus on younger staff to be updated with newer technologies Building of technical skills amongst potential land losers for them to be able to participate meaningfully in the industry
Improve non-technical skills,	Strengthening and augmentation of skills in areas such as land & revenue, environment & forest, marketing & sales, project management, etc. through training and integration with academic institutions
Increase diversity	DGMS may review any existing policies that stipulate certain conditions of participation of women in the coal sector in light of the increased application of technology. This may be done basis international benchmarking Explore employment of other diverse groups like retired and experience coal mining personnel
Training infrastructure	Expand the CoE network for mining education to other institutes/ agencies in collaboration with foreign research/ academic/ training institutes and OEMs. Technical education ambit to be increased beyond mining technologies to instrumentation, robotics, IT
Smart mines	Identify critical mines (10 MT or above) for coal PSUs for integrated mechanization and automation across the value chain
Modernization of OC mines	Formulate guidelines/ benchmarks for, Standardisation of HEMM for various pit capacities, Use of IT and digital technologies for fleet management, inventory, maintenance, safety, etc.
Modernization of UG mines	Plan for phasing out semi-mechanized operations across all UG mines in India.
	Target 10% of coal production by FY22 from large mechanized UG mines. Conceptualize and implement mechanized UG projects of capacity 5 MT and above; target at least 20 such operational mines by FY22

	Evaluate the feasibility of a separate BU in CIL for UG operations with a dedicated D (UG)/ ED (UG) reporting to CMD, CIL. The BU may be spun off into a separate subsidiary as and when operations achieve maturity
Alternate coal technologies	Increase R&D investment in alternate coal technologies (CBM, CMM, UGC, SCG) under public sector/ PPP/ foreign collaboration *(refer Demand Growth vision)*
Research and Innovation platforms	Create an R&D platform, say "Coal Sector Technology and Research Mission of India," for coal mining companies in India and Government to strengthen R&D activities in the sector
Equipment manufacturing	Under the aegis of 'Make in India' promote mining equipment manufacturers in India, taking advantage of the downturn in coal mining in other countries
Centre of Excellence	Create CoE focussed at mechanization and automation, and digital technologies in mining in collaboration with a leading global organization
Facilitating starts-up in coal mining in India	Focused sub-program within 'Start-up India', 'Skill India', etc. targeted at coal mining sector in India in the areas of data and analytics, technical advisory, planning & scheduling, etc.
Production planning	Mandate computerized model-based annual and rolling operational planning for all mines in India, particularly for coal PSUs, and declaration of grade on annual basis or more frequently, as required
Global collaboration	Facilitate Joint Study Group with other leading mining geographies for review of existing guidelines and development of future guidelines
IT Platform	Develop an integrated online safety system for notifications, submissions, approvals, reporting, and compliance
Optimize operating footprint	Sustainability Vision of CIL
Mine planning & scheduling	Implement integrated and detailed life of mine, medium-term and short-term planning, and operational planning
	A structured program for peer review of mining plans and geological models within the organization and in critical cases, with external technical experts
Drill & Blasting	Increased use of ANFO (for coal and OB)1, replacing emulsion products in dry holes to reduce cost, increase hole loading rates and improve fragmentation due to use of high heave energy explosives
UG Operations	Strengthening strata control practices - setting strata to control monitoring cell at area/mine level
	Installation of a man riding system in UG mines to reduce the travel time to face, increase available working hours at the face and reduce fatigue in workers
	Increased use of ventilation planning software

Surveying	Replacement of Theodolite with Total Station at all places, particularly in UG mines and gradual up-gradation to adoption of advanced EDM based survey technologies like 3D Laser survey, digital/ electronic Theodolite in OC mines
	Increased use of ground penetration radar for mapping old and water logged working in UG mines
Equipment productivity	Enhancing Asset Management and use of EAMS (Enterprise Asset Management system)
Technology modernization	Increased use of open-hole drilling and geo-physical logging for achieving higher exploration targets with cost efficiency

Metal Mining

The mining of metalliferous deposits is done worldwide using different mining methods, stope treatment, and men-machine deployment. Conventionally, underground mining is dusty, noisy, and dangerous work for those who run the big drills and haulers in the tunnels. Each day, miners descend thousands of meters into the dark bowels of the earth to operate huge rigs that drill, blast, and haul rock that contains ore. This paper reviews the latest developments in underground mining methods and technology used in developed countries for winning ore. A few mining companies have begun working with new innovative technologies to reduce the risk associated with mining and ore transport, thus improving the safety standards of the underground mining environment. This section presents a review of the recent innovations in newer technologies like fuel cell technology, arm-chair/tele-mining, mass blasting, high pressure direct injection, hydraulic pre-stress units and leaching, etc. The outcome of this section will help address the metal mining problems through CPS.

2.2 Review of CPS Systems in Mining

Automated technology is becoming more common in all embedded applications, and the mining industry is not lagging. However, it is not over; instead, it is just a noble beginning. Information technology in the Indian mining industry has entered half a century back. It was first introduced in the 1960s in staff function, especially in clerical activities like preparing pay rolls, listing store items, workforce control, etc. In the 1970s, it encompassed designing of civil engineering constructions, laying of tracks, roads, etc. In the 1980s, it was widely used in management information systems (MIS), mine planning systems (MPS), and Truck dispatch systems (TDS). In the 1990s, it came to global positioning system (GPS) and geographical information system (GIS), a visualizing technology that captures, stores, checks, integrates, manipulates, and displays data using digital mapping. It further spreads in areas like preventive maintenance, quality control, and other regions of technology and business-related to the mining industry.

This section mainly focuses on issues pertaining to some of the recent developments in the mine automations deployed in mines for safe mining operations and improving operational efficiency.

1. Autonomous Mining System

As a result of extensive research, miners today are starting to use externally controlled machines designed to be used by a single operator, the autonomous miner. Because of this technology, miners can be positioned in a non-hazardous location while steering the mining equipment. An autonomous mining system would prevent any health or safety concerns related to noise, vibration or dust because the equipment would work remotely, away from any human that may have a part of its operation.

Mining and Allied industries are now moving towards automation of their sub-systems with significant emphasis on:

- Drill and shovel monitoring for ground characterization
- Global Positioning Satellite applications
- Machine health and maintenance monitoring
- Expert systems in maintenance
- Automated mine design
- Geo-sensing and artificial intelligence
- Image analysis
- Communications
- Radio Frequency Identification technology
- Drilling intelligence and control
- Machine guidance and teleoperation
- Systems safety and human factors

2. Automated Underground Ore Haulage and Hoisting

The general trend is towards fully automatic underground ore haulage and hoisting system. Once the ore is dumped into the ore passes, the rest of the operations i.e. collection of the ore from the ore passes, dumping into an ore bin, primary crushing, loading the crushed ore to a skip, and hoisting, has been made fully automatic and man-less. Technological development is on the way for fully automated loading of ore from a stope by a load, haul & dump (LHD) machine, sorting the bucket according to grade, and dumping into ore-passes assigned for different grades. The underground mines are equipped with underground vehicle management and communication system for adopting this technology.

Kiruna Iron Mine of LKAB, Sweden, is an underground iron ore mine where an automatic locomotive was operating at 775 m level since the early 80s. The 775 m level haulage has now been moved down to 1,045 m level while upgrading all the ore handling systems with 26 Mt/year capacity. The component includes a new automatic rail transport system on 1045 m level, up-rating the hoists and crushers, and increasing the ventilation system capacity. Seven 500t capacity shuttle trains controlled from the 775 level collect ore from 10 ore passes and deliver it to one of the four crushing stations. 100 mm ore is then skip hoisted in two stages to the 775 m level and then to the surface. The Kiruna mine is divided into eight production areas, each containing its ore passes and ventilation system. The phosphorus content of the ore in LHD buckets is measured in real-time using Laser-Induced Fluorescence (LIF). Depending upon the phosphorus content, they are sorted to ore passes designed for a certain quality.

Finch Diamond Mine, South Africa, is using underground vehicle management and communication system. A similar system has been installed in Target Gold mine, South Africa, and Rocanville Potash mine, Canada. The system permits multi-channel voice and data transmission. The position of LHDs underground is monitored using a modular mining and dispatch system while the controller on the surface instructs the individual machines through the mine's vast communication network. Mount Isa Lead mine, Queensland, Australia, uses Micromine mine control system to control the rail system at level 15 and 19, dumping the ore and waste to crushing station at the base of U62 hoisting shaft and hoisting the crushed waste and ore to the surface. This mine has also invested in flexible mobile equipment and introduced tele-remote ore loading.

The Long Hole Open stoping in mines are generally highly mechanized using trackless drilling and hauling equipment. Holes of larger diameter depending upon the thickness of the orebody are used. The Room and Pillar method also has been made highly mechanized using trackless tyre mounted drilling and loading equipment in the stopes.

Sandvik AutoMine is an automated loading and hauling system for underground hard rock mining. AutoMine is a flexible modular system that can successfully be adapted to small-scale operations and massive block caving applications.

3. Tele/Arm Chair mining

Tele mining or armchair mining is a technology for getting miners out of the tunnels and into the control room. Tele-operation is a semi-automated process in which an operator manipulates equipment from a distance. Based on either optical systems or lasers, Guidance systems are installed underground, allowing vehicles to travel through tunnels autonomously. The company has a distribution agreement with Atlas Copco Wagner, a manufacturer of mining vehicles.

The Stobie Nickel mine in Aurora, Ontario, remotely operates four long-hole carbide drills from a control center 10 miles away. It also remotely works two LHDs, which move 3,000 tons of rock per day on a 24-hour, seven-day-a-week schedule.

Distance has become irrelevant in teleoperation. The response time of the equipment is 100 milliseconds. However, with no miners nearby, the equipment must be able to detect fire by itself. The machinery is equipped with fire suppression systems that off-site operators can trigger.

A Swedish company, LKAB has introduced automation to its iron ore mines in Kiruna and Malmberget. It started using the first driverless underground train to transport ore at its Kiruna mine in 1970, but has since expanded to remote-controlled drilling and loading and LHD operation.

4. Mine Safety Technology

National Institute for Occupational Safety and Health (NIOSH) is developing several computer-based programs for longwall and room-and-pillar mining methods to help mine planners design coal pillars. Making longwall coal mining safer and more productive has been the subject of a long-running CSIRO project funded by the Australian Coal Association Research Program, which has also come up with new technology designed to locate and guide coal-cutting equipment in longwall mines. CSIRO has produced commercial-standard automatic face-alignment systems, which ensure the cutting drums follow the coal seam accurately. Pre-commercial prototypes are now being used at Xstrata's Beltana and BMA's Broadmeadow longwall mines. CSIRO has also created prototypes for automatic horizon control and longwall information management systems ready for commercial production.

An advanced monitoring and communications system for underground mine safety and stable production has been developed through joint research conducted with the Commonwealth Scientific and Industrial Research Organization (CSIRO). This collaborative research also aims to build a basic system for risk information management that allows the real-time evaluation of different disaster risk factors (relating to work, environment, devices, and machinery). As an early detection technique, an odor sensor based on worldwide standards is now being studied in a joint research project with the Safety in Mines, Testing and Research Station (SIMTARS).

5. Computer-Aided Mine Planning and Optimisation

Optimizing mining operations in an underground mine requires a broader perspective to understand the synergy among various processes. Several professionally developed software is available to address this complex problem efficiently. Carlson is a CAD-based software used for design, mapping, and ore body block modeling. Datamine has been developing another software in collaboration with Anglo Platinum in South Africa and the University of Queensland, Australia, to have multi-parametric models incorporating Rock mass rating, Uniaxial compressive strength, Fracture frequency, and rock quality domain apart from the geological structure and metal grades to achieve a new level of mine optimization. It has also changed Datamine Studio block modeling and the NPV scheduler software to generate pits and pushbacks using dynamic designs optimized to the modeled geotechnical parameters.

Newmont Mining has selected the Maptek MineSuite production management information system for its Leeville and Midas underground gold operations in Nevada, USA, to fulfill increased productivity and performance requirements by providing shift managers with real-time information on the production as the status of equipment, delays, and assignments. The Gemcom Minex software released by Gemcom Software International is specifically designed for coal and other stratified deposits. It provides an integrated system for surveying, modeling, planning and scheduling, and blast design to interchange the information in an error-free environment. It integrates all aspects of mining from exploration through rehabilitation, ensuring that resources are evaluated accurately and mined efficiently, improving productivity and profitability throughout the mining lifecycle.

Runge has developed a methodology of the overall framework called 'method and system of integrated mine planning' of its enterprise solution, mining dynamics. It facilitates any information from geology through to mine engineering, planning, scheduling, operations, and reconciliation can be easily visualized, interrogated, and reported to the executive, processes, and systems management teams.

Martinez and Newman report a mixed integer programming approach for optimizing the long and short-term production schedules at sublevel caving LKAB's Kiruna mine in northern Sweden. The long-term model determines which machine placements to start mining in each period over the horizon to minimize deviations from planned production quantities while considering vertical and horizontal sequencing constraints and restrictions on the allowable number of LHDs in each shaft group. The model minimizes variations from monthly pre-planned production quantities while adhering to operational limitations.

Ventsim is a ventilation network analysis software featuring a full 3D graphics interface suitable for thermodynamic heat simulation, economic airway size prediction, recirculation prediction, and variable speed fans calculations.

6. Mine Robotics

Some of the examples of robotics-based mine equipment are mentioned below:

- Tele-operated and automated load-haul dump trucks that self-navigate through tunnels, clearing the walls by centimeters.
- The world's largest "robot", a 3500 tonne coal dragline featuring automated loading and unloading.
- 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.

Unlike their counterparts commonly found in the manufacturing industry, mining robots have to be smart. They need to sense their world, just like humans. Mining robots need sensors to measure the three-dimensional structure of everything around them. As well as sight, robots must know where they are placed geographically within the mine site in real-time and online.

CSIRO is developing vision systems for robots using cameras and laser devices to make maps of everything around the machine quickly and accurately as it moves and works in its ever-changing environment.

The thrust area where lots of research need to be carried out by the mining fraternities to deploy robotics in mining & allied industry are as follows:

- Use of remote-controlled manipulators for mechanization of miner's actions
- Multifunctional technological robots armed with automated drill and roof bolting system having arrays of sensors for assessment of mine atmosphere
- Introduction of information robots or mine rescue robots in case of mine disasters
- A manipulator equipped with a TV- cameras and force sensors

7. Communication & Tracking Technology

Traditional coal mining monitoring systems are based on wired networks. Some of the mines even lack real-time environmental monitoring systems due to greater depths of coal seams, which result in expensive processes of laying cables in a shorter period. Due to the continuous increase in industrialization and ever-increasing coal demands, more and more areas are being excavated to meet the requirement needs quickly. There is an immense requirement of a rapid technology that can be implemented quickly and provide safety for better coal production. The wireless mode of communication has emerged as a useful tool, which incorporates rapid data transfer (voice, video, etc.) applications. Various researchers have done a few studies to develop embedded as well as wireless systems for mine safety.

Some of the recent applications of communication and tracking technology in dealing with safety issues in mines are described in this section.

a) Mine Multimedia Rescue Communication

At present, the communication instrument equipped to rescue workers is a mine rescue telephone. This equipment can not precisely reflect the actual status of the mine disaster situation because of its limited capability of information transformation. Besides, the underground communication condition, especially after a disaster, is very bad. Traditional wire communications will be hard to work. Therefore, the command of rescue will be delayed or even blocked. The voice communication system, which lacks capabilities such as data saving, replaying, etc., could not provide adequate first-hand data for analyzing disaster, summing up the experience, and improving rescue strategies. Hence, developing a mine multimedia rescue communication system with high-speed data transmitting ability is necessary.

b) Close Proximity System (CPS)

The purpose of a CPS is to give drivers a warning/indication that a person or a light vehicle is near the truck, enabling them to react to the threat present. Such a CPS can be based on a single sensor or even be a multiple-sensor system. Some of the proximity systems presently being used in mines include Collision Avoidance Systems (CAS), and Strata Proximity Systems. Several other proximity systems, such as proximity warning systems based on the Global Positioning System (GPS) and a computer-assisted stereovision system, Preview Radar System, and Electronic Tag-Based Systems, are also under development.

c) GPS-based systems

These systems require all mobile equipment to have a GNSS receiver, thus allowing absolute real-time position information of the equipment. This position information is then exchanged using wireless radio to evaluate relative position e.g., between a truck and a light vehicle and issue an alarm if necessary. Full GPS coverage is needed for such systems to operate successfully. Nevertheless, multi-path issues and satellite shadowing may occur e.g., when a person is close to a truck. Fatalities among equipment operators in open pit mines can be reduced if GNSS technology is incorporated in their machines.

d) Radar / Laser-based systems

These systems are based on range and bearing sensors and actively detect objects being close to the truck. They usually don't provide an identification of the object detected. Radar systems also usually don't detect persons underneath a truck or fail to notice them if they walk under the radar beam.

e) Vision-based systems

Computer image recognition usually builds the core of such a system. A simpler version of a vision-based system requires the driver himself to identify intrusive objects. A disadvantage is unreliability due to possibly varying light conditions.

f) RFID based systems

These systems usually equip mobile equipment to be protected with a Radio Frequency (RF) tag, which will be detected by an RF tag reader attached to the source of danger (e.g. truck) when in close proximity. Based on the technologies presented, RFID is the most feasible technology from both a technical and financial perspective that can provide complete sensor coverage of the dangerous areas around and even under a truck. All the other technologies presented here fail to provide comprehensive coverage or can give it only at dramatically increased cost and installation efforts.

Researchers at the Spokane Research Laboratory, National Institute of Occupational Safety and Health, Spokane, Washington have developed a radio frequency identification (RFID) system to avoid collisions between haulage equipment and pedestrian workers underground. The system consists of tags mounted on pedestrian worker's helmets, the reader antenna unit on the vehicle and an alarm unit mounted in the operator's cabin and connected to the reader via a cable.

Extending the use of this RFID technology, Mineware Consulting, South Africa in association with the tracking solutions company Accutrak, has implemented a Smartrail system, which allows mines to analyse the amount of rock being transported underground as the grade and movement of each load.

Canadian mining communication specialist Mine Radio Systems (MRS) has introduced multi-com line amplifiers to the leaky feeder system inserted at every 350m along the cable. The amplifiers use automatic gain control (AGC), which operates independently in forward and reverse directions. The feature allows the amplifier to automatically adjust its gain control to compensate for changes in the system.

Supervisory Control And Data Acquisition (SCADA), mobile vehicle and production tracking, personnel identification, security, vehicle location and ventilation system monitoring, and control with integrated ventilation system simulation are all part and parcel of the modern mine's everyday needs. But this all relies on communication technology that needs to operate in an environment that has been described as a close approximation of hell and where the 'shop floor' is forever changing its topology.

Underground mobile platforms such as locomotives, LHDs, continuous miners, etc. need reliable connectivity with the central management system, which may or may not be situated on the surface. In the absence of reliable communication, management of these costly resources becomes very difficult and hence proper utilization of the same can't be ensured.

In several fully mechanized mines worldwide, centralized fire and hazard detection systems are installed that have the unique feature that all the sensors connected to the cable are powered from the surface so that the sensors will continue operating even if the underground power is discontinued in the case of an emergency.

8. 3D Visualization: GIS and Remote Sensing in Mining

Geographic information and imaging systems visually portray layers of information in new ways to reveal relationships, patterns, and trends. Software from vendors such as ESRI and ERDAS provides the functions and tools needed to store, analyze, and display information about places.

The use of Geographic Information Systems (GIS) as a powerful tool to analyse and display data gathers momentum in the mining industry. The latest mapping technology like Geographic Information System (GIS) and Remote Sensing is growing in mines worldwide. The Remote Sensing technology has been extensively used in mapping the regions affected by underground fires in mines and its surrounding areas. This technology, integrated with GIS, has become an effective tool for developing and implementing a rehabilitation plan for the region. GIS technologies create efficiency and productivity opportunities in all aspects of mineral exploration and mining. GIS enables a mineral exploration geologist and mine operator to mine intelligently, efficiently, competitively, safely, and environmentally.

a) Cavity monitoring system (CMS)

This system is developed by Noranda Technology Centre (NTC) and Optech System, Canada. It can scan the extent of stope from a position within the cavity, giving it a significant advantage over the conventional survey method. It is the primary tool used by mine surveyors to survey underground stopes and other cavities. In most of cases, CMS is the only means of determining the extent and volume of an otherwise inaccessible underground cavity. CMS is also used to determine the ore recovery and dilution.

b) Remote Survey Vehicles

With the advanced wireless robot, the Remote Surveying Vehicle, rapid 3-dimensional surveys can be conducted with limited exposure in the working environment. With rates of 1.5 km per day, far greater data collection is achieved than through standard surveying methods. It provides instant, remote voice and high-speed data connectivity for all stages of the mining cycle, from mineral exploration to mine closure. Exploration teams can send test data, still images, and video to geophysicists back in the lab for immediate analysis and results, wherever they are working or for how long - increasing the success rate of exploration and enabling one to act faster exploit new deposits. It is possible to remotely process the data, which means one can operate from anywhere in the world, with a suitable internet connection. It allows one operator to survey drives and tunnels without continuously setting up the instrument on tripods and moving from one station to another.

c) Virtual Reality in Mineral Industry

In September 2001, Laurentian University, Sudbury, Ontario, officially opened a state-of-the-art virtual reality laboratory as part of its center for integrated monitoring technology (CIMTEC). This facility, designed to meet the mineral exploration and mining industries' needs, offers a team interpretation environment for earth modeling applications. The Virtual Reality (VR) technology can significantly assist in mine planning and design through its strong capability to visualize the overall impact of various factors in a complex mining environment.

9. Summary

Recent advances in computing, communication, sensing & control technologies have changed the scenario in the current automation landscape and are providing significant benefits in improving overall efficiencies. This section has highlighted some of the recent innovations in the mine automation deployed in mines for safe mining operations. The shape of survey systems and equipment seems poised for revolution with further developments in Robotics, Information Technology, GIS, Remote Sensing, Satellite Communication, etc. This shifting paradigm provides new opportunities to exploit the reserves of some of the world's most extreme and inhospitable places. Over the next few years, automated mining technologies backboned with information technologies will become much more prevalent at large-scale mining operations at deeper horizons because these technologies satisfy the two most important goals of any mining operation: improved productivity and safer working condition. A summary of R&D needs in Exploration, Mining, and Processing is presented in Table 2.3.

Table 2.3: Summary of CPS related R&D needs in Exploration & Mining

Type of technological Innovation	Key applications	Exploration	Mining		Min. Processing	Health & Safety	Environment
			OC	UG			
1. Enabers of big data							
Sensor technologies	• LIDAR (Light detection and ranging) sensor technology in autonomous vehicles	X	X	X			
	• Remote operations and precision planning: Smart sensors connected to automated vehicles/helmets and a range of other tools can better help control/remotely monitor equipment and infrastructure; identify obstacles		X	X		X	X
	• Predictive maintenance: Smart sensors combined with algorithms can help predict breakdowns; detect anomalous conditions/ installations and maintenance		X	X			
	• Sensors to detect the grade, hardness and size of ore coming into the processing facilities.				X		
Connected smart portable devices	• Personal protective equipment (PPEs) with built-in tag	X	X	X	X	X	
	• Co-bots: Characterized by small size, versatility and are affordable in price	X	X	X			

Type of technological Innovation	Key applications	Exploration	Mining		Min. Processing	Health & Safety	Environment
			OC	UG			
	• Touch technology • Captive pads • Helps detect fatigue and stress levels	X	X	X		X	
	• Supervisory control and data acquisition	X	X	X	X	X	X
Drones (UAVs)	• Stockpile inventory and management		X	X	X		X
	• Mine monitoring and operation planning		X				X
	• Assessment before and after drilling and blasting		X				
	• Hazard identification and mitigation		X	X		X	X
	• Geological mapping and surveys	X	X	X			
	• 3D data output	X	X	X		X	
GPS	Helps in navigation, surveying, tracking. Frequently used in: • Control of heavy machinery • Control of bucket wheels and dozers • Drill guidance • Road grading and maintenance • Fleet management systems for haul trucks and other vehicle tracking and dispatch • Access and zone control for visiting vehicles • Detecting dangerous driver behaviour • Collision avoidance applications	X	X			X	X
2. Users of big data							
Machine learning (ML)	Those analytical techniques can be applied to solve real-life problems, i.e., • Descriptive: Identify patterns of behaviour • Predictive: Anticipate what will happen • Prescriptive: Provide recommendations on what to do to achieve objectives • Clustering: Individual data sets with common	X	X	X	X	X	X

Type of technological Innovation	Key applications	Exploration	Mining		Min. Processing	Health & Safety	Environment
			OC	UG			
	characteristics—or with ability to create synergies—are assembled Applications include: • Image classification • Facial recognition • Voice recognition Quantum computers augment data crunching						
Advanced analytics	• Enable end-to-end tracking and communications and real-time supply and demand management	X	X	X	X	X	X
	• Descriptive analytics	X	X	X	X	X	X
	• Predictive analysis: Can pinpoint requirements; address bottlenecks; determine output		X	X	X	X	X
	• The data collected (geological; metallurgical; operational) will allow the use of 3D visualization and digital twinning	X	X	X	X	X	X
	• 3G/4G connectivity can send data in real time	X	X	X	X	X	X
Automation: Hardware automation/ Autonomous assets	• Autonomous haulage systems		X	X	X	X	
	• Operators remotely controlling multiple rigs simultaneously	X	X	X		X	
	• Mine automation system		X	X		X	X
	• Telematics (condition monitoring) to avoid downturn		X	X		X	X
	• Vehicles without drivers and monitored from a distance		X	X		X	
Robotic process automation (RPA)	• Process automation and configuration • Graphical user interface (GUI) automation • Advanced decision systems	X	X	X	X	X	X
	• Capabilities by orders of magnitude.	X	X	X	X	X	X

Type of technological Innovation	Key applications	Exploration	Mining		Min. Processing	Health & Safety	Environment
			OC	UG			
Software automation	• Software guiding remote controlled excavators, tele-operated vehicles etc. • Software to guide drivers toward most optimal routes to reduce transportation time		X	X	X	X	X
Digital twin	Management can use the simulator to manipulate a huge number of variables over a given time period to see how changes will affect both up- and downstream processes		X	X		X	
Cloud computing	• Data management • Collaborative platforms and virtual workspace • Requires strong cyber security	X	X	X	X	X	X

2.3 Challenges and Strategy of TexMin

Given the country's potentiality towards mineral exploration and exploitation for sustaining the growth trajectory, it is essential to understand the challenges being faced by the agencies involved in exploration and exploitation of mineral resources. The strategy for meeting the country's demand for minerals smartly and safely should primarily address the challenges.

Technology has transformed many industries across the world and changed the way companies perform. Mining is one such industry that is maturing over the last few decades on the back of an ever-increasing demand for mineral resources on one side and a need for sustainable mining on the other. The mining industry currently faces a unique set of challenges – improving productivity and reducing costs while protecting the health and safety of their workers, safeguarding fixed assets, and environmental conservation. Miners often put their lives at risk, traveling deep underground in dangerous conditions to bring these precious elements to the surface.

Challenges in the Coal sector

To achieve the objectives of TexMin, which is technology driven with more and more intervention of CPS technologies, primarily to improve productivity and safety through automation and digitization, it is essential to draw a blueprint of technological up-gradation in mining systematically through gradual absorption of cyber technologies to address the limitation of human capability as well as keeping the human away from the inherent mining hazards. The current status of technological adoption in the Indian coal sector is mentioned below:

Limited adoption of technologies by the coal sector: Indian coal mining sector is still beset with relatively small scale mining with limited mechanisation / scale of equipment. About 50 per cent of CIL's total production comes from 15 mines (all opencast) having a total production of 279MTPA. Remaining 452 mines produce only 274MTPA, approximately 0.60MTPA per mine. Similarly, in case of SCCL, 83 per cent of total production comes from only 14 mines; remaining 48 mines are able to produce only 11MTPA. The small scale mining constrained the extent of mechanisation. Technology adoption in underground mining is even more limited. Approximately 87 per cent of the underground coal mines of CIL are either semi-mechanised or non-mechanised (manual).

Operating performance is lower than global peers: There is a significant gap in productivity norms of similar class of equipment in mines in India and those around the world. For instance, similar class of shovels in international mines are operated 40–50 per cent more hours annually than they are at CIL. Equipment utilisation rates at mines operated contractually have been observed to be better than those operated departmentally by CIL. For example, in ECL, in 2016–17, the utilisation rate of hired excavators was 93 per cent as compared with 73 per cent utilisation rate of departmental excavators. This requires much greater focus on operational excellence and asset management practices.

Safety performance, lower than global peers: The Indian coal sector has seen improvement in safety performance over the last few years. However, there is a need for further improvement. This implies greater focus and investments is required in safety systems and in better implementation of safety norms. A dedicated effort has to be made to ensure achievement of the goal of zero fatalities and injuries.

Cost of production: It would also be imperative to look at 'low-cost production capacity' from the standpoint of 'low landed cost of power to end consumers'. If a low-cost coal mine has to transport coal to a distant and inefficient power station, then the benefit of the low-cost production capacity is lost. Hence, it is imperative to look at system costs going forward. Other than for strategic considerations, it can also be empirically stated that India should move towards pit-head thermal power capacities instead of load-centre power stations. This can have implications on environmental pollution of coal-belts and, hence, investment may have to be stepped-up in terms of R&D investment in carbon sequestration efforts. Historically, coal mining companies have invested lesser in R&D for carbon sequestration, and other clean coal technologies in comparison to power utility companies. The last few decades may prove to be the lost decades in terms of global coal sector's efforts in this direction. However, it has become imperative for coal companies to give serious consideration to these efforts to address business continuity, while they still can. If the amount of R&D funds that are now being attracted into solar would have been invested in the last few decades into carbon sequestration globally, this exercise may not have been required.

Lack of thrust on UG coal mining: Indian coal reserves are mostly shallow, up to a depth of 300 metres, and are typically exploitable using surface mining methods. However, as some of these coal reserves are located below settlements or dense forests (areas for which surface mining approval is difficult to obtain), going underground might ultimately prove the only feasible solution if these deposits are to be tapped, as it avoids resettlement and damage to local ecology. Coal occurring at depths greater than 300 metres is usually economically extractable only with underground mining techniques. Worldwide, mining companies have been successful in economically and safely extracting coal at great depths, but unlocking the full potential of India's deep seated coal resources will require significant technological improvement in underground mining technology.

Current production from UG accounts for only 6% (approx.) of CIL's total production. There was only 5.38% production from UG mines out of total production of 567 Mte in 2017-18 – reduced from 11% in last 10 years. There is a gross mismatch between trend in production from UG and OC – which is not sustainable.

Main problem for long term sustainability of country's energy growth with over dependence on opencast mining includes, but not limited to, the following:

Increasing Environmental concern: With the continued and significant impact of global warming due to environmental degradation by surface mining, environment management has become more challenging than ever. It is becoming more and more difficult to get free land for opencast mining. Moreover, the past poor record of reclamation of mined out areas in Indian coalfields is also not encouraging to get social licensing. In a country where population density is so high, it is difficult to get such huge land for open cast mining including the waste dumping land. Moreover, the increasing cost of managing the environmental impact within the acceptable limit, cost of mining will be increased significantly.

Land acquisition : With the new law, Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013, with successive amendments in 2014 and 2015, and Compensation, Rehabilitation and Resettlement and Development Plan) Rules, 2015, cost of land has increased manifolds and economic viability of such opencast projects will be doubtful.

Inferior Quality of coal from opencast mining: quality of coal from opencast mining compared to underground mining is much inferior because of dilution of coal with overburden rocks. In general, Indian coal is inferior in nature, particularly in the upper horizons, because of its high inherent ash content. Further mixed with rocks while extracting by opencast method, it becomes too inferior for the thermal plant, posing huge challenge for maintaining the efficiency of the plant as well as for disposal of huge volume of ash. The problem may be better controlled by underground method by selective extraction and also avoiding dilution. Moreover, the quality of coal in the deeper operating horizons of underground mining is superior in nature. Hence from quality point of view, opencast mining may not be sustainable.

Increasing depth: The opencast mines are now approaching economical depth limit of 250-300m. Beyond 300m, as stripping ratio will be quite high, economic viability of such open cast mines will be doubtful. However, underground mining will be techno-economically suitable for deeper horizons, with appropriate technology.

Need for Introduction of Mass Production Technology: Therefore, balanced growth of underground and opencast mining is needed for sustainable coal production from Indian coal mines in the long term. In view of the continuously declining trend of coal production from underground mines of India, there is urgent need for overcoming the challenges being faced by the underground mines and for modernization of these mines so that their full potential can be realised and underground coal mining can be made economically viable and competitive. However, significant increase in UG production is not possible with the existing technology and infrastructure in Indian mines. It is only possible to improve the production and productivity by introduction of mass production technologies (MPT) like longwall mining and mechanized room & pillar mining with Continuous Miner, Shuttle car, Roof bolter, belt conveyor etc. and suitable supporting infrastructure. Total production from longwall is around 12-15% of Underground production and less than 1 % of overall production whereas Room & Pillar is contributing around 30- 40% of Underground coal production and less than 2 % of overall production. However, there is potentiality of increasing production from UG mining through application of MPTs in Indian coal mines provided some urgent steps in terms of strategic policy planning, technological interventions, R&D support and skill upgradation are taken in a systematic manner.

Quantum jump in UG production is not possible unless Mass Production Technologies (MPTs) suitable for Indian geo-miming conditions are adopted systematically. It is imperative that introduction of such technologies shall be done systematically with due considerations to the challenges of underground mining; past experience, both of success and failure; global experience; existing capability in terms of technology management & skill; long-term & short-term economic viability; etc. Absorption of technology is more important than introduction of technology and hence Indigenisation of mining machinery should be given priority.

Some of the critical challenges of coal production from underground mines in India are given below:

- Low technological, R&D or skill-development input in underground mines
- Lack of suitable scheme of mechanisation
- Mismatch of production components – drilling, blasting, loading, transportation, supporting, ventilation, communication
- Lack of commitment towards high degree of mechanisation due to early history of failure of mass production technology
- Imported technology is not sustainable - Lack of absorption of overseas technologies
- Less than adequate safety performance due to lack of CPS based technologies in UG mines, which are inherently more hazardous
- Lack of investment for infrastructure development and mechanisation resulting in capacity reduction

Strategy for improving UG Production: Keeping in view the challenges of augmenting production from UG mines, the following strategies may be adopted:

- All new underground mines are to be planned with high degree of mechanization; Large scale introduction of mass production technologies like longwall mining technology, continuous mining technology etc.
- Planning for high capacity UG mines with state of the art technology, facilities of electronic monitoring, control system and facilities comparable to the best available in the world
- Exploring the possibility of application of automation, digitization and application of artificial intelligence in improving operational efficiency in each unit operation
- Improving safety and health condition using safe machines, providing automated safety features in machine, continuous online monitoring hazards, its analysis using AI and seamless communication;
- Adoption of telecommunications in underground mines;

Need for Innovation, Automation and Digitalisation and Application of Artificial Intelligence

- Automation and Digitalisation plays a critical role in accomplishing the strategies outlined above. Automation and Digitalisation are touted to be the most defining mining industry trends, aimed at enhancing productivity and addressing the challenges faced by the mining industry.
- Innovations in artificial intelligence (AI), machine learning and the industrial internet of things (IoT) all have the potential to save the sector an estimated $373 billion and hundreds of lives by 2025 by automating machinery operation, planning and scheduling, facilitating predictive maintenance, improving man, material and asset traceability, harnessing the power of real-time data and analytics, and providing visibility across the mine-to-market value chain. People, process, and technology are the drivers of change and the key to the transformation and future success of the mining industry.
- The future of underground mining will be characterised by, amongst other things, Integrated remote operation centres wherein everything from cutting and loading of coal, to conveying of coal / mineral, both horizontally and vertically, roof bolting for ground control, underground environmental monitoring and ventilation control, all will be done from remote control centres located miles away from where the physical assets are located. Configurable Stockyard management systems can be used to digitalise the complete material handling chain, acting as a digital replica to the physical asset. Material flow can be modelled across conveyor belts and transportation equipment, with material properties and quality information, conveyed via automated data interfaces, to drive operational optimisation.
- There is a critical need to transform the way mines operate in India, by creating a digitally-enabled environment that is safe, clean and sustainable, with a workforce carrying out exciting, stimulating tasks. The present and future mining workforce will need to embrace new technologies In order to meet the challenges of the mining industry and reap the rewards offered by a new generation of automation solutions. Automation is the answer to future proof mining operations in India by increasing productivity, promoting the more sustainable use of resources, while simultaneously lowering fixed costs.

Strategies to be adopted for automation and digitization in Indian mines

When we are talking about TexMin 4.0, and the way forward, we need to consider where we are and how we can adopt large scale automation and digitization. Considering the necessity and potential for augmenting production from UG coalmines, it is expected that the coal companies will pay their attention in increasing production from UG mines by introduction of MPTs adopting the following strategies:

- Formulation of long term strategy for exploitation of coal resources with due consideration to production & productivity, safety & health, environment, conservation and economics in a phased manner matching with demand, available reserves and resource requirement
- Long-term planning for systematic introduction of underground mass production technologies (MPT) considering Indian Geo-mining and socio-economic conditions
- Revival of uneconomic underground mines by introduction of suitable MPTs
- Project Planning and Designing of underground mines, using latest software, both for greenfield as well as brownfield
- Assessment of environmental impact of underground mining and preparation of Environmental Management Plan for mitigation of adverse environmental impact on land, water, flora & fauna, socio-economic condition of mining fields etc.
- Augmentation of UG Coal evacuation system, surface coal handling and dispatch system.
- Addressing technological issues related to mass production
    - Adoption of continuous mining system introducing (a) high capacity longwall panels under suitable geo-mining conditions using state-of-the art technologies and high capacity equipment like shearer, powered supports, Armoured face conveyor, stage loader, outbye belt conveyor etc., (b) mechanised room & pillar mining with continuous miner / bolter miner, shuttle car, articulated haulage system, flexible conveyor, (c) Adaption of new methods like Wongawilli, Rib Pillar extraction, Shortwall, Short longwall mining with caving or stowing , (d) Use of remotely operated mobile breaker line support system, bolting machines
    - Process Optimization of each unit by continuous sensor based monitoring and scheduling of operations,
    - Reducing machine downtime by sensor based online machine condition monitoring and analysis using modern software and seamless communication
- Addressing issues related to safety and health
    - Improving ground control system by continuous strata monitoring and analysis using software
    - Reliable and continuous gas monitoring (tube bundle / tele-monitoring), machine mounted environmental monitoring system (sensor based), use of Gas Chromatograph for analysis of mine gases, use of software for analysis of atmospheric conditions and activating mitigation or control measures
    - Continuous monitoring of indicators of spontaneous heating using sensor based detectors, analysis of spontaneous heating indices using analytical software and activation of control measures including Mass inertisation (N_2 or CO_2), withdrawal of persons etc.

- Sensor based monitoring of respirable air-borne dust, Diesel Particulate Matter (DPM) & automatic activation of its mitigating measures
- Continuous monitoring of Subsidence using geophysical, satellite or drone based image processing and analysis of subsidence measurements using analytical software for prediction and mitigation
- Coal dust explosion prevention
  - Automated application of bulk stone dust or other explosion inhibitors
  - Sensor based real-time sampling and analysis of roadway dust – and activation of automated application of stone dust or other inert material
  - Sensor based activated explosion barrier
- Detection of the presence of inaccessible waterlogged workings, presence of subsurface cavities or unstable or fire-affected areas using geophysical instrumentation / handy tools using geophysical properties
- Seamless Communication in underground and Tracking of work persons and Machines
- Innovative machine design considering Ergonomic issues

- Indigenous manufacture of UG mining equipment and spare parts for a guaranteed supply of services and spares
- Cooperation with global technology providers for the successful introduction of MPTs
- Need-based R&D in support of addressing technological and safety issues
- Skill development

2.4 Strategy for application of CPS system in the mining value chain

The strategy to be adopted in Indian mines should include, but not limited to:

- **Computer-Aided Mine Planning and Optimisation**
- **Optimizing Tonne-Kilometres** Per Hour (TKPH) by reducing machine idle time, ensuring full load (not overload) and optimizing speed on haul roads, automatic GPS positioning of trucks
- **Autonomous Mining System**
- **CPS based Communication & Tracking Technology**
- **Application of Robotics**
- **3D Visualization: GIS and Remote Sensing in Mining**

Figure 2.3 shows that with the cyber-physical system in mining, some conventional technologies viz., as core logging, face inspections, and manual plant assays, will no longer be required.

Introducing process changes for disruptive technologies can be difficult because people operate in a certain way. Organizations like TIH will have to show them that a different way of doing it could be better. To achieve a successful selection and adoption of technology, specific processes (exploration, planning, production, maintenance etc.) or asset (haul trucks, shovels, draglines etc.) may be chosen and then technologies can be introduced to capture (collect, connect and centralize), analyse, and visualize the data and information to gain operational intelligence. Each steps would lead to deeper understanding of what has been done and what is currently happening – enabling the organizations from reactive decision making to pro-active decision making to improve the performance and productivity. The process never stops and constantly uncovers opportunities to improve. The end goal is to create an environment where data can guide intervention at any stage to increase productivity, minimize losses and drive profits.

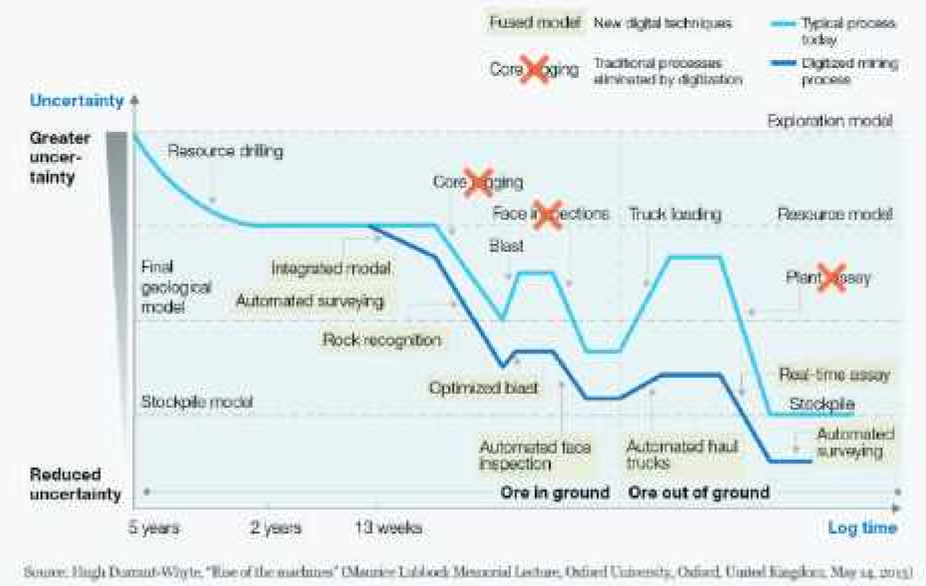


Fig 2.3: Significant potential comes from better understanding the resource base

A. Digital twin

Integrated system provide a central platform by which to optimize and manage planning, scheduling and execution across the value chain in a coordinated and complementary way. Digital twins and advanced analytics allow for the modelling of various scenarios across the value chain to determine optimal planning and scheduling outcomes. Increased optimization will result in a reduction in bottlenecks and it also has the potential to reduce or eliminate the need for large stockpiles of ore.

It is proposed to develop an integrated system combining skills, operations processes, and technology from across the business to deliver exceptional collaboration and operations excellence.

Without end-to-end visibility and integration across the value chain, the management of operational variables such as asset health, process performance, or geological variance is often reactive, siloed, and misaligned with downstream activities, creating disjointed end-to-end productivity. By implementing the integrated system and leveraging digital twins, upstream information, and advanced analytics and modeling, the management of production variables can be streamlined and optimized to determine the best long and short-term management outcomes. This will result in decreased variability within the end-to-end system, increasing overall throughput. An improved understanding and optimization of material characteristics and mineral flow through the system will increase overall product quality by reducing dilution with unwanted waste material. This will improve processing productivity as greater certainty around ore quality will allow for better alignment of plant set points and quality management, etc.

B. Improved drill and blast design through the use of all geological information

Poor tracking of blast displacement can lead to product dilution. Predictive blast displacement provides an opportunity to increase the delineation of the ore body and increase the run of mine (ROM) grade. Reduced dilution can realize benefits downstream, including improved loader productivity due to a reduction in waste re-handling. A complete dataset of the information collected upstream captures the material characteristics of the area being blasted. The application of advanced analytics to this data provides the opportunity to predict the displacement of material caused by blasting. 3D simulation and visualization technology can enable the tracking of blast displacement to be optimized through testing outcomes.

C. Sensor Technology

The extraction, crushing, and transport of minerals in a mining environment can generate significant volumes of combustible dust, putting workers and mining equipment at risk of dust explosion. To mitigate against these risks, workers must take care to employ suitable hazardous area equipment. Intrinsically safe sensors can eliminate the threat of dust explosion. The sensor technology has to be upgraded to suit the future of AI to make them smarter accurate, and more AI compatible. A wide range of embedded and attached sensors are required for structural health monitoring applications, including strain gauges, accelerometers, fiber optic sensors, active ultrasonic sensors, passive acoustic sensors, wireless sensors, etc. Fiber optic sensor has been emerging as an increasingly important tool for structural health monitoring due to their unique advantages in sensitivity and multiplexing capability.

India has to establish itself as a leader in Design, Manufacturing, Supply, Installation, Maintenance, Monitoring, Analysis, and Interpretation of high-quality instruments to the Geotechnical, Geophysical, Structural Health Monitoring, etc., in Mining & Mineral Sectors.

The golden triangle of TexMin is shown in Figure 2.4.

Fig. 2.4: The golden triangle of mining 4.0

The high-quality sensors, data standardization, and AI solutions are the golden triangle that can propel the mining industry forward. Especially in the area of streamlining, standardization, automation of the mining sector.

It is said that what cannot be measured cannot be improved. This fact is very much applicable to the exploration and mining sector. Figure 2.5 shows the various parameters requiring real-time detection and monitoring through robust sensors in a hazardous and dynamic environment.

High Quality, cutting-edge, interoperable sensors are playing a crucial role in the success of the project. If we compare our measurements to the rest of the world, we need to bring world-class sensors. This would help us fast-track some research by piggybacking on initial analysis.

D. Data standardization

"Without standardization, comparison and further improvement will not be possible." A collaborative data mining project involves more complexity than one that is small and local, but there are benefits to combining expertise. The TIH can play a crucial role in bringing multiple stakeholders into this standardization journey.

"Data is the new currency of the future," Back-boning tens of hundreds of research means saving millions of person-hours of effort and multiple new solutions instead of re-inventing the wheel. In collaboration with partners, TIH can bring to the table a range of universities, industries, mining companies, safety experts research organizations, and other entities that can assist with data acquisition and speed up the process. The expert teams from TIH and partners such as GSI and other organizations can collate geographical, geophysical, and geological data of a particular region of interest from public data sources and further curate the datasets through the extraction of geoscientific information from scanned OCR and non-OCR historical exploration reports.

Earth-moving machinery and mining Autonomous and semi-autonomous machine system safety follow ISO 17757 standards. Safety requirements for general mobile EMM and mining machines and operators, trainers or passengers on the machine are given by other International Standards (e.g. ISO 20474 and the future ISO 19296). ISO 17757 addresses additional hazards specific and relevant to ASAMS when used as intended.

Fig. 2.5: Various parameters requiring real-time detection and monitoring through robust sensors in a hazardous and dynamic environment

E. Modelling through AI

"AI is the key in the mining race", AI can bring access to minerals to once think as non-profitable for extraction. It can save the environment by reducing drilling exploration. Can automate repetitive tasks, perform critical systematic decision on the ground and perform tasks that were once considered unsafe for humans. AI can monitor equipment and alert even before a problem arises. AI can predict mineral perspectivity. AI can overall add to productivity. The four pillars for AI are data, computing power, model, and expertise. According to business insiders, AI know-how is the most sought-after expertise of this decade.

V100, T4, TPU, P100 are the most popular hardware(s) sought after for training and testing. Dockers, Kubernetes, ASIC, SoC, VDI are some of the popular hardware for deploying AI.

Usually, a large AI project is broken into multiple medium size projects with centralized coordination. Typical medium AI projects has a team size of 10-12 with more emphasis on data scientist at the beginning, AI architects in the later stage and Deployment experts in the end. Usually, initial data standardization would take about two months. Post that, initial data modeling would take about three months. AI solution would typically be in 12 months window, and deployment would take about a month. Figure 2.6 shows a layout of the Agile model for deep learning. Figure 2.7 shows the stages of developing a maturity model for AI in Mining 4.0.

How to avoid overlapping

In India, the sponsored R&D projects are funded through government agencies viz., DST, MoM, MoC, MoEF, MoES. The proposed Project advisory committee will have core members who are experts. The expert members will be from a typical government funding agency such as the Ministry of Mines, the Ministry of Coal, the National Mineral Exploration Trust, etc. The proposals would be sent to the expert members to typical comment on any such activity that has been taken up by them. We would be sharing our funded projects to these funding agencies. The data acquired will be made available on the portal, which other users can download.

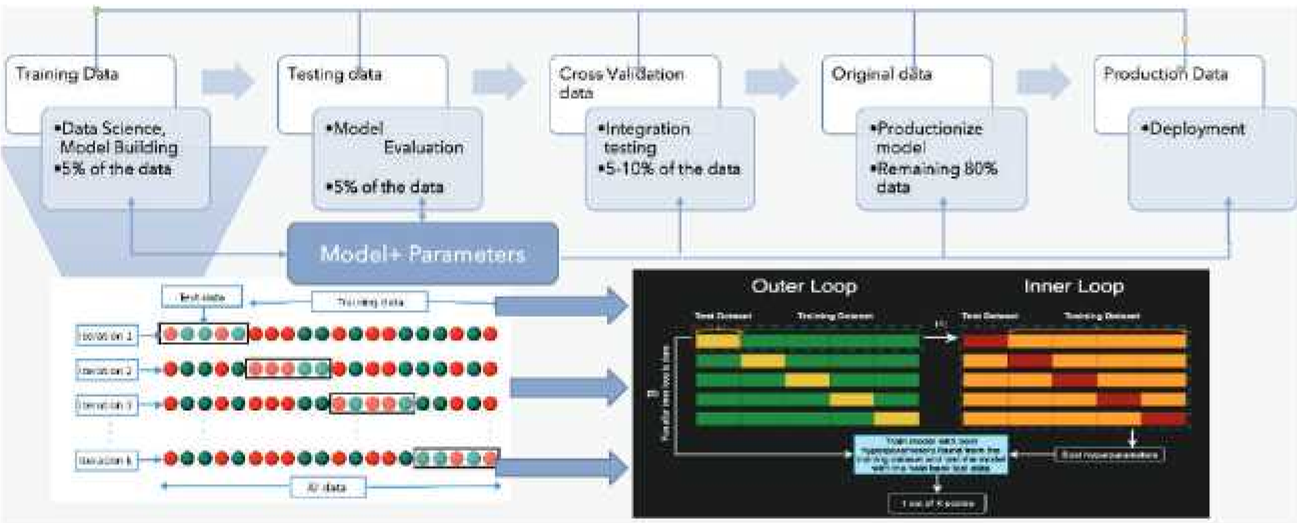


Fig. 2.6: Agile model for deep learning

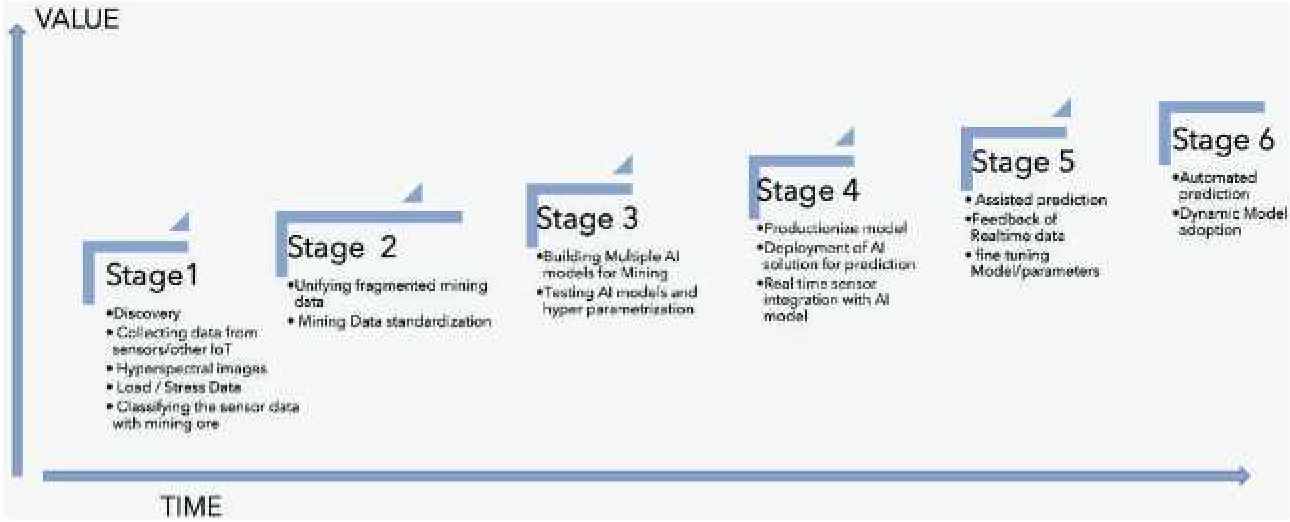


Fig. 2.7: Maturity model for AI in Mining 4.0

Critical Success Factors of CPS Adoption & Implementation

- ✓ Industry Culture and Communication
    - Resistance to new ideas, especially those concerning automation
    - Irrational fear of job losses
    - Lack of trust in AI/Machine Learning
- ✓ DATA
    - Incomplete/ inconsistent/ non-standardized data or Low volume data.
    - Under-sampled / Hyper Sampled / non-representative data
    - Simpson's Paradox
- ✓ Team and Skillset
    - Teamwork - Data scientists, ML developers, Hardware team, and Domain experts all work as One Team
    - Sponsors and Delivery Co-ordinators
    - Technical – ML Engineers, Developers
    - Architecture –Chief Architect, cloud and hardware specialists
    - Domain Experts
    - Data – Data Scientists, Data Engineers
- ✓ Hardware Sizing – Data will drive the Algorithm which in turn will decide the hardware. For instance V100 (multi lable sickit learn, eSRGAN, Naive Bayes), TPU (Tensor flow based, Keras) or T4 (Yolo, densenet, K nearnest neighbours)

2.4.1 Public-Private Partnership

The technology development projects for TRL 4 and above will have Industry Partners. We have identified a few industry partners in the mining domain: Coal India Limited, Sandvik, Dassault, Accenture, Vedanta, CDAC Kolkata, NVidia, and PMT Infrasciences. The thrust of Coal India Limited is on mining Technologies, CDAC on AI & CPS, NVidia on Cloud-based computing, and PMT Infrasciences on Sensor technologies and artificial intelligence.

TIH, in collaboration with PMT Infrasciences, will develop intelligent sensors in mining. They would also collaborate in developing AI algorithms for improved resource discovery and predictive maintenance. These two partners will also help in skill development.

The developed products will be deployed in some of the mines before commercialization. Once these are developed and deployed, these would be commercialized.

3 TECHNOLOGY PROBLEMS IN MINING AND MINERAL EXPLORATION

TexMin is mainly focused on two great problems related to Exploration & Mining:

- **Mineral Exploration**: Enhanced Resource Discoveries and Locating Deep Concealed Deposits using CPS systems to resist drilling
- **Mining**: Development of Integrated CPS-based Technologies for Smart, Safe and Sustainable Mining (3S Mining).

3.1 Mineral Exploration

For decades, the story of India's mining industry has been one of the vast potentials that have yet to be truly unlocked. The country shares a geological history with resource-rich regions such as South America, Australia, and South Africa, which along with South Asia, formed a single supercontinent called Gondwana before it broke up in the Jurassic period 180 million years ago.

GSI has a repository of more than 8500 geological reports (GR) of mineral investigations. These reports can be beneficial for planning exploration strategies and focusing on targets. Metadata of all these reports are accessible on the GSI portal.

Baseline geoscience data generation carried out by GSI has resulted in identifying an area of nearly 0.57 million sq. km. of Obvious Geological Potential (OGP) (NMEP, 2016). The mineral potential of geological terrains needs to be evaluated periodically by incorporating the latest primary geoscience data and exploration data as and when it is available. The concept of OGP is dynamic and needs to be regularly revisited with the up-dation of the database for various mineral commodities.

India has an area of 3.146 million sq. km. is mappable, and GSI has covered 3.1189 million sq. km. (99.14%) on 1:50,000 scale till March 31, 2018. GSI has identified 0.571 million sq. km. as an Obvious Geological Potential (OGP) area for minerals. A major part of this OGP area is yet to be fully explored. With fast depletion of easily accessible and shallow or near-surface ore bodies and decline in the rate of locating new mineral deposits within shallow depths, the challenge lies in identifying new areas for locating near-surface deposits and "deep-seated" and "concealed/ hidden" ore bodies through modern and sophisticated exploration methods/ techniques based on conceptual studies.

Adopting the mineral system concept means acquiring deep-penetrating geophysical data sets using passive seismic and magnetotelluric (MT) surveys in association with gravity data sets.

Several mineral system components can be associated with a detectable geophysical response viz., (a) fluid/metal source zones "altered" by the process of fluid/metal expulsion, (b) major magma chambers, which sourced magmas for orthomagmatic deposits, e.g., PGE, Pt, Ni-CuS deposits in mafic and ultramafic rocks, and, (c) lithospheric architecture, which would have influenced the movements of fluids, e.g., the faulted margins of major crustal blocks, and (d) palaeofluid reservoirs, where metalliferous hydrothermal fluids were stored before periodic and transient release. Understanding the geophysical responses of fluid source zones and palaeofluid reservoirs requires understanding the petrophysical characteristics of the alteration associated with the implied fluid-rock interactions.

Improving resource discovery needs to be tackled by multifold (a) to be precise with the target for drilling through deposit scale modeling and mineral discrimination, (b) defining a region to be a geologic province, (c) providing a detailed geological map, (d) REE and PGE Exploration, and (e) developing drones and sensors for drone survey. There are examples whereby using only 4% data; the prediction was accurate up to 86% in mineral exploration. Earth AI applied these tools to increase the resolution by 50X. Figure 3.1 presents an example how AI has improved the geological map of the area.

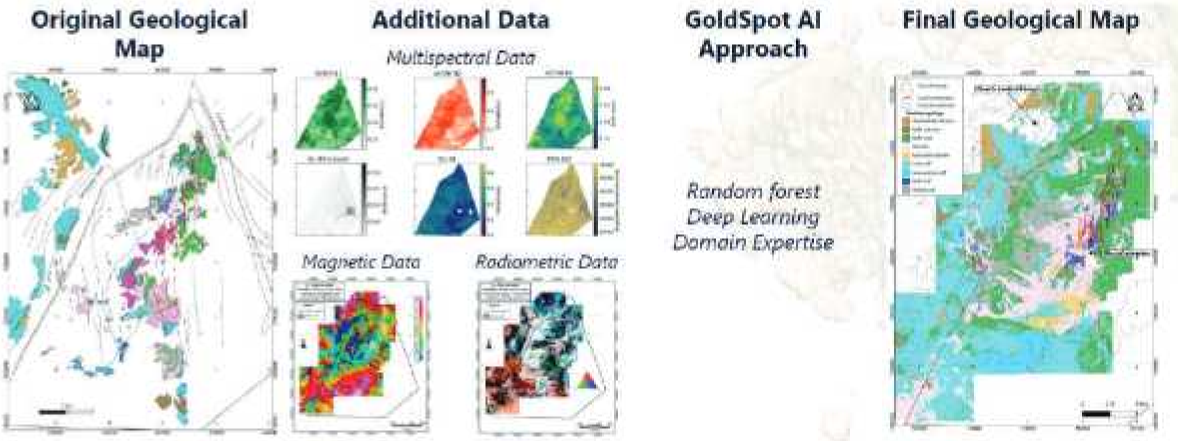


Fig. 3.1: Application of AI in improving geological map of an area

The idea is to initially use all the available data sets and apply different AI tools to generate prospective maps and find 100% of the existing deposits. Subsequently, less percentage of data to be used and determining the percentage of accuracy. In other words, suppose 5% of existing data is used, and the prediction up to 80% of the existing deposits. This would significantly reduce exploration time and cost. Earth AI, Australia, has built a proprietary mineral targeting technology based on AI to predict the location of new mineral deposits 50X better than the traditional exploration methods.

This requires the acquisition of new data sets and new strategies for the acquisition of geophysical data sets. In line with the GoI policy, the country is covered with NGPM, NGCM, and proposed for NAGPM; there should also be a conductivity and seismic map of the entire country. Drone-based acquisition needs to be initiated.

The following grand problems in Exploration are under the scope of TexMin Hub.

3.1.1 Enhance Resource Discoveries

Discovering new sources of minerals can be notoriously difficult, but also very rewarding. According to Goldspot (2020), the chance of finding a new deposit is around 0.5%, with odds improving to 5% if exploration takes place near a known resource. Machine learning and artificial intelligence (AI) can solve two of the mining industry's biggest challenges: rising exploration costs and a lack of discoveries.

The concept of artificial intelligence needs to be applied in defining new discoveries and reducing cost and environmental impact by optimizing drilling. The tag line for this objective is Resist Drilling.

The various problems with scopes, status, gaps and deliverables are as under:

a. Deposit Scale Modelling

Scope: To define the potential ore geology and to generate the target for drilling. Once the mining progresses the data should be used on regular basis to monitor the health of the reservoir.

Present Status: The geological maps and geophysical maps are not similar for deposit scale modeling. The geophysical maps are available at a typical prospecting level, whereas geological maps are on a regional scale.

Gap: India, as such, does not have a detailed geological map on a local scale. However, the geophysical surveys are conducted on a local scale. Thus, it becomes difficult to integrate the geological and geophysical maps on the same scale.

Deliverable:

- Geological and Geophysical maps on the same scale.
- 3D and 4D maps on the basis of integrated studies.

b. Mapping Lithospheric Architecture

Scope: A favorable geodynamical setting and lithospheric architecture, the origin of a mineral system include other factors such as sources, drivers, path-ways of metal carrying fluids along with their transport, depositional, and preservation processes.

To successfully target major new economic mineral deposits under cover requires a better understanding of the architecture of the whole lithosphere that focuses magmas and fluids on producing large deposits or deposit clusters.

Present Status: Passive seismic and magnetotelluric (MT) surveys have been adopted to acquire deep-penetrating geophysical data sets, particularly in mineral-rich country Australia. One of the extensive programs in this regard is the Lithoprobe program in Canada that has led to a comprehensive understanding of the evolution of the northern half of North America. In general, in deep surveying, one or more components of the mineral system is targeted to obtain a detectable geophysical signal response. Recent studies have mapped deep crustal structure in a mineralized Archean terrain using MT resulting in the discovery of two suture zones which are possible key indicators of regional-scale prospectives for multiple types of mineral deposit.

The fluid inclusion study provides the fluid pathway to focus mineralizing fluids into the upper crust. Geochemical, isotopic, ore-petrographic and geochronological studies can help us constrain the regional extent of any mineralized zone in three dimensions when combined with high quality geophysical and structural data obtained for the subsurface.

Gap: The acquisition and interpretation of geophysical responses of the various components of a mineral system are among the significant challenges of deep-penetrating methods. While the geophysical responses of some of the components are quite well-understood, such as those of major fault zones, other still remain elusive and are far less understood.

- The ultimate goal is to define the mineral system for understanding the metallogenic province through Developing 3D optimization tools for joint inversion of data sets constraining with petrophysics
- Identifying deep-penetrating faults and crustal suture zones, which are important controls on the movement of metal-bearing fluids and hence indicators of perspectivity.
- Formulation of self-consistent numerical models of the mineralogical evolution of fluid chambers in lithosphere and upper mantle.
- Development of laboratory models to study the fluid-rock interaction resulting in rock deformation and thermal transitions in mineral systems due to heat transfer.
- Understand and characterise the fluid bearing mineral system components with respect to their response to geophysical exploration methods.
  - Formulation of self-consistent numerical models of the mineralogical evolution of fluid chambers in lithosphere and upper mantle.
  - Development of laboratory models to study the fluid-rock interaction resulting in rock deformation and thermal transitions in mineral systems due to heat transfer.
  - Understand and characterise the fluid bearing mineral system components with respect to their response to geophysical exploration methods.

c. Mineral Discrimination

Scope: One of the major problems of mineral exploration is the ability to distinguish between uneconomic mineral deposits and economic mineralization reliably. The mining industry uses many geophysical methods to locate mineral deposits, but mineral resources identification and characterization is a challenge. There is an urgent need to reassess such mineralization, especially within the most promising metallogenic host, using ecologically friendly approaches (for instance, minimizing the need for drilling). Induced Polarization (IP) is a non-intrusive electromagnetic imaging technique looking at the low-frequency polarization of rocks occurring typically in the frequency band 1 MHz-200 kHz.

Present Status: Though important information is expected from the non-linear behavior of IP, hardly a rock has been performed. Recently, Andre Revil and his group have reassessed the mechanisms responsible for the linear induced polarization response of mineralized rocks.

Gap: IP has limited use due to: (1) lack of a fundamental unified theory of its causes for ore bodies, (2) non-linear induced polarization of mineralization is terra incognita with very few exceptions, (3) a large dataset of experimental data looking at the effect of ore types, salinity, temperature, and non-linear effect is, to date, missing, (4) there is a gap between the way IP is classically imaged and what could be done by merging more information (such as geological, petrophysical, and geophysical data).

Deliverable

The goal is to improve our fundamental understanding of the linear and non-linear polarization phenomena of natural mineralized porous media at various scales and over the frequency band 1 MHz-30 MHz. The interfacial and textural properties of rocks will be characterized.

d. Petrophysical Data Base

Scope: Physical property data become essential when the geophysical datasets are interpreted with fewer geological constraints than for shallower targets because of the high cost of deep drilling.

To understand the geological controls on physical properties in hard rock environments it is necessary to analyse the petrophysical data not only in terms of the properties of different rock types. It is also necessary to consider the effects of processes such as alteration, weathering, metamorphism, and strain, and variables such as porosity and stratigraphy.

The petrophysical data can be combined with geochemical, petrological and mineralogical data to derive explanations for observed physical property variations based not only on rigorous rock classification methods, but also in combination with quantitative estimates of alteration and weathering.

To understand how geological processes will affect different physical properties it is useful to define three end-member forms of behaviour i.e., bulk, grain and texture Thinking in terms of how geological processes change the key characteristics of the major and minor mineralogical components allows the resulting changes in physical properties to be understood and anticipated.

Present Status: Canada and Uganda have created a petrophysical data base.

Gap: Even the datasets of Canada and Uganda consists mainly of density and susceptibility not of other physical properties. India does not have such database

Deliverable

- Petrophysical data sets of different metallogenic province of India consisting of density, susceptibility, conductivity, resistivity, chargeability, and velocity, location, stratigraphic unit and lithology, information of weathering, alteration, metamorphism and porosity, and geochemical and mineralogical information

e. Remote Survey Hyper-spectral imaging

Hyperspectral imaging is a special case of spectral imaging where often hundreds of contiguous spectral bands are available. The commercial impact will be enormous, particularly in the field of mineral exploration. While gold occurs in amounts too small to detect with any available technology, more common minerals like kaolinite and arsenic, which are products of some of the same geological processes, are clearly visible in open landscapes, as is the case in much of the American West or Australian desert. For the diamond industry, kimberlite pipes, the volcanic formations that brought diamonds to the surface, are easy to identify from the air with hyperspectral imaging.

Present Status: Hyperspectral remote sensing for mineral exploration and also it is an effective tool for the identification and mapping of minerals over large and often remote and inaccessible areas. Currently, there is an increasing number of sensor technologies which have encouraged researchers to use hyperspectral imagery. Furthermore, detailed and comprehensive mineral maps of the drill core samples provide an in depth understanding of the entire ore body.

Gap: Routine use of existing hyperspectral systems by the minerals industry has been hampered by the unavailability of systems for industrial use, the high cost of hyperspectral data (when available) compared to typical multispectral data, the need for additional research into the processing of hyperspectral data, and what types of features should be extracted from pixels.

Deliverables

- System development and deployment
- Mineral mapping and feature extraction for HSI. In HSI one of the biggest challenges is determining what types of features should be extracted from pixels.

f. Rare Earth Elements and Platinum Group of Elements

Scope: Rare-earth elements (REE) are an essential component of numerous advanced technology applications including high efficiency batteries, emerging energy technologies, and key defence systems. India's rare earths reserves sit at 6.9 million MT, and the country produced 1,800 MT of rare earths in 2018. Reports suggest that the country's rare earths industry has strong potential and has nearly 35 percent of the world's beach and sand mineral deposits, which are significant sources of rare earths.

The platinum-group elements (PGE) include platinum, palladium, rhodium, ruthenium, iridium, and osmium. These metals have similar physical and chemical properties and occur together in nature. The properties of PGE, such as high melting points, corrosion resistance, and catalytic qualities, make them indispensable to many industrial applications.

Present Status: Of late there has been significant interest in REE and PGE exploration. In an annual exploration review, Wilburn and Karl (2018) reported that the United States Geological Survey (USGS) conducted extensive hyperspectral surveys in Alaska and evaluated the mineral potential for REE in addition to other metal deposits throughout the State in 2017. India which account for about 5% of the world's REE reserves, currently exploits its primary resource, monazite. The Geological Survey of India (GSI) has taken up number of REE exploration projects across the country during the last 5 years. The search for REE mineralization includes identification of anomalous concentration zones on the basis systematic geological mapping (SGM) at scale 1:50,000, specialized thematic mapping (STM) at scale 1:25,000, and National Geochemical Mapping (NGCM) at scale 1:50,000 and delineation of target zones for enhanced potential through reconnaissance stage investigations.

Gap: Exploration strategy, looking for source not for indicator

Deliverables

- to develop geophysical approaches to rare earth element evaluation,

- to conduct geochemical and mineralogical analyses of heavy mineral sand samples from both archives and field efforts,
- analysis of new and existing data on the samples to be performed to evaluate links between geophysical, geochemical properties, rare earth element content and local geologic processes
- rare earth element content and local geologic processes,
- synthesize geophysical, geochemical and geological data using AI, and to relate results to geological processes acting on a regional scale, and
- dispersion of REE/PGE in secondary environments such as placer deposits, weathered horizons and gossans.

g. Cross Well Tomography

Scope: It has been observed the sub-surface properties are frequently changed from one place to another and sometimes due to limitation in the resolution of surface-based geophysical data the sub-surface heterogeneity is not properly captured. Even same sub-surface properties may not belong within two nearby drilled wells. In this survey P, S and surface waves with different wavelength can be used to image the sub-surface geology. Wavelength variation, distance of source receiver and different array coverage will generate the tomography model with various resolution. The velocity model will be used for detail and high-resolution interpretation of sub-surface geology and would help in obtaining 2D and 3D images.

Present Status: This is quite common in oil and gas industry and hardly being used in the mineral exploration. There are some studies on mathematical simulation and laboratory studies.

Gap: The mathematical simulation and laboratory studies have shown encouraging results in resolving uncertainties. But real field application has not been attempted.

Deliverables

- Cross well tomography maps
- Integration of these with surface maps to reduce uncertainties

3.1.2 Get Real-Time Data

Retrieved by AI instruments that are installed onto drill rigs, real-time data aids in accelerating timelines for multiple mining stages and decision-making intelligence. Remote sensing data is used for rock-face identification and soil classification, while satellite imagery, aerial photography, geophysical maps, and drone-based monitoring are used to predict mineral prospectively, or the locations of potential ores.

a. Development of an autonomous multirotor unmanned aerial vehicle for geophysical survey

Scope: An autonomous aerial vehicle can be utilized for geophysical survey in remote/inaccessible regions. Off the shelf market solutions can only provide battery powered multicopter which may not be able to provide the lifting capacity and flight time, both at the same time. Hence, a fuel powered multicopter UAV with customized requirements for geophysical survey is the need of the hour.

Present Status: Gem systems have the capabilities of manufacturing the drones that can undertake airborne surveys. Earth AI implements its own software only onto readymade drones.

Gap: The platform of Gem systems can only carry maximum of 4 kg payload, also their magnetometer is 3.5 kg in weight with fly/hover is only up to 20 minutes. The drone of GEM Systems is not suitable for mounting any instrument other than their magnetometer.

Deliverables

- To develop an unmanned aerial vehicle UAV which can carry up to 10 kg payload (geophysical instruments, measurement systems etc.) and fly/hover for up to 90 minutes.
- To develop the craft by avoiding the use of materials that can potentially interfere with the functionality of the instruments being carried as a payload.
- To develop appropriate interfaces to provide the power required by the onboard devices during survey.
- To minimize the turn-around time so that it will be easy to prepare for the next round of survey.
- To develop a friendly and nearly autonomous user interface for the ease of operation.

b. Drilling Technology

Scope: The mineral exploration involves drilling to discover what is below the surface. Drilling generally represents the largest single cost associated with mineral exploration and the delineation of an ore deposit once it has been discovered. Decreasing the number of drill holes, increasing the drilling rate, or reducing the energy requirements for drilling would have a substantial impact on mineral exploration and development costs.

Present Status: In mineral exploration the conventional drilling technology is used unlike oil industry.

Gap: No significant changes in mineral drilling technology or techniques have been made for more than three decades. This contrasts sharply with spectacular advances in drilling technologies, including highly directional drilling, horizontal drilling, and a wide range of drilling tools for the in-situ measurement of rock properties, for the petroleum and geothermal sectors.

Drilling is the invasive aspect of mineral exploration. The environmental impacts of exploration activities could be significantly reduced by the development of drilling technologies that would minimize the footprint of these activities ground, viz., miniaturization of drilling rigs, the ability to test larger areas from each drill site and better initial targeting to minimize the number of holes.

Deliverables

- Interpretational techniques for hyperspectral data
- hand-held and down-hole analytical instruments

- directional drilling, better bits, down-hole logging
- improvements in slimhole drilling and in-situ measurements

c. Virtual Reality (VR) Technology

Scope: The mineral exploration industry has always faced enormous and varied risks concerning safety, politics, regulations, fluctuating markets, and physically challenging environments, to name a few. Further, as one goes deeper, the challenge is more complex than ever with cost of exploration is pretty high, the discovery of new deposits has been rare and market volatility. To unlock value, companies are emphasizing efficiency, a goal that depends on highly skilled individuals. Meanwhile, the industry is undergoing a crew change, with large numbers of older employees leaving. As a result, the demands for the dwindling ranks of experienced personnel are escalating, and companies are struggling to leverage their expertise.

Further, the deep exploration will make the pace of operational change across the industry dramatically changed. Can with minimum travel requirement, employees can work remotely. The bottom line is to reduce the exploration cost, i.e.; companies have to do more with less, on tighter budgets, with fewer employees, and at unprecedented speeds.

Present Status: No VR Technology in mining.

Gap: The oil and gas technology has been a virtual reality but not in mineral exploration. It has the potential to alleviate the profound challenges faced by the industry. Moreover, various factors — the abundance of data, the increasing availability of that data thanks to IT/OT conversion, and the trend toward digital transformation — uniquely position the industry to capitalize on the technology.

Deliverable

- VR Technology

3.2 Safe, Smart, and Sustainable (3S) Mining

By deploying best practices in mine planning, scheduling, and process improvements, mines will reap direct and indirect cost savings and become more productive, predictable, and profitable. Each mine is different, but key to deploying best practices is the use of a modern integrated mine planning and Scheduling solution that can keep pace with the incoming mine data, ensure accuracy, accelerate mine modelling and plan output, facilitate information sharing, enable the mining of complex geographic areas, and free up valuable human resources to focus on continual improvement and operational excellence.

As the mining industry moves toward complete integration of production systems, planning and production process will be integrated seamlessly. Technologies for integrated mine planning, scheduling, and production process will be developed to cater to the variabilities of mining operations. Optimization algorithms will account for uncertainty in all parts of the production process, from variability in geo-metallurgical properties to reliability and availability of fixed and mobile plants to fluctuations and trends in costs. TIH will use industry standard technologies of mine planning and operation and develop an integrated solution using CPS technologies.

3.2.1 Smart Mining

a) Optimization of mining machinery and resources using CPS

Scope: To produce the desired volume of minerals with due regards to safety and productivity through the application of state-of-the-art technologies, minimizing human intervention in decision making applying artificial intelligence tools and data analytics; and remote operation of mining equipment, wherever possible, adopting sensor-based automation under hazardous work conditions. The scope of this study includes improving the operational efficiency (OE), availability and utilization of machines through predictive maintenance, resource optimization through optimum machine deployment, and energy optimization.

Present Status: Worldwide mining companies typically collect vast amounts of data from drills, trucks, processing plants, and trains. Yet rarely is this information used to generate insight; in some cases, miners use less than 1 percent of the information collected from their equipment (Fig. 3.2). However, they use 80% of their time in data acquisition and only 20% time in data analysis. Analyzing the data and estimating the probability of failure of specific components—rather than using a traditional time-based approach—helps reduce maintenance spending and prevent unplanned interruptions that cost metric tons.

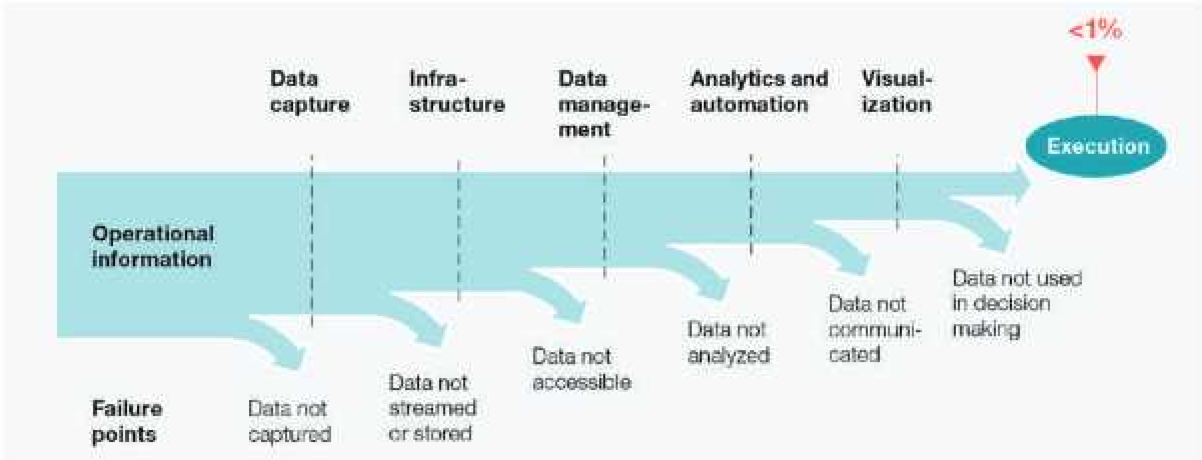


Fig. 3.2: Mining companies use only a fraction of their data

However, Indian Mining companies at large are still in the process of looking for standardization of the data to be retrieved from various operations at floor level, including their integration. Most mining companies currently operate using a calendar-based preventive maintenance model. By prescribing maintenance work on fixed time schedules – or based on basic operational statistics or best practices. An even more fundamental approach to maintenance is 'reactive maintenance'. This strategy involves letting an asset run until it fails. This approach only works for non-critical assets with low replacement costs and does not disrupt operations' overall safety and reliability. As of now, energy audit for all unit operations right to mine to mill is not yet being practiced in Indian Mining Industry. As a result, there is no benchmarking of energy consumption for each operation.

Gap: Less than an adequate application of CPS in OE, resource, and energy optimization. Lack of maintenance strategies using data analytics paired with predictive maintenance

Deliverables

- Improving OE by optimizing the unit operations in mining through application of smart sensors, real time data acquisition, data transfer and analysis for performance prediction using CPS.
- Increasing machine reliability and availability through continuous machine condition monitoring and online real time data transfer using suitable sensors and IoT, prediction of failure through data analysis of condition monitoring using AI; and implementing routine & preventive maintenance schedule based on machine health condition monitoring.
- Resource optimization through optimum machine deployment through capturing real time data on machine down time, idle time, operational delays etc. and its analysis using AI.
- Energy optimization in all activities from mine to mill through capturing unit-wise energy consumption data and its analysis using CPS and bench marking of energy consumption.

b) Mine Simulation Systems

Simulation of mining process is required to optimize the process, predict productivity, and test practicality of a given mine plan and schedule. In a mining process, production planning is quite complex and requires more advanced systems for simulating and predicting the outcomes regarding quality and quantity of ore, equipment system productivity and fleet size, operating cost etc. For examples, simulation of mining methods, equipment productivity, slope stability, underground mine ventilation etc. using modern technology tools would be some of the works that would be done extensively at the TIH in association with the industry and with local and international collaborations. The scope of the study includes: improvement of Accuracy in Geological Modelling, Accelerate Data from Field to Plan, Create & Analyse Multiple Scenarios, Combine Short & Long Range Models, and Integrate Planning & Scheduling

Present Status: Goldspot Discoveries Inc. aims to make finding gold using machine learning, Goldcorp and IBM Watson are collaborating to use artificial intelligence to review all the geological info available to find better drilling locations for gold in Canada

Rio Tinto is creating an intelligent mine that should deliver its first ore by 2021. Some companies have begun to use smart sorting machines that can sort the mined material based on whatever criteria a company wants.

Gap: Artificial intelligence and knowledge based expert systems can be utilized for planning of mining operations. Approach to planning of mines involves property selection, site characteristics, equipment analysis, and mine parameters. Traditionally, the time and resources required to continually collect this data, model and remodel scenarios, build and adjust mine plans, and plan out the effects on scheduling, has meant that no one could keep pace with the reality of what's happening in the ground. Even the best mine plans were still full of inaccuracies and best guesses based on past experience, not quantifiable data. This resulting gap between a mine plan and reality is where costly surprises creep in to negatively affect production schedules, output, and ultimately, mine profitability.

Deliverables

- 3D simulation & Modelling
- Digital Twins: By creating a virtual model that is fed real-time data from the field, scenarios can be quickly tested, and operations and production can be optimized
- Autonomous Drilling
- Autonomous Equipment: Greater use of self-controlling machines in harsh environments
- Reducing environmental impact with AI: Sensors and IoT to monitor excavation, extraction, and general mining activities, keeping tabs on the spread of waste and harmful materials.
- GIS analytical information with graphical representation for better understanding and policy making and AI based decision support system

c) Reduce risks: Development of Smart Communication, Sensing and Monitoring Technologies

A robust IT communication infrastructure sync with arrays of sensors and tracking tools in mine will enhance safety and provide real-time information, resulting in a quick response to some fatal situation. Communication and tracking technologies capable of bearing the rough terrain and extreme environment inside a mine and between the surface and underground workstations is a critical factor for remotely monitoring various mining operations. Internet of Things (IoT) can play a massive role in the mining operations to improve the safety of the workers with enhanced productivity. Wireless communication, which is a part of IoT setup, is already playing a vital role in underground mine communication (UMC).

Scope:

a. Development of effective and rugged communication systems in dynamic and adverse environment for surface and underground mines
   - Development of enhanced TTE system for UG coalmines
   - High Speed Communication Network for Opencast and Underground Mines (Coal and Metal)
   - Development of Portable Communication Systems for Miners in UG Coal & Metal Mines

b. Development of Integrated monitoring and AI based Predictions systems for failure of waste dump or working benches in opencast mines
   - Development of system of design and construction of dump through process control system of generation, transport and dumping of waste for maintain proper sequence and scheduling of dumping matching with operation sequence using by continuous measuring of waste generation, distance of source of waste generation and dumping site, phases of dump, slope angle of dump and using analytical software based on AI
   - Development of integrated monitoring system of stability of waste dump
     - UAV mounted sensors for real time continuous and precise movement monitoring of waste dump, active as well as old dumps.
     - Provision of alarm level and withdrawal level
     - Automatic messaging system
     - Development of a low-cost AI/ML portable RADAR system for Monitoring and prediction of Rock and Dump Slopes failure in Open Cast Mines.

c. Geospatial Technologies for Mine Surveillances & Monitoring

- Precise Monitoring: Global Navigation Satellite System (GNSS) and Underground Positioning System (UPS)
- Air-borne based Mine Surveillances and Earthworks Estimation (LIDAR/Drone)
- Spatial Visualization using AR, VR and LIDAR Technologies
- Mining Area LRM: BIS and LIS integration through GIS
- Land Dynamics: LULC; Change Detection using RS
- Mineral Resource Mapping

Present Status: The World Economic Forum, 2017, has classified mining technologies into four main categories:

- Automation, Robotics, and Operational Hardware: Autonomous Operations, Smart sensors etc.
- Digitally Enabled Workforce: Remote Operations Centre
- Next-Generation Analytics and Decision Support: Advanced Analytics and Simulation Modelling, AI
- Integrated Enterprise, Platforms and Ecosystems: IoT, Asset cybersecurity, integrated sourcing, data exchange, commerce etc.

These above areas have the potential to add more than $315 billions of additional value to the mining industry. A few of the Indian mines at present are using active RFID (Radio Frequency Identification System) wireless mesh networking technology with Real Time Locating System (RTLS) and Real Time Sensing System (RTSS) with data acquisition system for underground mine communication and sensing.

Gap:

- Global mining productivity has declined 3.5% a year over the past decade (Mckinsey). This calls for digitalization of mining operations.
- In India, in the past 26 years on an average 0.31 individuals have lost their lives per thousand persons employed every year [DGMS]
- Monitoring the spatial and temporal underground information in the dynamic environment to maintain the health and safety of the personnel is still a challenge due to limitations of communication and sensor technologies in such an environment.
- National Mineral Policy, GoI (2019) emphasizes on the development of robotics, and automated equipment for mining, especially for deep mining and transportation to surface.

Deliverables

- Development of an effective underground mine communication system under dynamics and difficult sub-surface environment: Improved Through-The-Earth (TTE) Communications for Underground Mines.
- Portable communication devices based on UHF frequencies for the miners in underground coal mines.
- Development of Underground Positioning Systems (UPS): Smart portable system for tracing miners including mine safety monitoring and alerting.

- Development of a low-cost AI/ML portable RADAR system for Monitoring and prediction of Rock and Dump Slopes failure in Open Cast Mines.
- A Novel Surveillance and Evacuation System for Underground Mine Safety
- Application of Drone, LIDAR, GIS & Remote Sensing based Mine Surveillances System

3.2.2 Safe Mining

Current scenario of mines safety in India

During the year 2019, there were 51, 40 and 6 fatal accidents involving 55, 42 and 11 fatalities whereas in 2018, there were 49, 45 and 2 fatal accidents involving 70, 48 and 2 fatalities in coal, metal and oil mines, respectively. The number of fatal accidents during 2017 there were 61, 39 and 1 fatal accidents involving 67, 63 and 1 fatalities in coal, metal and oil mines, respectively.

Occurrence of disasters

According to Directorate General of Mine Safety (DGMS, 2016), there were 222 major accidents (accidents with 4 to 9 fatalities per accident) and 60 disasters (accidents with 10 or more fatalities per accident) occurred due to different causes like roof fall, inundation, explosion, fire etc. in Indian coal mines between 1901 and 2019. Out of these 60 disasters there are 25 disasters only due to explosion, 18 cases belong to inundation, 11 disasters contributed by roof fall/side fall, collapse of pillars, 3 disaster from fire and rest 2 disaster because of other causes like air blast, rope and chain breaking in the shaft etc. This can be evidenced by the major accidents including disasters are the function of those 4 causes which repeat time to time and play a significance role from 1901. Indian coal mining industry alone has experienced 282 major accidents including disasters killing 2239 persons from 1901 to 2016 due to some specific regions like Roof fall/side fall, Explosion, Inundation, Shaft accidents, Fire and Others causes.

Disasters are occurring almost at regular interval which attracts concern of all the stakeholders including industry, regulators, researchers etc. Indian coal mining industry has lost 167 precious lives on account of eight disasters that occurred in past twenty years i.e., 2000-2019.

Experience of coal mining in rest of the world is not much different. In 2010, due inflammable gas/ coal dust there were four coal mine disasters in mines viz. Pike River Coal Mine, New Zealand (29 casualties), Upper Big Branch Coal Mine, United States (29 casualties); Raspadskaya Coal Mine, Russian Federation (90 casualties); and Anjan Hill Coal Mine of India. However, this excludes disasters that occurred in Public Republic of China. Soma coal mine disaster, Republic of Turkey claimed 301 precious lives in 2014.

Major and repetitive causes of disasters are:

- Spontaneous heating of coal and Mine Fire
- Methane Explosion
- Coal dust explosion
- Inrush of water or unconsolidated mass
- Strata failure
- Roof & Side Fall in Underground mines
- Bench and Waste Dump failure

Other than disasters, major accidents causing single or multiple fatality or serious bodily injuries, or health hazards occur due to

- Uncontrolled movement of mobile equipment – collision, run-over, toppling, hit by machines
- Blasting
- Failure of structural integrity of machines / plants / infrastructures
- Exposure to toxic gases, DPM, Dust
- Unstable surface due to subsurface cavity or fire caused by underground mining activities
- Fatigue and Physiological stresses

3.2.2.1 Major hazard mitigation using CPS

Strategy for improving safety and health performance of Indian mines through Technology Development with Cyber Physical System (CPS) intervention is discussed here.

a. Spontaneous combustion of coal

Scope: History of Spontaneous heating of coal in Indian mines is more than a Century old. There had been fire in mine workings and coal seams in almost all the coalfields in India basically due to higher susceptibility of Indian coal in general and inappropriate mining methods adopted in particular. Fire in coal mines extends over large area horizontally as well as vertically. Safety and productivity of many mines are seriously affected due to presence of fire in working coal seams, as well as, in overlying and underlying coal seams of same mine or adjoining mines. Extent or progress of fire could not be controlled effectively in the past due to lack of adequate procedure and fire mitigation technology. Million tonnes of coal are lost due to such large scale fire across the country and many underlying seams are not safe to work because of fire in the upper seams. Unless these fires in the upper seams are controlled, million tonnes of coal in the lower seams will remain unworkable.

There had been many disasters due to spontaneous heating in coal in the past like New Kenda disaster in 1995 killing 55 persons, Jagannath disaster in 1981 killing 10 persons or coal dust explosion due to coal fire is a serious challenge to Indian mining industry.

One of the primary reason of very less coal production from underground mines in India is spontaneous heating of coal. Environmental impact of spontaneous heating of coal seams is also huge as millions tonnes of coal are being burnt giving off huge quantity of CO or CO_2 causing large scale greenhouse gas (GHG) effect of atmosphere for a long time.

Present Status: The status of application of technology for detection, monitoring and control of mine fire due to spontaneous heating is abysmally poor. The predominant method of extraction of coal by underground mining method in India being conventional bord & pillar mining, extracts only 40-50% of in-situ coal reserve and rest of the coal is lost. Such huge quantity of coal, highly susceptible to spontaneous heating in most of the cases, remain in the underground to cause large scale spontaneous heating, if not adequately and effectively isolated. Similarly, absence of state-of-the-art continuous, reliable and effective gas monitoring system, inadequate handheld portable detection instrument, lack of suitable technology for quick and accurate analysis of mine air samples etc. results into failure of detection of such events of spontaneous heating at early stages and allow it to grow beyond control, thereby seriously endangering the lives of work persons present in the underground and also loss in property, coal reserves and mining equipment. However, the picture of countries like Australia is quite different. Learning from the past, they have adopted risk based legislation requiring real time and continuous monitoring of mine atmosphere like telemonitoring system, tube bundle system, online transmission of data and its analysis to detect any event of spontaneous heating at very early stage and effectively dealing it before escalation of the fire beyond control. The system is also capable of locating the source of heating, if any, quite precisely to deal without much delay. They also have risk assessed protocol of safe withdrawal and re-entry of persons.

Gap: There is significant gap in the approach and methodologies for dealing with such mining hazards having potential to cause disaster. The gaps are mainly in the area of failure in prevention of oxidation of coal, detection at early stage, effective dealing in containment of the spontaneous heating event and also in rescue or recovery. There is a strong need to carry out research in the area of adoption of suitable mining methods and technologies for prevention of large scale oxidation of coal, adoption or development of suitable technologies for early detection and mitigation of such event to prevent loss of lives & property by effective isolation by designing the work place and mass inertization and timely withdrawal and rescue of persons by self-escape or aided escape methods.

Deliverables

- Development of integrated system for continuous monitoring of indicators of spontaneous heating using sensor based technology, analysis of spontaneous heating indices using artificial intelligence (AI) based analytical software and activation of control measures including Mass inertisation (N_2 or CO_2), withdrawal of persons etc.
- Development of wearable portable sensors for detection of gases like CH_4, H_2, CO
- Detection of portable sensors for detection of hotspot

b. Explosion in coal mines

Scope: In Indian coal mines, 278 major accidents (with 4 or more persons killed in each accident) resulted into the deaths of 3367 persons and serious injury to 276 persons since 1901 to 2019. Out of these 278 accidents 39 accidents are due to explosion killing 1275 persons.

The explosion in coal mines take place mainly due to methane and coal dust explosion. Most of the methane explosions in coal mines are converted into coal dust explosions. There had been three disasters due to explosion in the last two decades killing 69 persons. Two main factors of methane explosion in mine are accumulation of methane in explosive range and source of ignition. The main cause is failure to detect accumulation of inflammable gases beyond threshold limit due to lack of continuous, reliable real-time monitoring of concentration of such gases in mine atmosphere, failure to take mitigating measures of diluting the concentration of such gases and preventing source of ignition mainly from fire in mines or electrical or frictional sparks. The other reason to prevent a major explosion is containment of the explosion due to lack of application of explosion inhibitor like water, stone dust etc. In most of the cases, huge number of persons are involved in such explosions as explosions are sudden and propagate at a very high speed across the whole mine. Failure to detect the explosive atmosphere well ahead of time results into failure in withdrawal of persons from the mines.

Present Status: The status of application of technology for continuous monitoring and detection of accumulation of inflammable gases in mine atmosphere is abysmally poor. In most of the mines, flame safety lamps and portable gas detectors are being used for detection of such gases. Very few mines are having continuous gas monitoring system, which are smart, reliable and capable of detecting all inflammable gases including methane, hydrogen, carbon monoxide and predicting correctly the explosibility of mine atmosphere in real time.

However, the picture of countries like Australia is quite different. All the underground coal mines have real time and continuous monitoring of mine atmosphere like tele-monitoring system, tube bundle system, online transmission of data and its analysis to detect any event of accumulation of inflammable gases at very early stage and effectively dealing it before escalation of the condition beyond control. At the same time, there are provisions for preventing any likely source of ignition from electrical sparks or frictional ignition by having interlocking power supply with gas detectors or water spraying etc.

Gap: However, there is significant gap in the approach and methodologies for dealing with such mining hazards having potential to cause disaster. The gaps are mainly in the area of failure in detection of accumulation of inflammable gases at early stage, effective diluting the concentration not allowing it to go beyond safe limit, prediction of explosive condition and automatic activation of mitigating measures.

Deliverables

- Development of Integrated system of continuous monitoring of accumulation of inflammable gases in mine atmosphere using sensor based detectors, analysis of explosibility indicators using artificial intelligence (AI) based analytical software and activation of control measures including ventilation on demand, withdrawal of persons etc.,
- Design and activation of sensor based explosion barrier to prevent propagation of explosion,
- Design of sensor based instrumentation for detection of methane layering by sensor based instrumentation,
- Development of portable sensors for detection of inflammable gases like CH_4, H_2, and CO, and
- Development of portable sensors for determination of inert content in roadway dust.

c. Inrush of huge quantity of water or unconsolidated mass

Scope: Sudden inrush of huge quantity of water or unconsolidated mass has caused many disasters in mines across the globe. The inrush of water may be from underground or surface sources of water. Causes of such disasters are mainly due to inadvertent connection of mine workings with waterlogged workings. Such inadvertent connections happen mainly due to failure in identifying existence of waterlogged workings in inaccessible areas or sometimes due to breach of barriers against water bodies due to wrong survey or lack of reliable methods for determining the size of barriers.

There had been 33 accidents (causing death of 4 or more persons in each accident) due to inrush of water killing 834 person and the worst mine disaster in India happened in 1975 at Chasnala Colliery killing 375 persons. There had been three disasters killing 60 persons due to inrush of water since 2000. In many occasions, there had been narrow escapes from such disasters because of absence of workers in the mines at that point of time.

Present Status: The primary method of determination of waterlogged mine workings is mainly conventional surveying. One of the critical existing statutory requirements against this hazard is drilling of advanced boreholes ahead of the working to prove the presence of waterlogged workings or any sources of water. However, such process is highly cumbersome and requires special drilling equipment (Burnside drilling apparatus) and skilled driller.

Gap: Error in surveying or plotting and sometimes incomplete mine plans result into accidental connection with waterlogged workings leading to sudden inrush of huge quantity of water into mine workings endangering the lives of the persons present in mine workings. Advanced boreholes ahead of working is seldom fulfilled relying only on physical examination by supervisors and information from mine plan. There is always chances of failure in observation and over-ruling or normalizing of indications of presence of water bodies or water logged workings in the vicinity, ultimately resulting into wrong decisions of advancing the workings without further precaution leading to failure of partings and causing inundation of workings.

Deliverables

- Development of geophysical method or instrument for identifying presence of water bodies /water logged workings / accumulation of unconsolidated material ahead of mine workings, which are inaccessible, and analysis of geophysical parameters of presence of water bodies using AI for predicting the location of such water bodies.
- Development of handheld portable water body detector for proving presence of water bodies immediately ahead of mine workings
- Continuously monitoring inflow of water into mine workings and analysing the data using AI to identify the probable hazard of inrush of water.

d. Ground failure in Underground mine workings

Scope: As the minerals are extracted, it creates a void and forces of different magnitude and directions start acting on the strata around the excavation. If the forces or load acting on the strata is more than the strength of the strata, there will be failure of strata. The strength of strata depends on many factors including its compressive and tensile strength, presence of joints or slips, inflow of water etc., and the load depends on size of excavation, depth of workings, presence of in-situ stresses etc. However, based on study of different parameters, strength of strata are calculated using empirical formula and based on that support designs are made using artificial supports like roof bolts or hydraulic props or powered supports.

One of the major hazards in underground mine workings is ground failure, i.e. failure of roof and sides of mine workings and endangering the lives of mine workers. In India, underground mining was predominantly manual in nature. Hence any failure of strata used to have serious impact on the safety of mine workers. From the past records it is observed that there had been

160 accidents, causing death of 4 or more persons in each accident, resulting into a total fatality of 928 persons since 1901. One of the main reasons of decreasing production from underground mine is the repetitive occurrence of accidents due to ground failure. Though manual mining is stopped since more than a decade now, total manpower engaged in underground mining is still very high and the risk of ground failure is unacceptable.

Present Status: Introduction of steel roof bolts replacing conventional timber supports have improved the safety performance and the rate of accidents have come down to a large extent, but the actual number of deaths due to ground failure is still very high. In the recent past, there had been 10 such accidents killing 54 persons from the year 2000 to 2016.

One of the major failure is in estimating the load on supports based on empirical formula, which is based on many assumptions. Though numerical modelling is used nowadays to estimate the strata behaviour, again it is subjected to lot of assumptions.

Gap: One of the critical contributing factors of such accidents is lack of predictive tools and methods of failure of roof and sides, thereby leading to failure to withdraw or removal of work persons before the actual failure.

Similarly, one of the current controls against the hazard of roof or side fall is physical examination by frontline supervisors, without any detecting tool. Some handy tools may be developed using the geophysical parameters of strata and showing the presence of bed separation and its location accurately. This will help the supervisors to take on spot quick decisions either to erect additional supports or withdrawal of persons

Deliverables

- Development of integrated strata management system for continuous monitoring of strata behaviour and analysing the data using artificial intelligence based software for prediction of failure of strata ahead of time.
- Development of handy tool for detecting presence and location of bed separation in roof rock, based on onsite monitoring of geophysical parameters of roof rock and digitally expressing the failure by using analytical software.
- Development of integrated strata management system for monitoring the strata behaviour by using sensors on the existing support system like hydraulic props, powered supports etc. and real time analysis of monitoring data for prediction of strata behaviour as well as activating the controls on support system as required.
- Continuous monitoring health condition of support system and prediction of failure of support system. Activating alarm for taking action and also activating alarm for withdrawal of persons in case of imminent failure.
- Monitoring behaviour of goaf in caving method of mining, using cavity scanner or similar other instrument, analysing data using AI to predict the behaviour of caving, like interval and magnitude of periodic weighting, main weighting, movement of strata vertically as well as horizontally, impact of superimposition of caving panels etc.

3.2.2.2 Minor hazard mitigation using CPS

Scope of intervention of cyber physical system and technology development against hazards other than principal hazards causing disasters is discussed in this section.

Other than the principal hazards in mining having potentiality to cause multiple fatality from a single event / accident, there are many other hazards in mining which causes significant impact on the safety and health of mine workers. Some of the critical areas where there is significant scope of CPS intervention are mentioned below:

a. Blasting

Scope: Drilling and blasting is the first unit operation performed in exploitation of minerals which influences all downstream operations. Drill and blast is used to unlock mining value, utilising digital and automated technologies to create safer, and more productive blast outcomes for mine operators.

At the core of the technological advancements are digital transformation of the blasting process, where rock recognition informs intelligent and dynamic blasting to deliver predictable and consistent outcomes. The downstream impact of variable and poorly controlled blast outcomes today impact as much as 80% of the total cost of operation of a mine. This presents an enormous opportunity to deliver value to the industry with intelligent, data driven blasting optimisation technology.

Blasting of rock is a very common and primary operation in mining, both underground and opencast, which causes significant impact on safety and health of persons. If the explosive energy is released uncontrolled due to various design and operational factors, it may cause serious accident. One of the common causes of accident due to blasting is accidental detonation of misfired shots. This mainly happens due to failure in identifying the location of misfired shots buried under the blasted material. The other common cause of accident due to blasting is hit by fly rocks generated by explosive energy due to uncontrolled release of explosive energy. The fly rocks in the form of projectiles may hit a person or equipment present in and around the site of blasting. The effect of blasting is not limited within the mine leasehold area, it goes beyond that in the form ground vibration and air overpressure due to blasting. The genesis of all these problems is mainly design and implementation of blast design. The other mitigating measure is management of blasting operations and implementing exclusion zones. For each blast, the exclusion zone is to be determined and enforced to ensure that no human or equipment is present within the exclusion zone. This is very difficult for large opencast mines without application of CPS technologies like identification tag, use of GPS coordinators and tracking system and effective communication system.

Present Status: Historically, blasting in mines has caused number of accidents causing fatal or serious injuries across the globe. This problem has been further complicated due to ever increasing size of blast , i.e. increasing quantity of explosives per round of blast for operational efficiency, which sometimes go up to 1000 te of explosives per round in some of the high capacity mines in the world. The problem in Indian mines is further complicated due to close proximity of human habitats, sometimes even less than 100m from the blast site. In 2018, 5.26 % of the serious accidents in non-coal mines and 3.5% fatal accidents in coal mines occurred due to use of explosive in mines whereas in 2019, 11 % of the fatal accidents in non-coal mines and 2 % fatal accidents and 2 % of serious accidents in coal mines occurred due to use of explosive in mines. Big MNCs in mining use complete Blast Control solution, which delivers sustainable improvements that reduces the overall cost of drill and blast operations by eliminating rework, excess drilling and explosives consumption, improves productivity through autonomous and seamless data transfer between blast engineers and field crews, and facilitates regulatory compliance. The information management component of the platform allows blast engineers to collate data from across the drill and blast process into a secure, centralised online location to speed up planning, analysis and auditing of blast data to meet regulatory requirements. However, in India, except few sites, such solutions are yet to be applied.

Gap: The next generation cloud or PC based platforms designed specifically to optimise blasting outcomes by integrating data and insights from digitally connected technologies at every stage of the drill and blast process, driving continuous improvement for miners. This enables the improvement in blast performance by seamlessly connecting data related to the entire drill and blast process under a single platform, linking geoscientific, blast modelling and design data with measured field operations data, optimised blast delivery and advanced learning for continuous improvement.

These cloud based Softwares include Blast information management system, blast design, blast modelling and simulation tools, blast pattern simulation and analysis tools, fly rock estimation and prediction tool, fragmentation prediction, blast induced ground vibration modelling and prediction, air blast prediction and muck profile prediction and estimation. The Measurement while Drilling (MWD) technology coupled with AI and machine learning to ensure the right explosives are used in the right place and initiated at the right time is under trial. The application of technology is with the aim of empowering rapid decision making, better operational efficiencies, better blast control to reduce damages due to blasting and preventing occurrences of fly rock or ground vibration, increasing the speed of implementation and importantly, maximising operators productivity, cost reduction and regulatory compliance.

Deliverables

- Development of suitable sensor based portable detector for identifying the presence and location of misfired shots by scanning the profile of blasted material and using AI for analysis of scanning data
- Development of App based tracking system using sensors or tags for ensuring human and equipment exclusion zone during blasting in opencast mines. Same system may be useful.
- Prediction of fly rocks from data of blasting detail using AI
- Development of expert system for measurement while drilling (MWD) technology coupled with AI and machine learning to ensure optimum blast design

b. Collision of mobile equipment or hit by machines in UG mines

Scope: Many accidents take place in mines due to collision of vehicles or other mobile equipment on mine roads and workings in underground mines. When the same roads are used by light vehicle as well as heavy vehicle, probability of heavy to light vehicle collisions increases significantly. In recent times, many mining accidents are caused due to run over while reversal or forward movement of large mobile machines. For underground mines, visibility is a challenge due to sharp corners and limited width of roadways. Similarly, many accidents take place in UG mines due to run over / hit by machines because of blind spot or lack of visibility or obstruction. As the sizes of mining equipment are increasing, the problem of visibility or blind spot is also increasing. It is very difficult to trace and track the movement of pedestrian or other vehicles by the operators of large machines without the provision of cameras and sensors. However, lot of studies are going on in this area to prevent such collision with the aid of intelligent sensors and warning system.

Present Status: A study of Indian mining accidents from 1973 to 2013 (Dash et. al. in Procedia Earth and Planetary Science 11 (2015) 539 – 547) indicated that 1735 fatal accidents, which is 31% of the total fatal accidents in Indian coal mines, occurred due to Collisions or run over on mine roads. Average number of accidents due to wheeled machinery on mine roads during the same period was ranging from 47.2 to 28.3 per year. The recent status of fatalities in last five years due to mobile equipment on mine roads are also similar, 26.47%, 25%, 32.78%, 31.58% and 22% in the year 2015, 2016, 2017, 2018 and 2019 respectively.

In countries like Australia, USA or Canada, the mobile equipment on mine roads are provided with number of cameras or sensors for detecting the proximity of any physical object and automatically warning the operators through audio-visual alarm signals. However, in India, some of the mines are now using proximity detection devices.

A recent circular No. DGMS (Tech) circular No. O 6 of 2020 Dhanbad dated 27 .02.2020 has been issued by DGMS on Minimum Design requirements for various Safety Features to be incorporated for use in Heavy Earth Moving Machinery (HEMM) & Heavy/Light vehicles in Open Cast Mines. The circular has very specifically mentioned about the provision of Rear vision camera meeting certain minimum requirements and standards

Proximity Warning Device - a system designed for early detection of static and moving objects, vehicles, human beings encountered within virtual target area during movement of Dumper / Tipper and for triggering warning the operator to prevent collision or run over.

Though proximity detection / warning is a requirement now, proximity detection for underground mine workings has yet to be made compulsory under current statute. Federal Regulations in USA requires operators of underground coal mines to equip place-changing continuous mining machines with proximity detection systems. MSHA has approved some proximity systems for use in underground coal mines that meet the "permissibility" requirements.

Gaps: Smart Proximity System is in use in the mines of USA and Australia maintaining operating zones around the equipment, like initial warning zone and shutdown zone. However, no such system is in use in Indian underground mines. There is significant scope of developing such smart systems for Indian mines

Deliverables

- Development of Sensor based proximity detection devices capable of detecting the proximity of another equipment and activating an alarm to both the operators.

- Development of Sensor based tags or personal wearable devices to send an alert signal to the machine operator approaching within the operating zones and similar audio-visual alert to the persons approaching the machine.

c. Potholing and collapse of important surface structures due to unstable subsurface areas from mine workings or subsurface mine fire

Scope: Potholing and sudden collapse of ground is very common in and around old mining areas like Jharia and Raniganj coalfield. Many accidents have taken place in the past as well as in recent times causing collapse of surface structures, houses, roads and railway lines and many times resulting into death of persons living in and around these unstable areas. The Howrah New Delhi Grand cord railway line is also affected due to unstable surface areas. Dhanbad Chandrapura railway line was stopped for more than a year apprehending collapse of railway track due to subsurface mine fire. These unstable areas are the legacy of past unscientific mining. All these areas are thickly populated and the risk to human lives due to these unstable areas are unacceptable. The main challenge of this problem is detection of the inaccessible unstable areas before the sudden collapse. However, research shall be conducted to identify such unstable areas using geophysical method based on geophysical characteristics of such subsurface structures.

Present Status: Underground mining in the shallow depth of Jharia and Raniganj Coalfields has made these coalfields prone to subsurface hazards like potholing and subsidence. Hazards that are associated with mine voids and subsurface cavity can lead to major accidents like subsidence, inundation from surface and instability of the ground.

There has been recent cases of potholing in the areas of Jharia Coalfield and its local inhabitants are in great danger, as the people are dwelling over these areas are unaware about the magnitude of the problem. The importance of Jharia coalfield in India lies in the fact that this is the only source of prime coking coal in the country. Jharia coalfields is affected by many subsurface Hazards and the ground is highly unstable. Incidents of potholing in the vicinity of Jharia coalfield due to subsurface coal mine fire, subsurface cavity and mine void is very common and as observed in a study, 29 such incidents have taken place since 2008. Number of persons, local habitats, have been killed due to such sudden dangerous pot holing and collapse of ground.

There had been occurrences of pot holing within 45m of acquired land of Jharia Baliapur road in the past. Since the workings were not approachable and extent of fire cannot be ascertained hence the stability of the area cannot be vouched safe. The Dhanbad Chandrapura rail route was kept closed for more than two years since 2017 as the rail line has been seriously affected by underground coal fire making the ground below track unstable.

Gaps: Risk due to instability of the areas because of sub-surface cavities or fire areas leading to potholing, sinking or sudden collapse of ground is a serious challenge. The main challenge is identification of potential unstable areas vulnerable to potholing, sink holing. Suitable method for precisely detecting / locating such subsurface unstable areas are yet to be developed. There is significant scope of application of geo-physical technologies and AI for locating such unstable areas.

Deliverables

- Development of suitable technology using geophysical method for detecting subsurface unstable areas and application of AI for locating such unstable areas.

d. Exposure to Diesel Particulate Matter (DPM) beyond safe limit

Scope: Large number of diesel operated machines are being deployed in underground mines in India. In confined atmosphere like underground workings, concentration of diesel exhaust containing SOX, NOX or Aldehydes and Diesel Particular Matter (DPM) poses serious threat to miner's health. DPM is a component of diesel exhaust consists of soot particles made up primarily of carbon, ash, metallic abrasion particles, sulphates and silicates. DPM is a sub-micron aerosol and it is a respirable particulate matter, which is more likely to penetrate the deepest part of the lung, where oxygen enters the blood stream. This causes concerns, because in this region of the lung, the body has fewer means of removing hazardous particles which attach to the lung tissue. Another consequence of the small size means that DPM is not easily removed from the air stream. Once airborne, a portion of DPM will likely remain airborne all the way to the mine exhaust. DPM is highly carcinogenic and the allowable concentration of DPM is very less (100 micro gm per cubic meter). It is essential to study the exposure of DPM. However, in India, little initiative has been taken against DPM exposure.

Present Status: Recent studies in Indian underground mines have shown the level of concentration of DPM at working places are much higher than the stipulated limit. Primary reasons of higher concentration of DPM is are machine engine condition, oil being used, operational condition like steepness and floor condition of mine roads, deployment of number of diesel machines in a ventilation circuit and most importantly velocity and quantity of airflow. It is very critical to continuously monitor the discharge from the machines, its analysis and prediction of concentration of DPM or other harmful diesel exhaust and activation of mitigating measures like ventilation flow control, controlling movement of diesel vehicles based on the results of AI based analysis on board.

Mine Safety and Health Administration (MSHA) enforces different DPM standards at underground metal/non-metal mines and at underground coal mines. For underground Metal/Non-metal Mines, a miner's personal exposure to DPM must not exceed 160 micrograms per cubic meter ($\mu g/m^3$) of total carbon (TC) when measured as an 8-hour time-weighted average. Australian Institute of Occupational Hygienists Inc (AIOH) believes that worker exposure to DPM levels should be controlled to below 0.1 mg/m^3 as an 8 hour time weighted average value, measured as submicron elemental carbon.

There is no such regulatory provision regarding the exposure limit for diesel exhaust and Diesel Particulate Matter in the existing mine safety regulations in India. However vide DGMS Tech Circular 30 /1973 following provisions are provided:

"Adequate arrangements should be made to circulate such quantity of air up to the site of blasting as to ensure, after every round of blast, dilution of carbon monoxide and oxides of nitrogen in the blasting fumes to less than 50 parts per million and 5 parts per million respectively within a period of 5 minutes"

Gap: To comply with the statutory requirement, there is a requirement of Real Time Diesel Particulate Matter Monitor. The NIOSH 5040 method involves taking samples from work site and analysing at laboratory. Although this procedure may be the most accurate method for collecting and measuring compliance samples of DPM, the time and cost involved in the process make it an impractical method for mines that are looking to monitor the effectiveness of DPM controls. There are some other real time DPM monitors which gives results equivalent to NIOSH 5040 method. However, in India, such monitoring system is not yet been implemented. There is significant scope of developing sensor based continuous monitoring system of DPM in mine workings and also personal exposure to DPM.

Deliverables

- Development of integrated system for sensor based continuous monitoring of exhaust discharge from the machines like SOx, NOx, CO and DPM,
- Analysis of data using AI and prediction of concentration of DPM or other harmful diesel exhaust and
- Automatic activation of mitigating measures like ventilation flow control, controlling movement of diesel vehicles

e. Exposure to toxic gases beyond safe limit

Many toxic gases are generated in mine workings from different operations or from spontaneous combustion of coal. When the work persons are inadvertently exposed to such toxic gases, they are seriously affected and sometimes leading to death or serious health impact. This problem can be effectively dealt by detection of such gases and its concentration accurately so that the persons may avoid being exposed to such toxic atmosphere or don some safety apparatus like self-rescuer or oxygen breathing atmosphere.

Deliverable

- Development of Portable wearable sensor based detectors of toxic gases and activating alarm in case of concentration of such gases crosses threshold limit.

f. Workmen's Fatigue and physiological stresses or disorders

Scope: One of the critical factor of accidents at workplace is fatigue of operators or supervisors, leading to wrong assessment of workplace hazards and failure to operate machines safely, as mining is a stressful job and deployment of workers in different rotational shifts create huge fatigue to mine workers, particularly in night shifts. Similarly, long working hours and arduous working conditions result into high level of physiological stresses on mine workers, which may also cause fatigue, as well as, may sometimes lead to serious physiological disorders in the form high blood pressure or even heart failure. Ergonomically poor machine design may cause physiological disorder like Musculoskeletal Disorder (MSD).

Present Status: Studies are being conducted throughout the world on detection of fatigue level in critical work groups to take timely mitigating measures. Till today, fatigue is mainly being monitored by voluntary declaration, which is not a full proof method.

Gap: There must be some physiological effects of fatigue in human body. If these physiological effects are monitored and analysed using AI, level of fatigue may be predicted and accordingly, operation of the machine may be interlocked with the digital fatigue detectors to prevent mal-operation of machines leading to accident.

Deliverables

- Measuring and monitoring of physiological effects of human body due to fatigue, physiological stresses due to working and task conditions, and physiological disorders due to lack of proper ergonomic design of machines
- Prediction of fatigue level, level of physiological stresses and physiological disorders by analysing the data using AI.
- Activation of machine interlock with digital fatigue detectors.

g. Loss of structural stability and integrity of heavy machines or structures in mines

Scope: Large opencast mines of today are using very large capacity heavy machines like dragline, crane, shovel, drill machine etc. Structural stability and integrity of such heavy machines are highly critical, similarly, for underground mines having vertical shaft, structural integrity of winding headgear structures are also very critical. Risk of failure of structural integrity due to failure of some critical components is very high.

Again, structural stability of large mobile machines on uneven mine roads and mine workings is also very critical and there had been numerous cases of toppling of such heavy machines due to failure in maintaining structural stability of such machines due to change or modification in original structural design or dynamic effects of uneven road surfaces. The consequence of such failure in structural stability causing toppling of these machines may be catastrophic.

Present Status: Many accidents have taken place across the globe due to such failure resulting into loss of lives or injuries and huge loss of property or asset. Detection of such hidden micro failure in structure and analysis of effect of dynamic forces of operating machines in rough mining condition is very critical for safety of these machines. Loss of structural integrity and stability is a critical safety issue for large HEMM like Cranes, Draglines, and Bucket Wheel Excavators. There may be catastrophic failure of such structures in dynamic loading conditions. Similarly large mining equipment may lose its structural stability while in motion with load, mainly due to uneven mine roads.

DGMS has also issued guidelines in this regard (Ref. No. DGMS (Tech) circular No. O 6 of 2020 Dhanbad dated 27.02.2020).

h. Dump body stabilizers for tippers

The Dump Body Stabilizers for Tippers shall meet the following minimum requirements and standards:

Adequate and suitable mechanical arrangement(s) in the form of stabiliser to prevent toppling of Tipper / separation of dump body of the Tipper from lift cylinder(s) during dumping operation of the Tipper shall be provided in all Tippers. As far as possible, the dump body shall be designed during design phase of Tippers.

Recommendation of the seventh conference on safety in mines: Structural stability of HEMM should be examined periodically by an independent team of experts. Such an examination may invariably be made after every major repair to HEMM.

Gap: It is required to continuously monitor the structural stability of such machines while they are in operation by measuring certain effects of loss or change in structural stability. Monitoring results of imbalance in forces while in operation of such machines may be analysed to determine the likelihood of complete loss of integrity or stability, so that effective measures may be taken before any such mishaps. There is significant scope of use of sensors for monitoring imbalance in forces and movement of critical components and analysis of the same using AI.

Deliverables

- Sensor based continuous monitoring of structural integrity of complex and large size machines or structures in mines and prediction of failure by analysing the data using AI before actual failure.
- Sensor based monitoring of structural stability of heavy machines in mines and prediction of loss of stability by analysing data of physical effects of structural stability on different parts of machines.

3.2.3 Sustainable Mining

a) Reducing Green House Gas (GHG) emission, and monetization of methane gas through CBM/CMM activities

India has an abundance of coal resources. Given the current energy outlook of India indicative of the country's continued reliance on coal as a future energy source, the development, and application of technologies to improve the sustainability of coal mining is imperative. Most coal mines in India are classified as Degree I or Degree II gassy mines, indicating that they are moderately gassy, with few heavily gassy mines classified as Degree III mines. As India's demand for coal continues to increase, operators may be forced to target deeper and gassier seams. Although the number of deep underground coal mines in India is limited, they will eventually have to be developed to meet India's rapidly growing coal demand. Furthermore, the Ministry of Coal's decision to stop thermal coal imports from the financial year 2034-24 will force domestic producers to ramp up production. Methane emission from coal mining in India is a matter of concern which is around 1.2 billion m3 annually as per USEPA estimate. Without proper methane mitigation techniques implemented in the future, India's trend of increased methane emissions is expected to continue. It is worth mentioning that India had promised in the 21st Conference of Parties meeting in Paris, in December 2015 to lower emission intensity of GDP (quantity of emission to achieve one unit of GDP) by 33-35 percent from 2005 levels. Therefore, India's requirements for production enhancement are conflicting with its commitment made at the Paris Summit. This triggers the need for a strategy of a balanced approach that can serve both purposes.

In view of this, the application of coal bed methane (CBM) / coal mine methane (CMM) drainage technology in India would contribute to the national goal of increasing domestic natural gas and coal production, while helping the country satisfy its commitments made at the Paris Climate Summit.

Scope: The scope of CMM development is not limited to the reduction of GHG emissions. Pre-drainage of coal mines before the execution of mining operation paves the way for monetization of produced methane gas. It can enable the mine operator to generate a secondary revenue stream for the mine. The major scope lies with the development of a concept that combines the business process management with digital technologies to integrate subsurface data that exists in the form of geological, geophysical, petrophysical, coal reservoir and production data; Development of an AI/ML-based system where integration, evaluation, and reservoir characterization be properly conducted to determine the technologies that will optimize production; Development of a process-driven workflow to spot best locations for drilling development wells and reduce high upfront development cost; Development of robust Mechanical Earth Models (MEM) with the integration of reservoir geomechanics; Development of smart decision-making models and optimized real-time controllers in the drilling system for implementation of the vertical, surface to in-seam, and horizontal drilling in CBM/CMM coal seams; Development of AI-based production management and application of big data analytics to predict mechanical equipment failure and identify optimal operational plans to realize cost reductions while boosting production; Development of cost-effective technologies for treatment and management of water and wastewater.

Present Status: The amount of methane available in the major coal basins across the globe has been estimated at 85 - 222 TCM. A recently released report, "Global coal bed methane (CBM) market analysis size and segment forecasts to 2020" suggests that the global coalbed methane (CBM) market is set for substantial gains over the coming years to 2020. According to the report, Global CBM production was 2,920.3 Bcf in 2013 and is expected to reach 4,667.4 Bcf by 2020, growing at a Compound Annual Growth Rate (CAGR) of 7% from 2014 to 2020. USA, Canada, and Australia are the largest CBM producers, accounting for over 70% of global volume in 2013. The Asia Pacific is expected to be the most dynamic regional market, with significant unexplored reserves. China, India, and Indonesia are expected to lead the Asian CBM/CMM industry.

In India, a broad assessment of CMM resources (CMPDI, 2007) suggests that a total of ~ 24 billion tonnes of Coal reserve is available for CMM development from Raniganj, Jharia, Eastern & Western Bokaro, and Karanpura coalfields. According to the Directorate General of Hydrocarbons (DGH), total CBM prognosticated CBM resource is 2.6 trillion m^3. Govt. of India has allocated several CBM blocks in various coalfields to various govt. and private sector entities such as ONGC, IOC, Reliance Industries, and Essar etc. for extraction of CBM resources. Most of them are still exploring the resource with limited success. The exploration and appraisal activities in these allocated blocks have led to establishing 280.4 BCM of the total prognosticated resources as Gas-in-Place (GIP). In comparison to the production of CBM in the US and Australia, the growth of CBM production in India has been minimal. The commercial production of CBM started in 2007 with GEECL production from Raniganj (South) block. The current contribution of CBM in total gas production of India is about 2.5 %.

Although the contribution of CBM in total gas production of India is abysmal, the potential for growth is significant. The revision of the CBM/CMM licensing policy and gas pricing mechanism has opened the door for the growth of CBM/CMM production in India. Moreover, India's

Nationally Determined Contribution (NDC) under the Paris Agreement includes a target to reduce the emissions intensity of its GDP by 33-35 percent from 2005 levels by 2030, which further adds to the reason for the growth of CBM/CMM in future.

Gap: The majority of CBM projects in India are in the early stages of exploration and production. Therefore, there is a lack of exposure and learning curve with fully developed projects for CBM/CMM operators of India. There is a scarcity of experts equipped with knowledge and experience with implementing full CBM/CMM workflow of integrating geological, geophysical, petrophysical, reservoir, and production data from the CBM/CMM perspective. Though coal reservoir geomechanics plays a significant role in CBM/CMM well production behaviour, the existing knowledge in understanding the impact of reservoir geomechanics in the drilling, completion, and production behaviour of CBM wells is limited.

CBM/CMM projects are developed in stages – starting from exploration to appraisal (pilot wells) to development. One of the main reasons for the implementation of pilot wells is to realize the peak gas rate from CBM/CMM wells, which is difficult to predict during the exploration stage. Without the knowledge of the peak gas rate or well potential, it is difficult for the project operator to decide upon the scale of investment in production facilities. This has an impact on the project cost in two ways – 1) it leads to the delay in the development of the project, which is reliant on the results of the pilot wells, and 2) it leads to additional cost of implementation of pilot wells. A knowledge gap is obvious here which limits the operator from describing the potential of a CBM/CMM well at the exploration stage.

In addition to these, there is a knowledge gap existing in the form of a lack of skilled manpower experienced with the application of Artificial Intelligence (AI) and Big Data Analytics to optimize operational and development plans (and processes). The application of digital transformation is the key to cost reduction while boosting production.

Deliverables

I. Development of knowledge/method/process to determine the peak gas rate or well potential of CBM/CMM well in the exploratory stage and do away with the requirement of pilot wells.

II. Development of knowledge/method/process to deliver a robust Mechanical Earth Models (MEM) with the integration of geological, geophysical, petrophysical, coal reservoir, and production data with coal reservoir geomechanics.

III. Development of structured well-drainage-area based AI models as general methane production forecasting tool for coal seam degasification using ML-based algorithms.

IV. Development of policy framework and guidelines for the CBM/CMM drainage.

V. Development of a technical screening guide system using an artificial neural network (ANN) to assist in the selection of production methods such as drilling, completion, and stimulation in the CBM/CMM reservoir.

VI. Development of indigenous pneumatic controllers for cost-effective separation of gas and water in the separator and accurate metering of water.

VII. Development of technology and process that offers economical ways of carbon capturing and utilization in enhanced coalbed methane (ECBM) operation.

VIII. Development of an AI-enabled reservoir surveillance approach for timely identification of the reason for any production decline, the reversal of production decline by removing wellbore damage, and minimizing shut-down of CBM/CMM wells for an extended period.

IX. Development of indigenous permanently mounted sensors in CBM/CMM wells to enable smart well technology.

X. Development of cost-effective technologies for treatment and management of water and wastewater.

3.3 Enhancing mining activities and novel use of minerals/coal

a) Extraction Cost Reduction

Energy savings

Scope: Size reduction, crushing and grinding combined contribute about 60-70% of the processing cost for metals and mineral in addition to the blasting cost at the mine site. Quite similar is the case for coal where the contribution is about 40-50% of the cleaning cost. At present blasting product size, typically less than 1500mm for metals and minerals, is dictated by the ease and convenience of bulk handling, without taking into account the grinding end product size, typically <0.2 mm. Similarly, for coal, it is usually less than 1500/ 1000mm, whereas the crushing end product size, typically is <50/ 13mm. If blasting system design and crushing and grinding circuit design can be integrated by robust simulators aided by sensor based online PSA (Particle Size Analysers), processing cost and even capital cost can possibly be reduced.

Present Status: A major proportion (60%-99%) of the energy spent in industrial comminution (crushing and grinding) gets wasted without getting utilised in the actual breakage of the particles. It has been found that the energy efficiency of comminution processes depends on the size distribution of the feed, Bond's work Index and interestingly, on the Poisson's ratio of the material. Pre-comminution processes that lead to increased flaw generation within the particles have been noted to increase the efficiency of energy utilisation. In this regard, controlled blasting of downstream comminution products has been reported to reduce the overall energy consumption in comminution. Apart from blasting, rapid loading has also been found to increase internal crack generation and therefore, the energy efficiency. The energy input in comminution has been found to be wasted significantly in the wear of liners and media of the equipment. Further, repeated low-energy impacts have been found to be more energy efficient, in terms of breakage, as compared to high-energy impacts. The latest advances in increasing comminution efficiency include pre-processing techniques like microwave irradiation and novel comminution methodologies like dry air milling, HPGR (High Pressure Grinding Roll) milling, electrical comminution and centrifugal milling etc.

Gap: Randomness of particle loading in comminution equipment, particularly grinding mills, translates to several such loadings where the direction of the external stress and internal crack orientation are not aligned, and leading to wastage of energy. Effect of the brittleness/elasticity of the material is unaccounted. There appears to be inadequate assessment of the effect of blasting as a pre-comminution particle processing technique. Limited use of pre-concentration for reducing comminution costs is another area. To cap it all, there continues to be incomplete understanding of the physics behind breakage processes.

Deliverables:

- Estimation of the effect of different physical and chemical properties of particles on their breakage.
- Quantification of different particle processing stages' effect on comminution.
- Strategies for the introduction of efficiency-boosting techniques like controlled blasting and particle pre-processing within and around comminution circuits.
- Development of novel comminution circuits integrated with blasting for improving energy efficiency
- Development of robust simulators aided by sensor-based online PSA (Particle Size Analysers) to reduce the processing cost and even capital cost

b) Life extension of mining equipment

Scope: Besides energy cost, equipment/ equipment spares life is another significant cost contributor in the extraction process for metals and minerals, and in power plants. There are instances where screen panels, grinding media, liners have a life of just one month because of excessive wear and tear. In such cases of dynamic systems, rapid on-site repairs on large linear/non-linear surfaces can be performed by employing bottom-up approaches like Additive Manufacturing (AM)/3D printing that grows 3D volumes one fine layer at a time. One such potential technology to grow 3D volumes layer-by-layer is Cold-spray, a high velocity layer-by-layer direct energy deposition technique, in which micron-sized powder particles are accelerated to high velocities and heated by a suitable carrier gas (Air/N_2/He) and impacted on to a target surface to cause rapid layer deposition. Therefore, it leads to ultra-fast repair of equipment spares/ accessories which is equally applicable to railways, aerospace and defense, sensors playing a major role.

Present Status: The experimental cold spray research is highly sparse in India; as the setup is available only in a few academic institutions. Internationally, the potential of ultra-fast repair has been demonstrated by U.S. Army which used this technology to repair a component in Blackhawk helicopters, General Electric which is currently adapting the technology for civilian applications, and several others which have successfully used cold spray for high speed coating, 3D printing and metal/polymer additive manufacturing.

Gap: Mining equipment and accessories suffer heavy mechanical degradation and corrosion during its life which leads to replacement of worn out parts instead of being repaired. The need for a rapid, scalable and onsite repair technique, like cold spray technology, is imminent as it can significantly extend the life of the component and cut the cost of its replacement. However, cold spray is yet to be explored in the area of 3D printing and onsite repair of mining equipment and accessories.

Deliverables

- Development of AI-based prediction model of wear and tear of screen panels, grinding media, liners etc.

- Ultra-fast onsite repair of worn out and corroded components of mining machinery with the ability to prevent heat-related distortion, and requirement of inert gas or vacuum sealed environment
- Cost effective way to extend the useful life of mining machineries significantly

c) Deep cleaning of coal

Scope: Commercial coal cleaning is being carried out for more than a century now, with an objective to provide suitable feed for mainly power and coke making utilities. Apart from a source of energy coal is also a rich source of carbon – more than petroleum, on dry mineral matter free basis. However, coals, particularly Indian coals have considerable mineral matter content. This allows coal usage for industrial power generation, coke making, etc., albeit with trade-off of productivity, energy efficiency and eco-friendliness. The considerable ash content in coal precludes its usage as such for producing novel carbon-based nanomaterial, having superior properties but limited in usage due to cost. One of the issues with mass-scale production of such nanomaterial is the availability of the carbon rich precursor. Perhaps, coal represents the most significant proportion of world's exploitable carbon. Therefore, deep cleaning of coal is the next step in coal cleaning research for producing super clean coal product with negligible ash content. This product will increase the profitability and sustainability of its users in traditional applications of coal. Moreover, deep cleaning of coal might open up new avenues of coal applications in Rare Earth Elements (REE) extraction. Tentative product break-up (new products highlighted) could be as follows for a 41% ash ROM coal, typical for current BCCL/ CCL production. The questions of FBC coal and REE extraction have been discussed later.

Table 3.1 Percentage of various types of coal after deep cleaning

Product	Super clean coal	Metallurgical clean coal	Power coal	FBC coal	Reject for REE extraction
Yield (%)	0.5	20.0	50	15	14.5
Ash (%)	1.0	14.0	34	65	80.0

Present Status: Deep cleaning of coal is presently in nascent stage of development and is yet to find commercial application. Different methods have been applied for deep cleaning of coals with ash contents of less than 10%. However, most Indian coals have ash contents of more than 30%; with ash contents exceeding 40% becoming more common nowadays. A few works reported in literature have utilised standalone froth flotation of micronized coal for its deep cleaning. Some other works have combined oil agglomeration or selective flocculation for achieving deep cleaning of coal. Use of strong acids (like sulphuric acid, nitric acid, etc.) and bases (like sodium hydroxide, etc.), followed by membrane separation have also been reported in literature to obtain super clean coal. Yet, another study has reported selective dissolution of carbonaceous part of coal using organic solvent for achieving super clean coal. However, none of these techniques appear to have any commercial application, due to the application of high cost and hazardous production techniques.

Gap

- No technique for deep cleaning of high-ash coals, as common in India.
- Utilisation of hazardous and costly reagents and materials.
- Only wet processes have been attempted.

Deliverables

- Sensor based/Processor controller aided cost-effective, environment-friendly technology for deep cleaning of high-ash Indian coal
- Report on techno-economic comparison of different deep-cleaning techniques

d) Carbon based nanoparticles

Scope: Carbon based nanoparticles, such as, carbon nanotubes, graphene, carbon dots etc. have attracted much attention across the globe owing to their unique electronic, chemical and mechanical properties and potential applications in a number of fields such as in composites as reinforcing fibres, in molecular electronics as nanowires, in microscopy as probe tips, in fuel cells as cathode support, in gas adsorption as hydrogen storage medium and in catalysis as supports. Indian coals continue to be available in Jharia and Raniganj coalfields with the carbon concentration in the range of 70-94 weight% which has a high potential of being used as a precursor for the synthesis of C-based nanoparticles, coal being a low-cost and abundant resource as compared to petroleum/oil-based precursors.

Present Status: While there are several studies demonstrating the feasibility of using coal as precursor, studies on Indian coals are limited. The fabrication of fullerenes, porous carbon nanomaterials, CNTs, graphene etc. from Chinese, Australian and other coal have been shown possible in several studies until now. Similar study on Indian coal is at a nascent stage.

Gap: Indian coal needs to undergo a deep cleaning, as it typically contains high ash percentage, metal contaminations, in order to be suitable to be used as a precursor for synthesis of C-based nanoparticles. Hence, a deep cleaning approach where production of extremely low ash product will be integrated with the conventional products of clean metallurgical coal and clean power plant coal. Further, the C-based nanoparticle synthesis from non-traditional precursors like coal is a highly unexplored area of research which can help to establish the mass production of environment-friendly carbon based nanomaterials at low cost.

Deliverables

- Development of AI-based CNTs, graphene and graphene oxide for its usage as supercapacitors in high energy storage materials to increase catalytic performance and effective drug delivery in biomedical applications respectively.
- Mechanistic understanding of nanoparticle synthesis from heterogenous coal

e) Urban municipal waste processing for energy and precious metal recovery

Scope: The energy value present in the sewage sludge can be recovered by various thermochemical processes such as incineration, torrefaction, gasification and pyrolysis. Metals and minerals e.g. lead, mercury, phosphate etc. can also be recovered from the residues of thermochemical treatment where sensors and process controllers are expected to play a significant role.

Present Status: Rapidly increasing urbanization has resulted in significant increase in municipal waste/ sewage generation. Current sewage sludge (semi-solids produced, as a by-product during sewage treatment) disposal practices creates environmental and social issues due to the presence of heavy metals and other toxic polymers. Although sewage sludge has shown its applications in sanitary landfill, building material, agriculture, etc, what is ignored is the enhanced water recovery potential from the sludge and the fact that dewatered sludge contains commercial energy with calorific value ranging from 1700 - 3100 kcal/kg. There are operating mini to small municipal sludge based power plants in many countries of Europe and Middle East. Globally sewage sludge with high organic matter derived from urban or industrial wastewater treatment plants have emerged as a potential new renewable energy sources. Sewage sludge is a heterogeneous biomass, which includes a mixture of inorganic and organic carbon compounds such as nitrogen and phosphorus components, heavy metals and pathogens. The development of thermochemical conversion approaches has gained a tremendous attention due to its effectiveness in reducing quantity and toxicity. In India, the generation of wastewater is increasing at an alarming rate of about 10% annually.

Gap: Less than 25% of the generated wastewater undergoes simple sewage treatment and the rest is discharged without any treatment. Almost all the water bodies including lakes, ponds wetlands, streams, rivers and their catchments areas are severely polluted due to the discharge of untreated or partially treated sewage effluent. Urban municipal waste processing for energy and precious metal recovery remains a completely unexplored area in India.

Deliverables

- Sewage sludge as a source of energy.
- Sensor and AI based enhanced water recovery from sewage sludge.
- Pyrolysis char as a source of valuable metals/minerals e.g. phosphate, lead, mercury, etc.

f) Mixing sewage sludge with fine coal waste/ carbon anodes/ forest bio-mass to increase calorific value for subsequent use in cement plants

Scope: The scope of the work includes the utilization of different class of waste materials for energy production and their utilization in cement plant. These waste materials are sewage sludge, coal waste, carbon anodes and forest bio-mass.

Present Status: Application of sewage sludge by cement industry is well accepted throughout the world as it reduces the reliance on fossil fuel and also decreases the greenhouse gas emissions. However, the indicated utilization is hindered in India due to the absence of appropriate dewatering methods and its low calorific value (CV) generally in the range of 1700 - 3100 kcal/kg. The problem can be addressed if the sewage sludge is mixed with coal waste (CV: ≤4000 kcal/kg) generated by coal cleaning plants or used carbon anodes generated by alumina reduction plants(CV~7500 kcal/kg) or so far discarded forest bio-mass(CV: ≤8000 kcal/kg). The latter two are attractive choices due to high CV, low moisture and low sulphur content.

Suitable blends of these three classes of materials will help in increasing the input CV before feeding to cement plants, which are currently using high ash, low CV coal or low ash, high CV, high sulphur petroleum coke. Additionally, if there is a partial addition of waste coal fines during the dewatering stage of sewage sludge, that will act as a physical conditioner and help in moisture removal from sewage sludge, a challenge in itself. This approach may succeed only if finely tuned automatic process controllers are used.

Gap: Use of sewage sludge for energy production is an unexplored area in India. The mixing of sewage sludge with other industrial and forest wastes will reduce the overall waste generation by society and some industries.

Deliverables

- Sewage sludge as a source of energy.
- Proper utilization of coal waste /carbon anodes/ forest biomass to increase calorific value.
- AI/Sensor based cleaner cement production

g) Recovery of valuable metals from process plant water

Scope: Recovery of valuable metals from process plant water is another potential research area, given that no mining cost is involved. About 10% of the total industrial wastewater in the world is released from various mineral processing plants/ mines. Water released contains various metal ions including heavy metals and rare earth metals. If such water is treated using suitable methods and valuable metals are recovered, it will improve the processing plants economics with benefit to the environment and society at large.

Present Status: At present mines and mineral processing plants in India mostly focus on rudimentary treatment and disposal of its wastewater using a centralized process consisting of simple neutralization and/ or flocculation. International practices are much more elaborate involving substantial cost, though not necessarily very effective in metal ion removal. In most cases, primary treated water is recycled and mixed with fresh water to reduce its consumption or discharged to tailing ponds as wastewater. Release of such metal ion contaminated water in the surrounding environment seriously affects agriculture and hazardous for human health due to its consumption through the food chain. Treatment plants for recovery of metal ions have been little reported in literature. The following table shows the presence of various metal ions present in one of the iron ore processing plants process water, based on AAS analysis.

Table 3.2 Various metal ions present in iron ore

Metal ions	Fe	Cr	Cu	Pb	Mn	Al	Silica	TDS
Concentration (mg/L)	115.24	7.10	0.27	2.68	0.96	24.76	1.30	130.6

Gap: There are about two dozen of such plants in India treating million tonnes of iron ores on year-to-year basis. In addition to the metals indicated in the table, many strategic metals such as, Titanium, Nickel, Cobalt, Vanadium, Cerium, Lanthanum, Barium, Gallium, Strontium etc are also present at concentrations of lower level. Since, water availability to plants has become a major issue and release of metal rich water is environmentally not permissible, mine and processing plants are looking for simple, easy and low-cost solutions.

Deliverables

- Mine and mineral processing plant water as a source of precious metals
- Sensor and Process controller aided treatment of wastewater to make it available for use in agriculture, horticulture, fisheries and if possible, as potable water

h) Holistic utilization of end products to address social and environmental concerns

Dewatering of red mud

Scope: The scope of the work includes dewatering of red mud slurry generated during the processing of bauxite for the production of alumina using caustic soda by Bayer's process. The main purpose is its safe disposal or transportation for re-usage or by-product recovery at low moisture content. The application of AI in developing the process methodology shall be helpful for efficient dewatering.

Present Status: The handling of red mud is one of the most critical issues in an alumina refining industry that affects overall economics of a plant operation, and creates serious environmental and social issues related to the tailings disposal. Red mud is considered as a hazardous waste generated during the processing of bauxite for the production of alumina using caustic soda by Bayer's process. Red mud is generally discharged into the nearby tailing ponds, which are located in the vicinity of alumina refineries. The red mud of Indian origin typically contains around 45-55 % Fe_2O_3, 10-12 % TiO_2, 20-22 % Al_2O_3, 8-10 % SiO_2 and other associated oxides in minor quantities along with moisture ranging from 65-85% by weight. It may be noted that the dewatered red mud can be used in various applications such as construction material, ceramic industry, cement stabilizer, glass industry, catalysis, metallurgy, fertilizer, etc. A number of investigations have been carried out to highlight the utilization of red mud in the recent past. However, the dewatering of such red mud slurry, which is a pre-requisite for most of its re-use, has been least explored, thereby restricting the commercial application.

Gap: The red mud slurry is highly basic in nature with pH ranging from 10-13.5 when discharged from the alumina plants leading to soil and water pollution. The main roadblock for the re-use of red mud is the absence of appropriate dewatering technology for such a highly basic slurry.

Deliverables

- Application of AI in developing modified scheme for improved dewatering performance of Indian red mud slurry.
- Production of dewatered red mud for re-use
- Improved recovery of water from red mud slurry for recycling back to plant to reduce freshwater consumption.
- Increased availability of land, reduced pollution of nearby water bodies and land area, conservation of nearby forests, etc.

i) Utilization of Coal Cleaning Plant Rejects

Scope: Utilization of coal cleaning plant rejects is a major issue faced by Indian coal industry particularly its metallurgical (coking) coal segment. Most of these rejects generated in millions of tons every year in the state of Jharkhand and to a limited extent in West Bengal carry "just commercial" or "less than commercial, yet significant" heat values; and dumped in open air creating environmental, socio-economical and law and order issues. Also abundantly available are high heat value fallen Sal leaves, a forest produce, in all the coal producing states of India including Jharkhand and West Bengal. Both the materials have very limited use at industrial level as well as domestic level and are considered as waste. If they are burned using suitable cofiring methods in industrial burners, large amounts of waste material can be used efficiently as well as available energy can be used for electricity generation.

Present Status: Since most of the Indian metallurgical coal are of high ash (presently above 40% ash), coal cleaning generates significant amount of high as (> 60-65%) rejects. Presently FBC appears to be the only option available to use such reject coal, though the process is not very effective due to their poor combustion characteristics. This is a problem typical for India. In other countries cleaning plant reject coal contain little energy values. Limited research is in progress in Finland, Korea and China on co-combustion and thermal decomposition behaviour of coal, biomass and coal-biomass blends. An important finding of these studies is the synergistic effect during combustion process of biomass and coal blend. Already completed laboratory scale investigations by the proponents demonstrate that these rejects can be blended with high heat value fallen Sal leaves in a proportion of up to 80% reject and 20% fallen Sal leaves for co-firing to produce electricity. By product recovery can also be done by using bio-char obtained from fallen Sal leaves and co-firing the bio-char to produce electricity.

Gap: Virtually the entire research on combustion as reported on literature has been carried out on low-ash coals, less than 20%. Whereas technical feasibility has already been established and published by the proponents for the co-firing of cleaning plant rejects and bio-mass (fallen Sal leaves). Therefore, next level of research should be repeating the study on pilot scale in a drop tube furnace and integrating the work with deep cleaning of metallurgical coal so as to produce so-called "rejects" technically appropriate for co-firing with fallen Sal leaves and eventually other bio-mass.

Deliverables

- Sensor/processor controller aided blending of sal leaves and plant reject
- Potential for rural employment generation through the social forestry programme
- Reduction of carbon footprint by utilizing renewable energy sources
- Utilization of low-grade coal

j) Extraction of Rare Earth Elements (REE) from coal and its by-products

Scope:

REE are scarce in nature, and it has become increasingly important to develop a sustainable process to recover these elements. The REEs play a vital role in their usage in producing catalysts, rechargeable batteries, fluorescent lamp phosphors etc. The absence of viable ore deposits and their mining in many countries necessitate the recycling of REEs. It is also observed that only 1% REEs are being recycled. Therefore, it has become imperative to develop novel techniques for extraction and recycling of these metals employing integrated pyro and hydro metallurgical approaches. Coal cleaning plant rejects could be a source of REEs, yet to be explored in India. Platinum and platinum group of elements (PGE) are also equally scarce. Recent increase in demand for platinum and PGEs have propelled newer exploration in the PGE sector, because *Platinum and* PGEs have very limited deposits of economic importance world over. In addition, these deposits possess very low tenor and require pre-concentration to recover the PGE values. These minerals, mainly associated with chromite, are of diverse and intricate mineralogical association, exhibit very fine grain size mostly therefore, needs pre-concentration steps. However, the pre-concentration of PGE minerals is a very complicated and a challenging task. Further, the pre concentrated minerals require the application of pyrometallurgical routes such as smelting and converting or combination of hydro and pyrometallurgical methods, based on the concentrate grade and mineralogical association to extract the metal values.

Present status: Occurrence of REE in coal has been noted in several publications in the global literature. Extraction of REE from coal and its by-products has recently garnered research interest in several coal-rich countries of the world, due to the strategic importance of REE and shortage of its supply. Several works reported in the literature have found occurrence of REE in coal and by-products of several deposits and have correlated the origin of the same. However, only limited work has been reported in published literature which has recovered REE from coal and its by-products, possibly owing to the difficulties in the extraction. For the recovery of REE, leaching has been demonstrated to be successful on coal samples, with low-temperature plasma oxidation pre-application, as needed. For the extraction, particle size and mineral matter dispersion have been found to be critical factors. Presence of iron in the coal, was noted to be problematic and a contaminant. The extraction was reported to be aided by thermal or chemical activation. However, no such study on occurrence or extraction of REE from Indian coals seems to have been reported.

Gap:

- Lack of information on REE in the context of Indian coals.
- Lack of information on comparison of successful techniques for REE extraction from coal, other than leaching.
- Inadequate information on techno-economic viability of REE extraction from coal and its by-products.

Deliverables

- Database on occurrence of REE in Indian coals.
- Information on the distribution of REE in different by-products of coal utilisation.
- Sensor/processor controller aided technique(s) for the extraction of REE from coal at different stage of preparation and utilisation and comparisons thereof.

k) Carbon and Sulphur Capture

Scope: Release of Green House gases including CO_2 and SO_2 from utilities and automobiles are a major environmental concern. Overall concentration of these gases can be reduced by various chemical and natural treatment methods. In chemical treatment method, CO2 and SO2 may be captured by suitable adsorbents or liquid absorption process. Recently electrochemical reduction of CO_2 and SO_2 gases has gained popularity. By this method, both the gases are sent to electrochemical reactors, where they get converted to various organic chemicals such as methanol, formaldehyde etc, i.e. value added chemicals. Alternatively, both these gases may be trapped by conventional photosynthesis methods using Algae. Algae are simple organisms that are mainly aquatic and microscopic in nature. They have fast growth rate and produce bio-oils during photosynthesis. Such bio-oils can be extracted from Algae and after chemical modification, can be blended with petroleum oils for use in automobiles. Due to fast growth rate, Algae can capture atmospheric CO_2 and SO_2 fast and make the environment clean

Present Status: Electrochemical conversion of CO_2 to different organic chemicals like HCOOH, CH3COOH, methanol etc are being carried out by various researchers using Zn as catalyst in $NaHCO_3$ electrolyte solution. Some studies thermodynamically examined a two-step solar cycle for CO_2 splitting by using Zn/ZnO and FeO/Fe_3O_4 redox reactions. Titanium based electro catalyst for photo catalytic reduction of CO_2, SO_2 to fuels are also reported in literature. Some research reports the photochemical reduction of CO_2 on copper as cathode base and Pt as anode in various fuel generations. By such methods methanol, methane formaldehyde and formic acid were produced. Algae-based CO_2 and SO2 capture provides a promising opportunity to reduce CO_2 and SO_2 to gain carbon credits. Research work has indicated the possibility of CO_2 and SO_2 capture using different species of algae such as *Spirulina platensis. Literature suggests that f*lue gas with vastly different levels of CO_2 are appropriate for on-site biofixation and cultivation of algal biomass and long distance biofixation with cultivation of edible algae. Algal biomass can reduce 2.52 MJ/kg CO_2 in the total energy consumptions compared with final products of edible algae at same level of protein content with same specific productivity

Gap: Although both technologies are laboratory proven, pilot scale application in Indian context is yet to be established. Such study is necessary to reduce CO2 and SO2 emissions from coal fired utilities.

Deliverables

- Green and Clean method for CO_2 and SO_2 capture
- Sensor aided monitoring of Carbon capture and formation of conversion product
- Biofuels from CO_2 and SO_2 capture
- Obtaining carbon credit

l) Early detection and prevention of spontaneous combustion of coal using UAV

Scope: Detection of self-combustion of coal using Unmanned Aerial Vehicles (UAV) can be a potential research area, because self-heating of coal poses a challenge in securing the safety of man and material in the coal stock yards, reject dumps and opencast coalmines. Vindhyachal STPP of NTPC e.g. consumes on a daily basis 80,000 tonnes of coal at its rated generation capacity. Utilities endeavour to maintain a coal stock of minimum 3days to 30days, spontaneous combustion being a major issue for them.

Present Status: There are a limited number of methods for effective monitoring of natural ground heating and outbreaks of spontaneous combustion, due to the often large areas that require regular inspection. Traditionally, monitoring is performed by spot inspections by trained/ experienced personnel, resulting in many instances in late or no detection. Currently, available instrumentation may, however, attempt to detect thermal anomalies in surface temperature as large amount of heat is transferred to the surface from spontaneous combustion of coals by convective and conductive transport. During the past decades, satellite-based infrared-imaging (National Oceanic and Atmospheric Administration–Advanced Very High Resolution Radiometer (NOAA-AVHRR), Moderate Resolution Imaging Spectro radiometer(MODIS), Thematic Mapper (TM), Enhanced Thematic Mapper (ETM) and Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER)) have been used to detect spontaneous combustion/ fire, say in forests, from the anomalies of surface temperature. However, offered thermal imaging resolutions from these systems are too low for a detailed analysis of spontaneous-combustion / coal fires in a small area, which is an essential prerequisite for corrective measures. Unmanned Aerial Vehicles (UAV) and lightweight, low-cost thermal imaging cameras have become commercially available in recent years. The proponents are about to complete a UAV imaging based project for CAIR DRDO to design automated algorithms for improving detection accuracies of different objects from UAV captured videos (90% completed).

Gap: The system should be deployed to non-active coalmines or coal-stockyards, in which residual heating persists. The autonomous navigation management along with thermal imaging, optical imaging and ground mapping combine to a potential economically viable system for the coal producing and user industries to improve forecast and detection of spontaneous combustion and safety for man and material. Thermal camera payload housed in an UAV, is able to provide a cost-effective solution by undertaking sufficient resolution thermal imaging and regular surveys for management of coal-related ground heating and spontaneous combustion outbreaks. Lightweight imaging payload on a Global Positioning System (GPS) enabled UAV; that is capable of automated mission-based mapping of target areas; is required for such objective.

Deliverable

Early detection and prevention of spontaneous combustion of coal using UAV in coal-stockyards, non-active coalmines etc.

The system at a later stage can possibly be applied to localized forest fires.

m) Application of AI in enhancing the efficiency of material handling systems in coal and mineral processing and process metallurgy.

Scope: Storage and transfer of solid and slurry are one of the major activities in coal and mineral processing and raw material sections of process metallurgy plants and in logistics. It is said that belt conveyors and pumps are respectively the hearts of dry and wet processing plants. The handling process can be optimized with the help of AI by data optimization using the available data and day-to-day generated data. The AI will also help in monitoring the process data and predicting the possible failure of particular handling equipment

Present Status: Conventionally, the conveying of solid and transportation of slurry and water involve typical mechanical equipment. In majority of the cases the units are operated locally and manually with limited usage of instrumentation. As a result there are frequent shut down, enhanced down time, higher maintenance cost, reduced productivity etc. However, the integration of material handling units with the processing equipment dictates the ultimate plant performance in terms of operating hours per year (a global practice followed e.g., by Tata Steel), shut down period, tonnage of material processed etc. The material handling system design and layout philosophy, operation and control of belt conveyors, slurry pumps, water pumps, tanks, sumps, hoppers, bins, bunkers etc. need to be relooked. The major parameters that affect the overall performance include capacity, relative density, bulk density, moisture, flowability, particle size distribution, agglomeration behaviour, surface property, etc. In view of the moisture and clay content in most of the raw materials, the smooth flow of solids is a technological challenge in India through the moist seasons of the year. This is a problem typical for India, not usually encountered in the developed countries.

Gap: A reliable material handling system with minimum footprint with simple and less maintenance is required. The application of AI in integration of overall plant operation and control shall increase the productivity.

Deliverables

- Optimized use of material handling system through AI application
- Operating cost reduction
- Maximizing the operating hours

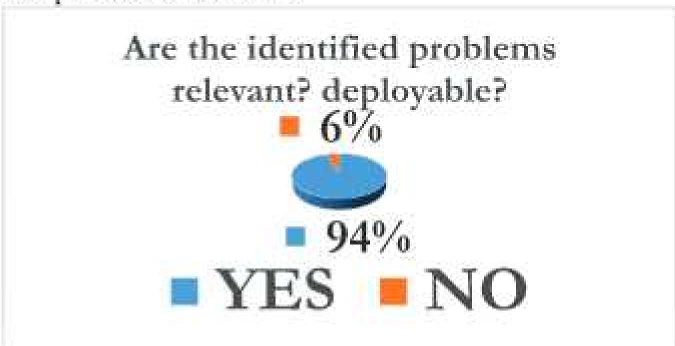
4 TEXMIN BENEFICIARIES

4.1 Stakeholders Consultations

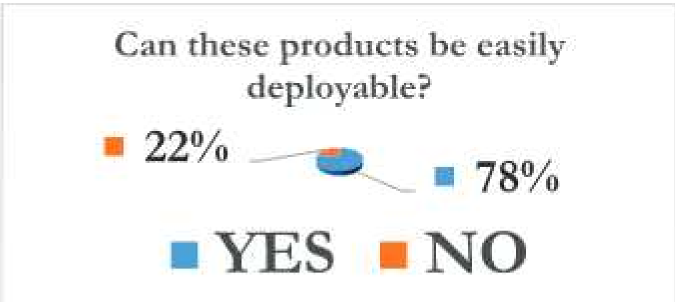
In order to get an exhaustive input on the present conditions and future needs of Mining industries in India, interactive sessions with major stakeholders were organized in recent past. Based on their inputs, a comprehensive list of problems requiring urgent attention in mining industries were prepared. While formulating the key issues in Indian Mining Industries and the possible solutions way forward, various strategic papers, white papers, vision documents published by major public and private sectors, Annual reports of Govt. and Public Sectors etc. were referred in length. The reference section lists their citations. The problem to be addressed through major CPS were shared with major stakeholders. Annexure 1 presents list of the stakeholders and their feedback received on the identified problems in Mining 4.0 which were supposed to be addressed at this TIH. The identified significant problems to be tackled through TIH has been formulated in consultation with major players in exploration and mining in India. In fact, some top academicians and industry of the world were also contacted for their views.

The questions which were asked to them were:

(i) Are the identified problems relevant?



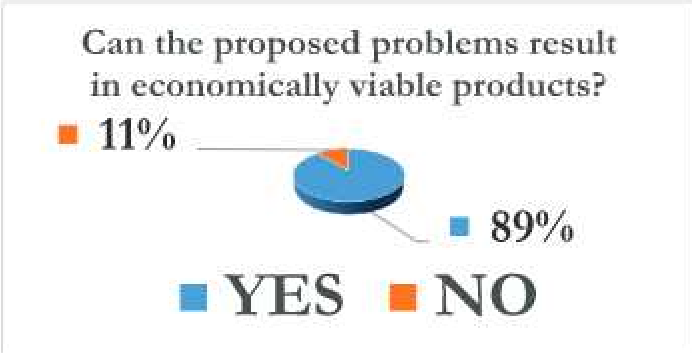
(ii) Is the scope of the work clearly defined for the identified problems?



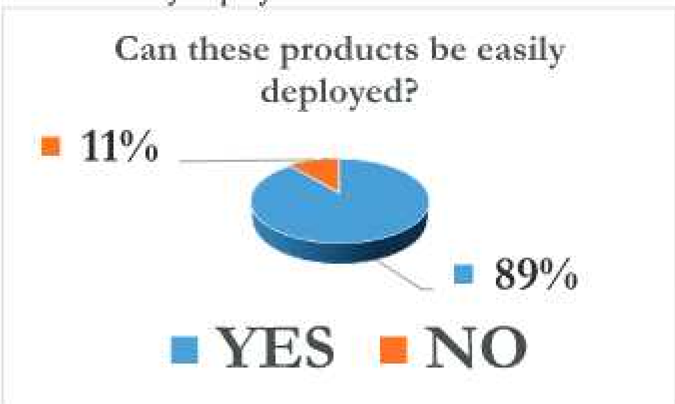
(iii) If No, then please give your inputs by adding to/modifying the problem (in 1000 characters)

The suggested corrections/modifications have been incorporated in the DPR.

(iv) Can the proposed problems result in economically viable products?



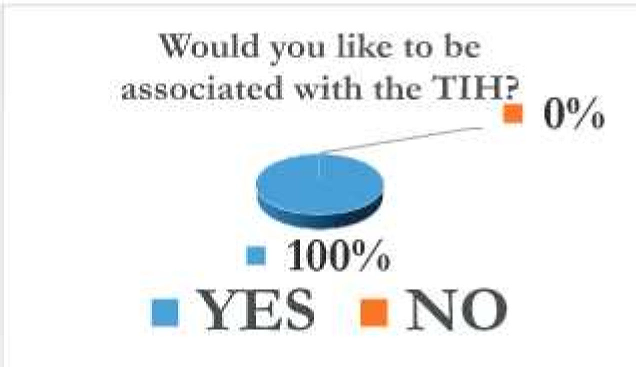
(v) Can these products be easily deployed?



(vi) Please mention two academic/industry partners (National/ International)

All of them have mentioned names of the academic and industry partners. They are being contacted to be a part of the TIH.

(vii) Would you like to be associated with the TIH?



The problems were further refined and fine-tuned to the requirement of Mining industries based on the feedbacks received from them. Almost all of the stakeholders found the problems are of substantial in nature and were in agreement with the TIH for their solutions through modern technologies. Annexure II lists the companies/organizations who have shown their expression to collaborate with the TIH in meeting stated objectives and developing technologies for Mining 4.0.

The major, coal mining companies, Coal India Limited has expressed its desire to sign a MoU with the TIH/IIT (ISM) Dhanbad for development and implementation of technologies leading to application of Cyber Physical Systems in the mines of CIL.

M/s CDAC Kolkata and NVIDIA have given their consent letters for collaborating with the TIH. M/s Coal India Limited and M/s Sandvik Mining & Rock Technologies, India have signed MoAs for setting of Centres of Excellences in Mining Innovations and Mine Automation Learning, respectively. M/s Dassault Systems have agreed in principle to collaborate with TexMin Foundation. Dialogs with Accenture is going on for collaborations.

Former Scientists, Experts, Representatives from various R&D organizations, Research Institutions, Public and Private Industries such as NGRI Hyderabad; Université Savoie Mont-Blanc EDYTEM, France; University of Western Australia; Geological Society of Australia; AuSIMM; GSI; DMT; Southern Illinois University Carbondale; University of New South Wales; FIMI; Reliance Power, PMT InfraScience; Caterpillar Inc, RPM Global etc. have given their consent to support TIH as either collaborator or expert.

A legacy of IIT (ISM) for more than nine decades in its niche areas of Earth Sciences, Mining, Oil & Gas, Mineral, and Mining Environment, has made it possible to consult and seek opinions from major stakeholders in Mining & Sciences Sectors in India and Abroad. Ongoing collaborations with major mining and earth sciences companies, organizations and institutes in India has further helped in identifying the major challenges in Indian mining sectors. The institute has active collaborations with all major mining companies, R&D and Academic Institutions, Govt. organizations etc. A brief list is presented below.

M/s Coal India Limited; Uranium Corporation of India Limited;, DVC Bokaro; CCL; Tata Steel; SCCL; BCCL; MCL; WCL; SECL; NCL; ECL; UCIL; West Bengal Mineral Development & Trading Corporation Ltd.; SGS India Pvt. Ltd., Kolkata; Essar Oil Ltd. Durgapur; SAIL; IEL; MECON Ranchi; Monnet Ispat and Energy Limited; NTPC; NHPC; ONGC; OIL India Limited; Rio-Tinto; Schlumburger Asia; Shell Technologies; PWC; Infosys; Atlas Copco; Vedanta; Hindustan Copper Limited; Hutti Gold Mines Ltd.; 3M India Ltd.; Essar Steel; e-Valueserve.com, FACOR, Bhadrak; Gujarat Mineral Development Corporation, McNally Bharat; Tega Industries Ltd. Etc.

Department of Science & Technology; Defence Research Development Organization; Ministry of Mines; Ministry of Coal; Ministry of Mines; Ministry of Mines & Petroleum, Islamic Republic of Afghanistan; Ministry of External Affairs, Government of India, Ministry of Environment; Forest and Climate Change; Ministry of Information & Communication Technology; Indian Space Research Organization; Department of Mines and Geology, Government of Jharkhand; Central Ground Water Board; Coal Miners' Provident Fund Organisation; Central Mining & Fuel Research Institute; CSIR, National Geophysical Research Institute-Hyderabad, Central Ground Water Board, NRSC, Hyderabad, SAC, Ahmedabad, IIT Kharagpur, IIT BHU, Wadia Institute of Himalayan Geology, Indian Institute of Science, Bangalore etc.

The collaborative R&D works in India and Abroad, Industrial sponsored project being executed at IIT (ISM), various workshops, seminars, symposiums, conferences, findings of strategic committee meetings etc. have also been taken into account for identification of major challenges ahead in Indian Mining Sectors.

This section presents key findings emerged from the various meets, workshops, symposiums, interactions etc.

Workshop on Digital Transformation

A two days' Workshop on digital transformation to increase mine productivity and improve profitability was organized by IIT (ISM) in collaboration with IBM during 18-19 October 2019. The key objective of this distinctive programme was to sensitize the mining industry leaders for a smooth digital transformation, much beyond the adoption. The programme was well attended by more than 50 participants from senior management of the Indian mining and mining equipment manufacturing industries including the regulators, both from public and private sectors. The programme dwelled upon Introduction to Mining Value Chain and Traditional Digital Technology in Mining, Digital Transformation/Industry 4.0, Technologies aiding Digital Transformation, Industry imperatives, Digitalization of Mining – Case studies, IoT, Big Data, Data Science, Analytics, AI - introduction, market trends, real-life use cases, world of possibilities, Block chain - Introduction to Blockchain, Blockchain in Mining Industry, Use case studies by Caterpillar, Adani Enterprises Limited (AEL), Sandvik, Reliance Power (Sasan Coal Mine), and HZL / Vedanta. The feedbacks from received from participants were quite useful in laying the base of possible applications of CPS technologies in Mining and Mineral sectors.

National Symposium on Advanced Technology Infusion for Sustainable Mining (January 12, 2020, CIL Kolkata and January 18, 2020, IIT (ISM) Dhanbad)

Indian Institute of Technology (Indian School of Mines) Alumni Association (ISMAA), in association with IIT (ISM) Dhanbad and in technical corroboration with RMIT University and CSIRO Australia, organized the above national symposium. The objective of these symposium were to focus on the latest research on advanced technologies that could be infused in the Indian scenario for improvement in efficiency in this sector. The symposium dwelled on the need and roadmap for Smart Sensing & Digital Transformation in terms of technologies enabling data-driven decisions such as Artificial Intelligence, Advanced Data Analytics and Machine Learning, Big Data and Cloud Computing etc. for sustainable mining processes and Production business.

Senior and mid-level executives, Academics, Researchers, and policymakers from Coal India Ltd (CIL), ONGC Ltd, Oil India Ltd, Northern Coalfields Ltd, Eastern Coalfields Ltd, Bharat Cooking Coal Ltd, Mahanadi Coalfields Ltd, Hindustan Zinc Ltd, Directorate General of Mines Safety, Tata Steel, Southern Illinois University, Carbondale, Federation of Indian Mining Industries, IIT (ISM) Dhanbad, CIMFR Dhanbad, CMPDI, CSIRO Australia, Melbourne University, Australia, Other Australian mining and resources services company Coffey Tetra Tech Company, METS and researchers from mining and energy sectors shared their experiences on the future requirement of Indian Mining Industries for sustainable mining.

It provided an opportunity to the stake holders to interact on development of innovative and Advanced Technology Infusion for Efficiency Enhancement that would benefit the mining Community as a whole.

Some key recommendations of the symposium are listed below:

- Computer – aided simulated training for skill development and related Safety aspects should be followed as a continuous process and should give need- based orientation.

- Sensor - based monitoring by the involvement of OEMs for better equipment utilization and availability would help to enhance performance efficiency in energy sector.
- Use of digital technology in scripted way can be a useful tool to optimize "Cost of management".
- Impact of digitization in mining process should be introduced in the proposed taught courses. Training should also be given in subsidiaries.
- Research Centres/ innovation centres are to be set up at IIT (ISM) along with industry – interactions so as to bridge the gap in "top down" approach preferably in Mission mode.
- Lessons learnt from implementation of advance technology and innovation strategy are to be customised and effectively implemented in mining sectors, specially the coal – as it is the mainstay for energy security of the Nation for decades to come. For performance evaluation, efficiency is an important key indicator. CIL should identify 8 to 10 mines for implementation of advance technology.
- Study should be done for using cleaner form of energy (CNG) in all the trucks/dumpers.
- Assets management should graduate from ERP application to use of Artificial Intelligence in Prognostic Monitoring on real time basis. Augmented Reality and Virtual Reality (AR/VR) Technology will be a helpful tool and can be implemented (to start with) in areas of mine safety, remote maintenance and monitoring of machineries for UG and OC Projects. Integration and automation must be included in future mine planning. It is worth mentioning that IIT(ISM) in collaboration with Coal India Limited and SIMTARS Australia is in the process of establishing Virtual Reality Mines Safety Simulator.
- Excavated space in mining areas may be identified for gainfully utilising for generation of hydro power and storage of energy.
- Future R&D theme (Two Opencast & Two UG Mine) should include MINING 4.0 in CIL.

National Conference on "ADVANCES IN MINING" (AIM-2020) during 14-15 February 2020 at CSIR-CIMFR, Dhanbad

The conference provided an effective common platform for interactions and deliberations amongst all stakeholders about the recent advances in mining, exchange ideas, addressing the core issues of mining for further advancement, promoting the growth and sustainable development of mining industries.

International Conference on Opencast Mining Technology and Sustainability (ICOMS-2019, 14th December, 2019; Northern Coalfields Limited, Singrauli)

The major recommendations were related to the following broad themes.

- Production, Productivity and Safety: New Methods to facilitate high stripping opencast mining with improved productivity & economics
- Design and development of software to design mine working slope and dumps
- Advanced Blasting techniques
- Methods to extract inter-mine boundary coal
- Unconventional Mining Methods
- Best Practices / Benchmarking in maintenance and operations in OC mining
- Automation and Artificial Intelligence

Annual Conference on Future of Mining in India (13 - 14 Feb 2020, India Infrastructure Publishing Pvt. Ltd., New Delhi)

Annual Conference on Future of Mining in India was organized to focus on current state and key trend in the Indian mining industry, notable developments and their impact, new technologies and innovations in Indian mining industry, global advances and best practices, key issues and concerns and mitigation strategies and etc.

National Conference on "Mining Industry: Challenges and Opportunities – 2020" (MICO' 20), January 10-11, 2020, Indian Mine Managers' Association and Bharat Coking Coal Limited.

Minimizing uncertainty across the mining value chain, reducing costs and increasing productivity are some of the key drivers requiring Indian mining industry to look forward for the adoption of innovative technologies for a visible and sustainable gain. Digitalization of mines in terms of technologies enabling data-driven decisions such as Artificial Intelligence, Advanced Data Analytics and Machine Learning, Big Data and Cloud etc. are poised to meet the major thrust of Indian Mining Sector in general and Coal India in particular. With technological advancements, the skill set of the existing employees of mineral sector would require sufficient skill up-gradation. Emphasis may be laid on adoption of mass production technologies with automation and mine information systems. To realize this, the manufacturing base of various equipment, bulk material handling systems, mechanized loading systems, man riding systems along with associated safety systems need to be established.

Recommendations of Safety Conferences of DGMS, Tech Circulars and Other Symposiums

- Preventing Mine Disasters from Inundation
- R&D efforts should be continued to develop a system for construction of water-tight chamber as last refuge below ground in case of inundation.
- Belowground Communication and Tracking System
- All belowground mines shall be provided with efficient voice communication from the working districts/places to the surface.
- Mining companies in collaboration with research institutions/ equipment manufacturers shall initiate and fund for, suitable research initiatives for establishment of appropriate communication system for below ground mines including to locate the trapped miners.
- Mine management in collaboration with equipment manufacturers shall evolve a system of proximity warning device in HEMM and initiate measures for its implementation.
- GPS-GSM Based vehicle navigation system
- Skill Development and Training General Skill Development programme should be undertaken for training of operators and all other associated staffs using state of the art technique including simulation and 3D Virtual Reality system.
- A system of digital tracking system for all transportation machinery while in operation within the mine boundary shall be deployed
- All near misses or incidents are properly enquired into by an official of the mine who shall also make appropriate recommendations for preventing recurrences. Such

recommendations shall be circulated by appropriate mechanism including digital / electronic mode to create awareness and for designing suitable strategies

- Minimum Design requirements for various Safety Features to be incorporated for use in Heavy Earth Moving Machinery (HEMM) & Heavy/Light vehicles in Open Cast Mines.
  - Warning System for Operator Fatigue
  - Auto Dipping System
  - Automatic Fire Detection and Suppression System (AFDSS) for HEMM
  - Dump Body raised position indicator with warning
  - Load Indicators
  - Dump Body Stabilizers for Tippers
  - Proximity Warning Devices
- Every mine may consider establishing a personnel tracking system along with an effective communication system to ensure that safety instructions, information and initiatives can be communicated.
- Research and Development to be encouraged in keeping with the needs of modern, safe and healthy mining. Some areas are:
  - Application of robotics and intelligent systems
  - GPS based automatic disaster warning systems
  - More effective body armour/PPE using appropriate material especially for front line operators of Continuous Miners, cable handlers and other personnel exposed to high risk operations.
  - Real time roof monitoring
  - Optimisation of ventilation systems based on Ventilation on Demand concept.

4.2 SWOT Analysis

SWOT Analysis carried out by IIT (ISM) Dhanbad

Strengths:

1) Rich expertise in mining research:
   - Expertise across mining value chain;
   - deep experience in geophysical and geological exploration techniques, airborne geophysical methods, remote sensing-based mine surveillance, application of advanced 3D imaging for mining, digital mine mapping, mine planning, scheduling and simulation solutions, implementation of sustainability principles across mineral value chain
2) Strong technical expertise:
   - Ability to develop sensors, IoT, Industry 4.0 platform, data capturing and data analytic tools, ML and AI solutions;
   - ability for inter-disciplinary research and development;
   - experience in using AR/VR for skilling of workforce with respect to technological change
3) Human resources:
   - large pool of talented people in form of undergraduate, postgraduate and doctoral students and institute faculty;

- availability of people with rich industry experiences and practices

4) Strong industry networks: well established network with academic & R&D institutions, mining companies and specialized technology firms
5) Infrastructure and others:
   - Robust in-house research and training infrastructure,
   - proximity to mining belt of India

Weakness:

1) Limited expertise in certain areas:
   - Inadequate in-house expertise for developing artificial intelligence solutions, machine learning solutions, IoT solutions and sensors for mining sector,
   - little to no expertise in developing cyber-physical systems for mineral exploration,
   - shortage of mine planning and execution skills
2) Limited experience in certain areas:
   - Lack of experience in using industry standard mine planning, scheduling and simulation software solutions and integrating them to execution technology,
   - low project management experience for medium to long term field-based projects
3) Work and research culture:
   - lack of ability to quickly adapt to new technologies in mining;
   - no impetus in past for development and implementation of innovative mining technology or disruptive technological solutions for mining industry

Opportunities:

1) Large mineral resource base in India: GSI has identified 0.571 million sq. km. as an obvious geological potential (OGP) area for minerals, a major part of which is yet to be fully explored
2) Unfulfilled market demand for minerals:
   - Large gap between demand and supply of mineral resources;
   - low overall mineral grades and poor quality control
3) Urgent need of innovation for better social and environmental outcomes:
   - Inherent high hazardous geo-mining conditions such as high susceptibility to fire;
   - legacy of old unscientific methods resulting in unsafe conditions and high fatality rates;
   - huge environmental impacts of drilling based mineral exploration
4) Large potential for use of technology in mining:
   - Huge scope of application of automated, remotely operated safer production technologies for improving safety, health, environment, conservation and sustainability;
   - huge scope for application of Industry 4.0 technologies - sensors and use of modern on-line network system, geological disturbance detectors, integration of strata monitoring with support etc., development of tele-robotics and remote

- operation technologies for underground coal mines, instrumented technological development and data analysis;
- huge scope for application of data capturing and data processing technologies such as sensors, IoT, big data etc. since mining processes generate large amounts of data

5) Several gaps in practices of mining sector:
   - low productivity, low equipment utilization, high costs, inadequate mine planning system, traditional practices for mine planning and operations, lack of integration between mine planning and operation, poor decision making,
   - lack of mechanization of UG coal mines,
   - lack of suitable technology for data transmission from underground workings,
   - inadequate use of automation and application CPS based technologies and application of AI etc. for data analytics
6) Limited technological exposure of mining industry:
   - Lack of exposure of Indian mining industry to global best practices and application of modern technologies;
   - predominant use of conventional systems for underground mines;
   - low mining expertise with new entrants from private sector;
7) Favorable policy environment:
   - Policy focus towards augmenting mineral production (doubling of mineral production by 2026), sustainable mining, clean coal technology, prevention of illegal mining, self-reliance in infrastructure materials and strategic metals;
   - strategic government initiative for introduction of AI, ML, technological innovation and automation in mining sector;
   - encouragement to innovation and incubation for indigenous development through "Make in India" initiative;
   - greater funds and impetus through clubbing of exploration with mining under NMP-2019 and government spending through NMET for exploration and exploration technology;
   - more technological resources such as Sustainable Development Cell for monitoring adverse impacts of mining
   - Stricter compliance requirements to control for over production, mining beyond lease, unsystematic closure etc.
8) Favourable industry environment:
   - Impetus for Industry 4.0 through technology:
   - emerging consensus within the mining industry that technology is going to be the critical differentiator;
   - more than 60% of mining companies view innovation as crucial to their long-term business strategies;
   - strong financial strength of major mining companies such as Coal India Limited, NMDC having large chunk of R&D funding for mining sector

Threats:

1) Government policies and regulatory hurdles:

- Import of mineral at less price to meet the growing demand
- FDI in mining will invite global players much ahead on the innovation curve.
- Regulatory hurdles for new innovations and technologies - statutory hindrance of prescriptive legislation in introduction of modern technologies – approval, licensing, permission
- Inordinate delays in permissions for field trial and approval for uses of developed technologies

2) Competition:
   - Threat to indigenous development by foreign technology encouraged through policy reforms
   - Threats from early Innovators and Startups who could be equally good in the areas remote surveying, wireless/TTE communication, teleoperation, automated mine safety appliances etc. at much low cost.
   - Strong existence of Indian establishments in terms of sensor developments and integration, communication & tracking technologies (RF & Microwave; Radars, drones, communication and navigational satellites) and AI & Data Analytics.
   - Availability of proven technology elsewhere in the world which can simply be adopted without much time for indigenisation.
   - Large MDOs of UG operations (Joy Mining etc.)
   - Early Innovators and Startups who could be equally good in the areas remote surveying, wireless/TTE communication, tele-operation, automated mine safety appliances etc. at much low cost
3) Mining culture and current business models of the industry:
   - Lack of trust or confidence of industry in non-invasive exploration and AI based analysis,
   - Less awareness about R&D among Indian mining
   - Lack of trust in indigenous technology due to technology failures in past
   - Lack of ability of Indian exploration companies (either government or public sector undertakings) to quickly adapt to new technologies
   - Large scale outsourcing of mining activities to small local contractors/MDOs who do not have incentive for innovation and technology adoption or priority for environment, safety health and sustainability
   - Insufficient provisions for use of technologies to ensure productivity, safety and sustainability in mining contract documents
4) Social issues and community resistance:
   - Negative social perception of fear of losing jobs due to automation and large-scale mechanization of mines and application of AI etc.
   - Community resistance to safety and environment related interventions due to high population density in and around mining areas
5) Large numbers of small, difficult to reach mines and illegal mining
   - Mines located at remote and isolated places having inadequate infrastructure
   - Small lease area are not amenable to deployment of high-end machinery and work on deep-seated mineral deposits

- Unregulated practices in small scale and unorganized mines such as over production, mining beyond the allocated area, unsystematic closure etc.

6) Increasing complexity of Geo-mining condition: increasing depth, difficult geology, workings in upper horizons largely affected by fire, waterlogging or unmined property
7) Unsuitable research and innovation culture at mining institutions:
   - Time delays in innovation and implementation of modern technologies due to lack of indigenous capability / availability
   - Inadequate funding
   - Hurried decisions in selection of technology without proper risk assessment of introduction or application of technologies
   - Changing requirement with rapid development of technology resulting into technology getting obsolete

4.2.1 The outcome of SWOT

The outcome of SWOT has also further helped in identifying the problems in mining industry and possible solutions.

The Technology drivers in Mining Industries are follows:

- Health and safety environment for mine workers.
- Reducing operational cost, Improving performance of assets and efficiency of operations
- Reducing the rise in capital cost by indigenization of technologies.

Geospatial Technologies (RS & GIS), Artificial Intelligence (AI), Smart cost effective sensors, Smart Communication Systems (5G wireless) and big data processing etc. have enabled the cost-effective applications of CPS systems in Mining Value Chain and have further laid the scope for Innovative Mining Systems.

Technologies to be developed and adopted in the mining sector can be classified in the following categories:

- **Digitalization of Mining Process**: Real-time digital data collection across various operations and make them available for processing & instant decision making (e.g., sensors, portable smart devices, GPS navigation, LIDAR and drones).
- **Big Data integration**: Enhancing the performance of mining processes and solving complex problems using Internet of Things (IoT) & blockchain.
- **Operation & Process Optimization**: Use of big data and robotics (e.g., machine learning, data analytics, automation, remote operation, digital twins).

A summary of possible innovations in mining leading to Mining 4.0 are listed below:

Exploration

- Identifying minerals, chemical compositions, and physical properties directly in the field
- Detecting deep concealed mineral deposits
- Exploration and extraction strategy for REE and PGE

- Modelling mineral deposits, their potential economic assets, and challenges right from the earliest stages of exploration

Smart and Efficient Mining

- Selective Mining using Automation & Robotics
- AR and VR based Mine Planning and Operational Processes
- Real-time monitoring of the flow of rock and ore through the mine and processing plant
- Asset Management System
- Operational Efficiency

Safe Mining

- Improved underground communication
- Risk Assessment and Safety Management System
- Ground Control Management System for Deep Mine/Slope Stability
- Increasingly sophisticated means of ore transportation
- Emergency response measures developed for the harshest conditions

Eco-friendly Mining

- Air-borne based Mine Surveillances and Earthworks Estimation
- Spatial Visualization using AR, VR and LIDAR Technologies
- Mining Area LRM: BIS and LIS integration through GIS
- Solutions to deal with acid mine drainage
- Solutions to transform mine tailings into beneficial products

Overall, the Technology Innovation Hub in Mining 4.0 is aimed at improving worker safety, increase efficiency, and minimize environmental impacts.

Impact of Mining 4.0

- **Productivity Improvement**: It is anticipated that there will be an overall improvement in productivity between 9 per cent and 23 per cent as a result of digitalization and other technological innovations
- **Health & Safety**: positive impacts on health and safety, efficiency and productivity
- **Job Potential**: Technologies like automation, repetitive and manual tasks—concentrated among lower-paid, lower-skilled, and less-educated workers—are at serious risk of obsolescence, while higher-skilled tasks such as those linked to the analysis of data, digital planning or remote centre operations will be created
- **Scale of Mining**: Large-scale and mega-mines have more financial means to invest in more advanced technologies than mid-sized or smaller mines

Barriers of the Technology Adoption

(i) Disrupting existing value chains: New technologies may disrupt established value chains.

(ii) New safety challenges: Rapid integration of new technologies may create hazards for workers not accustomed to working with them (e.g., failure rates of new technology, reliability, interoperability and connectivity issues in mine environments).

(iii) Managing labour transitions: Challenges of striking the balance between managing the transition toward a smaller workforce and filling labour gaps without losing the sector's licence to operate in communities that depend on mining jobs.
(iv) High upfront costs: Upfront costs of some technologies may hinder adoption until the sector can develop a better understanding of new financing models for high-tech applications.
(v) Standard, costs and regulations: Interoperability is a key issue in mining applications
(vi) Disrupting existing value chain: Local communities can react by strongly objecting to project development

A typical expected application of CPS in mining value chain is shown in the Figure 3.1.

As highlighted above, most of the changes occur at the mine-processing phase. The top four technologies are not surprising: they are (i) robotics and automation (over 50 per cent expected); (ii) the use of unmanned vehicles and drones; (iii) the use of wearable and other connected items; and (iv) remote operating centres, necessary to control all of the three other technologies. Taken together, those are sufficient to reshape the organizational and operational structures within the mining industry and the relationship it will have with its employees, suppliers, local communities and host governments. But this is just the tip of the iceberg, considering the potential of technologies in the pipeline.

4.3 Target Beneficiaries

The mining and minerals industry provide an important support to the economy and is of strategic importance to every country. Owing to the use of outdated technology, most of the mining companies are at times unable to explore and exploit deep seated ore reserves. There are opportunities for discoveries of sub-surface deposits with the application of modern techniques and processes backed with CPS. The TIH in Mining has identified hosts of problems that can be tackled through application of CPS systems with main goal of Safe, Smart, Simple and Sustainable Mining leading to increase in production & productivity. The demand for coal and minerals for energy and other requirements are growing with time. Meeting those demands will be a challenge for the mining and minerals industry worldwide.

The key sector beneficiaries are classified into following:

1. Exploration: GSI, MECL, CMPDI and other companies
2. Mining Companies:
    a. Coal India and its subsidiary companies; Tata Steel, Singerani Collieries Other Coal Companies
    b. NMDC, Tata Steel, SAIL, UCIL, HCL, MoIL, NALCO, VEDANTA (HZL), and other companies, State Owned Mining Companies
3. Mining Equipment Manufacturing Companies: BEML, HEC, APHMEL, L&T, Tata,
4. Regulatory Authorities: DGMS, IBM
5. Government Bodies: MoEF & CC, Ministry of Coal, Ministry of Mines, Ministry of Labour & Employment, State Department of Mines & Geology
6. Research Organizations: CIMFR, NIRM, NIOH, NGRI etc.

7. Human Resource Development: IITs, NITs and Other Institutes having Department of Earth Sciences and Mining Engineering.
8. Skill Councils: NSDC, SCMS
9. Society at large: Safe working condition, up-skilling of workforce, Social licencing
10. National Priority Missions

	Explore/ acquire	Mine development	Mine	Ore processing	Logistics	Sales & marketing
Robotics and automation (mobile and fixed assets)*	42%	47%	54%	45%	33%	24%
Advanced process control	22%	31%	37%	41%	23%	17%
Drones/UAVs	32%	30%	41%	24%	19%	11%
Remote operating centres	30%	29%	41%	36%	22%	17%
Mobile/tablet use	35%	36%	31%	26%	37%	36%
Wearables	32%	37%	41%	30%	23%	25%
Integrating planning	33%	32%	28%	30%	29%	27%
Digital platforms (cloud, etc.)	28%	25%	27%	19%	36%	39%
Real-time visualization of data	36%	28%	35%	31%	27%	23%
Real-time analytics	33%	28%	38%	30%	29%	23%
Video analytics	34%	29%	29%	28%	24%	15%
Image analytics	39%	29%	33%	29%	17%	17%
Virtual simulation of physical environment	32%	34%	37%	30%	21%	16%
Artificial intelligence and cognitive computing	37%	40%	39%	18%	19%	15%
Social media	32%	32%	27%	30%	25%	20%
Cybersecurity	23%	24%	22%	22%	29%	47%
3D printing	34%	32%	26%	24%	38%	33%

** Robotics and Automation (mobile and fixed assets) refer to those instances where respondents have/plan to employ Robotics and/or Automation in each respective mining activity.*

10–19% | 20–29% | 30–39% | 40–49% | 50–59%

Fig 4.1: Digital Technologies Being Adopted More Quickly By Mining Operations by 2022 (Source: Accenture *Consulting, 2017)*

For companies that embrace digitalization, it offers the promise of a more nimble and profitable business, with improved decision-making and increased employee empowerment. More importantly, when designed and implemented correctly, digitalization can improve health, safety and environmental impact – saving lives, reducing injuries, lowering emissions and waste, and increasing transparency and sustainability.

Digitalization can indeed create attractive jobs in safe control room environments, which provide space for the employee's full expertise and creativity: the control room receives online processed information from the "rock", from personnel, and from machinery, and control room equipment makes it possible to control and fine tune the complete operation, from resource characterization to the final product.

The mining industry's contribution (excluding petroleum and natural gas) to India's GDP is 1.63%, a sharp contrast to India's true potential, being a geologically rich country. A significantly higher contribution to GDP will go a long way in achieving India's dream of becoming a USD 5 trillion economy, as evinced across economies like South Africa where mining contributed 7.5% to GDP, and Australia where it is 6.99% to GDP.

Innovations in artificial intelligence (AI), machine learning and the industrial internet of things (IoT) all have the potential to save the sector an estimated $373 billion and hundreds of lives by 2025 by automating machinery operation, planning and scheduling, facilitating predictive maintenance, improving man, material and asset traceability, harnessing the power of real-time data and analytics, and providing visibility across the mine-to-market value chain.

Digital technologies have tremendous potential to move beyond stagnant growth and deliver exceptional shareholder, customer and environmental value.

The tangible benefits of adoption of innovative mining technologies are envisaged as follows:

- More than $425 billion of value for the industry, customers, society and environment over the next 10 years (to 2025). This is the equivalent of 3-4% of industry revenue during the same period.
- More than $320 billion of industry value over the next decade, with a potential benefit of approximately $190 billion for the mining sector and $130 billion for the metals sector. The total for mining and metals is equivalent to 2.7% of industry revenue and 9% of industry profit.
- A reduction of 610 million tonnes of CO_2 emissions, with an estimated value to society and environment of $30 billion.
- An improvement in safety, with around 1,000 lives saved and 44,000 injuries avoided. This equates approximately to a 10% decrease in lives lost and a 20% decrease in injuries in the industry

4.4 Outcomes & Deliverables

ICPS programme success criteria expected outputs/ deliverables, units, baseline data and measurable outpus/ deliverables are provided in the subsequent Tables.

Table 4.1: Targets to be achieved in the TIH as per laid objectives

S No	Target Area	Targets set by DST	Host Institute agreed targets					
			1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
1	**Technology Development**							
(a)	No of Technologies (IP, Licensing, Patents etc)	20	2	3	5	5	5	20
(b)	Technology Products	15	1	2	2	5	5	15
(c)	Publications, IPR and other	45	5	10	10	10	10	45

	Intellectual activities							
(d)	Increase in CPS Research Base	70	5	10	15	20	20	70
2.	**Entrepreneurship Development**							
(a)	Technology Business Incubator (TBI)	1	1	0	0	0	0	1
(b)	Start-ups & Spin-off companies	35	5	10	10	10	0	35
(c)	GCC - Grand Challenges & Competitions	1		1	0	0	0	1
(d)	Promotion and Acceleration of Young and Aspiring technology entrepreneurs (PRAYAS)	1	1	0	0	0	0	1
(e)	CPS-Entrepreneur In Residence (EIR)	21	10	11	0	0	0	21
(f)	Dedicated Innovation Accelerator (DIAL)	1	1	0	0	0	0	1
(g)	CPS-Seed Support System (CPS- SSS)	1	1	0	0	0	0	1
(h)	Job Creation	8750	150	1100	2000	2500	3000	8750
3.	**Human Resource Development**							
(a)	Graduate Fellowships	220	40	40	40	50	50	220
(b)	Post Graduate Fellowships	42	10	10	10	12	0	42
(c)	Doctoral Fellowships	23	5	8	10	0	0	23
(d)	Faculty Fellowships	3	0	2	1	0	0	3
(e)	Chair Professors	3	0	2	1	0	0	3
(f)	Skill Development	410	35	75	100	100	100	410
4.	**International Collaboration**							
(a)	International Collaboration	1	1	0	0	0	0	1

* Separate call for Proposals will be made for International Collaborations on the identified problems. However, the PIs from both the countries will formulate the problem.

Success criteria: The TIH will be considered a success if the measurable outputs/ deliverables mentioned in above table are achieved. Indicators are evolved considering the overall objectives of the programme, existing baseline data and investments that is contemplated on the programme. Though seems to be ambitious but achievable.

Table 4.2 lists the deliverables in the verticals Technology Development of TIH in Exploration & Mining. The Table summarizes the deliverables in terms of (a) Expert-driven new knowledge generation /Discovery (TRL 1-3), (b) Development of products /prototypes from existing knowledge (by experts or teams) (TRL 4-6), and (c) Technology /product delivery in specific sectors, i.e., projects that involve knowledge generation and also conversion to technology, demonstration of full working technology (by experts or teams) (TRL 7-10).

Table 4.2 : Deliverables in Technology Development of TIH

Objective	**Problem**	**Expected Deliverable**	**Technology Development Level**
Improving Resource discovery:	Deposit Scale Modelling	Geological and Geophysical maps on the same scale. 3D and 4D maps on the basis of integrated studies.	Development of products /prototypes from existing knowledge (TRL 4-6)
		Better resolution geological map using Artificial Algorithm	Development of products /prototypes from existing knowledge (TRL 4-6)
	Mapping Lithospheric Architecture	Developing 3D optimization tools for joint inversion of data sets constraining with petrophysics	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Identifying deep-penetrating faults and crustal suture zones, which are important controls on the movement of metal-bearing fluids and hence indicators of perspectivity.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Formulation of self-consistent numerical models of the mineralogical evolution of fluid chambers in lithosphere and upper mantle.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Development of laboratory models to study the fluid-rock interaction resulting in rock deformation and thermal transitions in mineral systems due to heat transfer.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Understand and characterise the fluid bearing mineral system components with respect to their response to geophysical exploration methods.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
	Mineral Discrimination	The goal is to improve our fundamental understanding of the linear and non-linear polarization phenomena of natural mineralized porous media at various scales and over the frequency band 1 mHz-30 MHz.	Development of products /prototypes from existing knowledge (TRL 4-6)
		The interfacial and textural properties of rocks will be characterized.	
	Understanding the geophysical	Formulation of self-consistent numerical models of the	Expert-driven new knowledge generation

	responses associated with deep-penetrating geophysical methods for mineral systems exploration	mineralogical evolution of fluid chambers in lithosphere and upper mantle.	/Discovery (TRL 1-3)
		Development of laboratory models to study the fluid-rock interaction resulting in rock deformation and thermal transitions in mineral systems due to heat transfer.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Understand and characterise the fluid bearing mineral system components with respect to their response to geophysical exploration met hods.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
	Petrophysical Data Base	Petrophysical data sets of different metallogenic province of India consisting of a. density, susceptibility, conductivity, resistivity, chargeability, and velocity, b. location, stratigraphic unit and lithology, c. information of weathering, alteration, metamorphism and porosity, and d. geochemical and mineralogical information	Development of products /prototypes from existing knowledge (TRL 4-6)
	Hyper-spectral imaging	System development and deployment	Technology /product delivery in specific sectors (TRL 7-10)
		Mineral mapping and feature extraction for His	
		In HSI one of the biggest challenges is determining what types of features should be extracted from pixels.	
	Rare Earth Elements and Platinum Group of Elements	to develop geophysical approaches to rare earth element evaluation,	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		to conduct geochemical and mineralogical analyses of heavy mineral sand samples from both archives and field efforts,	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		analysis of new and existing data on the samples to be	

		performed to evaluate links between geophysical, geochemical properties, rare earth element content and local geologic processes	
		rare earth element content and local geologic processes,	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		synthesize geophysical, geochemical and geological data using AI, and to relate results to geological processes acting on a regional scale,	
		dispersion of REE/PGE in secondary environments such as placer deposits, weathered horizons and gossans.	
	Cross well tomography	Cross well tomography maps	Development of products /prototypes from existing knowledge (TRL 4-6)
		Integration of these with surface maps to reduce uncertainties	
Get real-time data	Development of an autonomous multirotor unmanned aerial vehicle for geophysical survey.	To develop an unmanned aerial vehicle UAV which can carry up to 10 kg payload (geophysical instruments, measurement systems etc.) and fly/hover for up to 90 minutes.	Technology /product delivery in specific sectors (TRL 7-10)
		To develop the craft by avoiding the use of materials that can potentially interfere with the functionality of the instruments being carried as a payload.	
		To develop appropriate interfaces to provide the power required by the on-board devices during survey.	
		To minimize the turn-around time so that it will be easy to prepare for the next round of survey.	
		To develop a friendly and nearly autonomous user interface for the ease of operation.	
	Drilling Technology	hand-held and down-hole analytical instruments	Development of products /prototypes from existing knowledge (TRL 4-6)
		directional drilling, better bits, down-hole logging	
		improvements in slimhole drilling and in-situ measurements	
	Virtual Reality	VR Technology	Technology /product

	(VR) Technology		delivery in specific sectors (TRL 7-10)
Simplify mining operations	Applications of Robotics in Mine Automation	Tele-operated, automated and self-navigating load-haul-dump trucks.	Technology /product delivery in specific sectors (TRL 7-10)
		Automated loading and unloading features in dragline	
		A robot device for drilling and bolting mine roofs	
		A robotic drilling and blasting device for inducing controlled caving.	
Reduce risks	Development of Smart Communication, Sensing and Monitoring Technologies	Development of an effective underground mine communication system under dynamics and difficult sub-surface environment: Improved Through-The-Earth (TTE) Communications for Underground Mines.	Development of products /prototypes from existing knowledge (TRL 4-6)
		Portable communication devices based on UHF frequencies for the miners in underground coal mines.	
		Development of Underground Positioning Systems (UPS): Smart portable system for tracing miners including mine safety monitoring and alerting.	
		Development of a low-cost AI/ML portable RADAR system for Monitoring and prediction of Rock and Dump Slopes failure in Open Cast Mines.	
		A Novel Surveillance and Evacuation System for Underground Mine Safety	
		Application of Drone, LIDAR, GIS & Remote Sensing based Mine Surveillances System	
Go eco-friendly	Mine Simulation Systems	3D simulation & Modelling	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Digital Twins: By creating a virtual model that is fed real-time data from the field, scenarios can be quickly tested, and operations and production can be optimized	Development of products /prototypes from existing knowledge (TRL 4-6)
		Autonomous Drilling	Development of products /prototypes from existing

			knowledge (TRL 4-6)
		Autonomous Equipment: Greater use of self-controlling machines in harsh environments	Development of products /prototypes from existing knowledge (TRL 4-6)
		Reducing environmental impact with AI: Sensors and IoT to monitor excavation, extraction, and general mining activities, keeping tabs on the spread of waste and harmful materials.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		GIS analytical information with graphical representation for better understanding and policy making and AI based decision support system	Expert-driven new knowledge generation /Discovery (TRL 1-3)
Safe Mining	Loss of Structural stability and integrity of heavy machines or structures in mines	Sensor based continuous monitoring of structural integrity of complex and large size machines or structures in mines and prediction of failure by analysing the data using AI before actual failure.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Sensor based monitoring of structural stability of heavy machines in mines and prediction of loss of stability by analysing data of physical effects of structural stability on different parts of machines.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
	Workmen's Fatigue and physiological stresses or disorders	Measuring and monitoring of physiological effects of human body due to fatigue, physiological stresses due to working and task conditions, and physiological disorders due to lack of proper ergonomic design of machines	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Prediction of fatigue level, level of physiological stresses and physiological disorders by analysing the data using AI.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Activation of machine interlock with digital fatigue detectors.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
	Exposure to Diesel Particulate Matter (DPM) beyond safe limit	Development of integrated system for sensor based continuous monitoring of exhaust discharge from the machines like SOx, NOx, CO and DPM, analysis of data using AI and	Development of products /prototypes from existing knowledge (TRL 4-6)

		prediction of concentration of DPM or other harmful diesel exhaust and activation of mitigating measures like ventilation flow control, controlling movement of diesel vehicles	
	Potholing and collapse of important surface structures due to unstable subsurface areas from mine workings or subsurface mine fire	Development of suitable technology using geophysical method for detecting subsurface unstable areas and application of AI for locating such unstable areas.	Development of products /prototypes from existing knowledge (TRL 4-6)
	Collision of mobile equipment or hit by machines in UG mines	Sensor based proximity detection devices capable of detecting the proximity of another equipment and activating an alarm to both the operators.	Technology /product delivery in specific sectors (TRL 7-10)
		Sensor based tags to send an alert signal to the machine operator in case presence of other person within the NO GO ZONE. Similar audio-visual alert to the persons approaching the machine.	
	Blasting	Suitable sensor based portable detector may be developed for identifying the presence and location of misfired shots.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Presence and location of misfired shots may be detected by scanning the profile of blasted material and using AI for analysis of scanning data	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Suitable App-based tracking system using sensors or tags may be developed for identifying the location of blasting crew or other persons and interlocking the blast initiation system to prevent inadvertent entry into exclusion zone.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Same system may be useful for ensuring human and equipment exclusion zone	Expert-driven new knowledge generation /Discovery (TRL 1-3)

		during blasting in opencast mines.	
		Prediction of fly rocks from data of blasting detail using AI	Development of products /prototypes from existing knowledge (TRL 4-6)
	Ground failure in Underground mine workings	Development of integrated strata management system	Development of products /prototypes from existing knowledge (TRL 4-6)
		Development of handy tool for detecting presence and location of bed separation in roof rock, based on onsite monitoring of geophysical parameters of roof rock and digitally expressing the failure by using analytical software	
		Development of integrated strata management system	
		Continuous monitoring health condition of support system and prediction of failure of support system	
		Monitoring behaviour of goaf in caving method of mining, using cavity scanner or similar other instrument, analysing data using AI	
	Inrush of huge quantity of water or unconsolidated mass	Development of geophysical method or instrument for identifying presence of water bodies / water logged workings / accumulation of unconsolidated material ahead of mine workings	Development of products /prototypes from existing knowledge (TRL 4-6)
		Development of handheld portable water body detector for proving presence of water bodies immediately ahead of mine workings	
		Continuously monitoring inflow of water into mine workings	
	Explosion in coal mines	Development of Integrated system of continuous monitoring of accumulation of inflammable gases in mine atmosphere	Technology /product delivery in specific sectors (TRL 7-10)
		Design and activation of sensor based explosion barrier to prevent propagation of explosion,	
		Design of sensor based instrumentation for detection	

		of methane layering by sensor based instrumentation,	
		Development of portable sensors for detection of inflammable gases like CH_4, H_2, and CO	
		Development of portable sensors for determination of inert content in roadway dust.	
	Spontaneous combustion of coal	Development of integrated system for continuous monitoring of indicators of spontaneous heating	Development of products /prototypes from existing knowledge (TRL 4-6)
		Development of wearable portable sensors for detection of gases like CH_4, H_2, CO	
		Detection of portable sensors for detection of hotspot	
Smart Mining	Smart Mining	Improving OE by optimizing the unit operations in mining through application of smart sensors, real time data acquisition, data transfer and analysis for performance prediction using CPS.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Increasing machine reliability and availability through continuous machine condition monitoring and online real time data transfer	Development of products /prototypes from existing knowledge (TRL 4-6)
		Resource optimization through optimum machine deployment through capturing real time data on machine down time, idle time, operational delays etc. and its analysis using AI.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Energy optimization in all activities from mine to mill through capturing unit-wise energy consumption data and its analysis using CPS and bench marking of energy consumption	Expert-driven new knowledge generation /Discovery (TRL 1-3)
Get real-time data	Extraction Cost Reduction: Energy savings	Estimation of the effect of different physical and chemical properties of particles on their breakage.	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Quantification of different particle processing stages' effect on comminution.	
		Strategies for introduction of efficiency boosting techniques	

		like controlled blasting and particle pre-processing within and around comminution circuits.	
		Development of novel comminution circuits integrated with blasting for improving energy efficiency	Development of products /prototypes from existing knowledge (TRL 4-6)
		Development of robust simulators aided by sensor based online PSA (Particle Size Analysers) to reduce the processing cost and even capital cost	
Get real-time data	Extraction Cost Reduction: Life extension	Development of AI-based prediction model of wear and tear of screen panels, grinding media, liners etc.	Development of products /prototypes from existing knowledge (TRL 4-6)
		Ultra-fast onsite repair of worn out and corroded components of mining machinery with the ability to prevent heat-related distortion, and requirement of inert gas or vacuum sealed environment	
		Cost effective way to extend the useful life of mining machineries significantly	
Improving resource discovery	Exploring for New Products from the known sources: Deep cleaning of coal	Sensor based/ Processor controller aided cost-effective, environment friendly technology for deep cleaning of high-ash Indian coal	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Report on techno-economic comparison of different deep cleaning techniques	
Improving resource discovery	Exploring for New Products from the known sources: Carbon based nanoparticles	Development of AI-based CNTs, graphene and graphene oxide for its usage as super capacitors in high energy storage materials	Expert-driven new knowledge generation /Discovery (TRL 1-3)
		Mechanistic understanding of Nano particle synthesis from heterogeneous coal	
Go eco-friendly	Urban municipal waste processing for energy and precious metal recovery	Sewage sludge as a source of energy.	Development of products /prototypes from existing knowledge (TRL 4-6)
		Sensor and AI based enhanced water recovery from sewage sludge.	
		Pyrolysis char as a source of valuable metals/minerals e.g. phosphate, lead, mercury, etc.	
Improving resource	Mixing sewage	Proper utilization of coal	Development of

discovery	sludge with fine coal waste/ carbon anodes/ forest bio-mass to increase calorific value for subsequent use in cement plants	waste /carbon anodes/ forest biomass to increase calorific value. AI/Sensor based cleaner cement production	products /prototypes from existing knowledge (TRL 4-6)
Improving resource discovery	Recovery of valuable metals from process plant water	Mine and mineral processing plant water as a source of precious metals Sensor and Process controller aided treatment of waste water to make it available for use in agriculture, horticulture, fisheries and if possible, as potable water	Development of products /prototypes from existing knowledge (TRL 4-6)
Improving resource discovery	Dewatering of red mud	Application of AI in developing modified scheme for improved dewatering performance of Indian red mud slurry. Production of dewatered red mud for re-use Improved recovery of water from red mud slurry for recycling back to plant to reduce fresh water consumption. Increased availability of land, reduced pollution of nearby water bodies and land area, conservation of nearby forests, etc.	Technology /product delivery in specific sectors (TRL 7-10)
Go eco-friendly	Utilization of Coal Cleaning Plant Rejects	Sensor/processor controller aided blending of sal leaves and plant reject Potential for rural employment generation through the social forestry programme Reduction of carbon footprint by utilizing renewable energy sources Utilization of low grade coal	Technology /product delivery in specific sectors (TRL 7-10)
Improving resource discovery	Extraction of Rare Earth Elements (REE) from coal and its by-products	Database on occurrence of REE in Indian coals. Information on the distribution of REE in different by-products of coal utilisation. Sensor/processor controller aided technique(s) for the extraction of REE from coal at different stage of preparation	Technology /product delivery in specific sectors (TRL 7-10)

		and utilisation and comparisons thereof.	
Go eco-friendly	Carbon and Sulphur Capture	Green and Clean method for CO_2 and SO_2 capture	Development of products /prototypes from existing knowledge (TRL 4-6)
		Biofuels from CO2 and SO2 capture	
		Sensor aided monitoring of Carbon capture and formation of conversion product	
		Obtaining carbon credit	
Get real-time data	Early detection and prevention of spontaneous combustion of coal using UAV	Early detection and prevention of spontaneous combustion of coal using UAV in coal-stockyards, non-active coalmines etc.	Development of products /prototypes from existing knowledge (TRL 4-6)
Improving resource discovery	Application of AI in enhancing the efficiency of material handling systems in coal and mineral processing and process metallurgy	Optimized use of material handling system through AI application	Development of products /prototypes from existing knowledge (TRL 4-6)
		Operating cost reduction	
		Maximizing the operating hours	

Figure 4.2 sumarizes the deliverables under the TIH in Mining 4.0

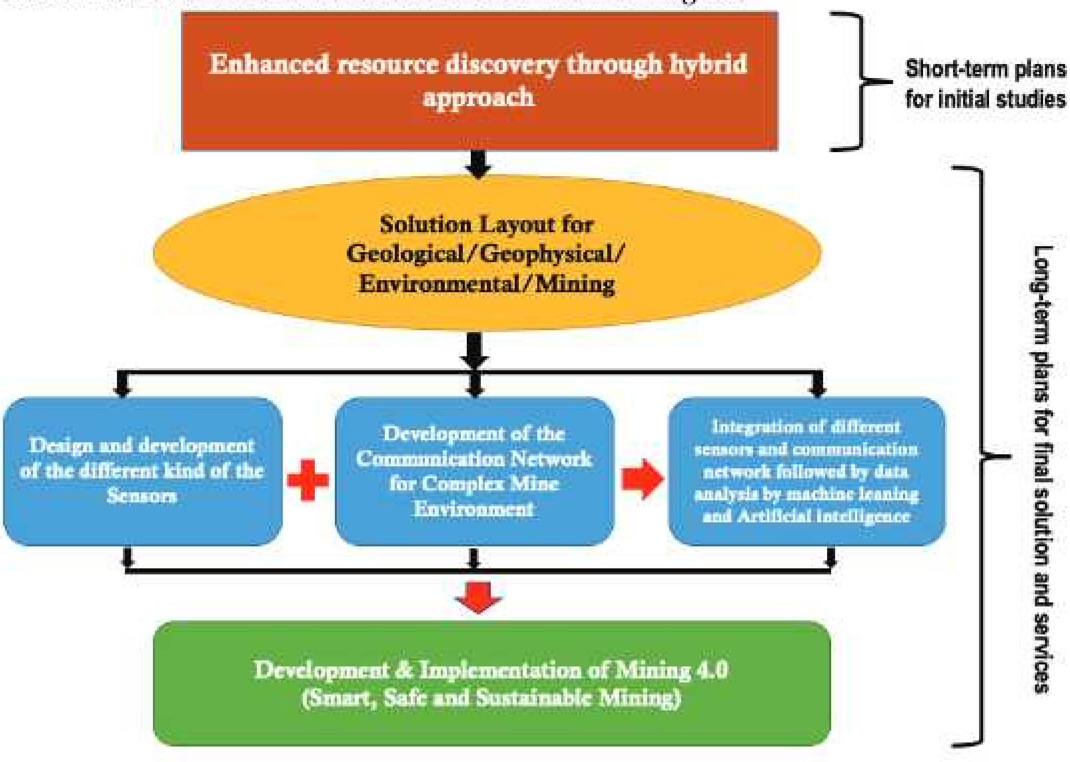


Fig. 4.2: Short and long – term deliverables under the TIH in Mining 4.0

5 CENTRE FOR MINE AUTOMATION & DATA ANALYTICS

The distinguishing feature of the Centre is its emphasis on tackling fundamental challenges to real-world cyber-physical systems towards safe, smart and simple mining. The centre would not merely react to cyber age but intends to catalyse it. The centre would spur innovation and accelerate the translation of breakthroughs into real-world applications and would certainly deliver large economic and societal impact for India across mining sector. CPS are essential for the future of the mining industry world-wide and collaboration at all levels, is necessary. The centre would be creating data ecosystems, developing talent pipeline, increasing R&D for product development TRL 4 and above all, calibration and standardization of CPS in Exploration & Mining.

5.1 Introduction

The Centre of Excellence under the Programme of National Mission of Interdisciplinary Cyber Physical System (NM-ICPS), Department of Science & Technology, Government of India is being proposed to be established at IIT(ISM), Dhanbad as **An interdisciplinary national facility for performance evaluation, calibration and standardization of CPS in Exploration & Mining.** The Centre would carry out domain-specific transnational research, training and capacity building, product, process and prototype development in the area of digging deep: exploration, exploitation and eco-restoration of mineral resources of the country with primary intervention of state-of-the-art interdisciplinary Cyber Physical System (CPS). The Centre will establish a National Facility for CPS prototype development for real-time data acquisition across the mine value chain, system integration, performance evaluation, calibration in a scaled mine environment. The basic objective of the facility is to create an integrated mine experimental facility for deployment of CPS systems, data standardization and seamless data capturing for AI based prediction and online decision support to increase operational efficiency and improve safety, health and environment. Primarily, different kinds of efficient sensors and active/passive devices like RF-**s**ensors, wideband antennas, low-cost RADARs, Photonics sensors, LNA design, passive sensors, etc. will be developed and tested in the centre.

5.2 Need for the Centre

The Centre of Excellence of (CoE) in Mine Automation & Data Analytics is a vital strategic asset to serve as the primary vehicle for managing complex change initiatives for implementing CPS in Indian mineral sector. The proposed Centre of Excellence will provide a team mandated to focus on research and development in mineral exploration, mining and mineral processing; bringing together faculty members from different disciplines and provide shared facilities. The CoE will be associated with development of technologies and human resource development. For an area like Cyber-Physical Systems, CoE will bridge two distinct systems- cyber and physical, embedded in several technologies, feeds on ever-evolving technological advancements and CoE will be instrumental in finding application across the value chain of a critical socio-economic as well as strategic sector like mining.

Status of application of modern technology to make the mines safe and smart is are far below the global standard and there is huge scope of intervention of CPS in all unit operations of mining starting from exploration to production of minerals to mineral processing. There is a strong need to establish a Centre of Excellence in Cyber Physical System applicable to mining and mineral processing sector in India with primary objective of TexMin Hub.

5.3 Objectives of CoE

The objectives of the CoE will be to carryout translational research and facilitate development, calibration, standardization and commercialization of processes and technologies in mine automation. The CoE would support and encourage innovative technology-based start-ups, mining and allied industries, that have an application and/or impact in the economy in our country. The Centre would also provide the incubation centres for start-ups with necessary guidance, tech support, infrastructure, access to investors, networking, and facilitating a host of other resources that may be required for the start-up to survive and scale. The proposed Centre of Excellence will create an effective ecosystem for promoting the activities of TIH in mining and to integrate the processes from conceptualization, to innovation, to technology development through international collaboration and to create a pool of human resources for implementing the mission of the TIH in a systematic and sustainable manner. The basic objectives of the Centre include the following:

(a) To integrate various activities of TIH like
   - Innovation and Incubation of new concept in the areas of application of Cyber Technologies like sensors, digital system for capturing real time data from operation and machines, analysing the data through data analytics and AI and develop expert system for decision support
   - Converting the concept to reality through Technology Development
   - Commercialization of developed expert system and technology through industry partnership to make the TIH sustainable
   - International collaboration to bridge the gap in technology
   - Undertake skill development programme to create pool of human resources competent for introduction and implementation of CPS in Indian mining industry

(b) To carry out relevant Research and Development activities by focusing on issues such as mine safety and disaster prevention & management mine through automation, effective communication, development of smart system using intelligent sensors and AI driven analytical tools.

(c) Introduction of advanced Geophysical surveys for mineral exploration to reduce the uncertainty of mineral exploration and augmenting mineral resources from deep concealed mineral reservoir using state of the art exploration technologies and use of data analytics and AI.

(d) To facilitate inter-institutional collaborative research work

5.4 Role and Functions of the Centre

The proposed centre will transform the Mining Value Chain (TMVC) and incorporates a wide array of activities from exploration, discovery, ore deposit characterisation, and environmental assessment, through to mining and ore processing with primary objective of improving efficiencies within this value chain, focussing on areas that will have a marked impact on India's mining and mineral sectors, thereby benefiting the nation's economy. These industries will benefit greatly through advanced CPS system and innovative technologies in the identified thrust areas. This will also enhance decision making process and maximise productivity and profitability of Indian mines.

5.5 People

The Centre will be operated by an Executive Director who will be guided by a Head of the Centre. The Head will be supported by respective domain experts and research scholars. They will be associated in the procurement of equipment, installation, supervision, support to data acquisition, maintenance and upkeep of the equipment, laboratory etc. This is apart from rendering assistance to the concerned faculty undertaking R&D, Consultancy and training. These domain experts and full-time manpower in the Centre would be utilized in the establishment and operation of laboratories, coordinating between the faculty members and industry, helping the Operational Heads and faculty members involved in R&D, Consultancy and Technical Services. He will also assist in formulating and executing various technical training programmes organized by the Centre. For further support to R&D activity of the centre need based research scholars are required to be admitted.

Technical assistants have been proposed for each thrust area to render all technical services for accomplishing different activities of the Centre both in the field as well as in laboratory. These technical assistants will be diploma holders in Engineering.

5.6 Longwall Training Gallery

IIT(ISM) has a unique facility in its campus, the Longwall Training Gallery (LTG), which replicates a longwall face of underground coal mine in true scale. Longwall is the most modern, fully mechanized mass production technology across the globe capable of producing 2 to 10 million tonne of coal per annum. The LTG in IIT(ISM) is a state of the art training gallery for demonstration of actual operations of longwall face equipment like Shearer for cutting and loading coal, Armoured Face Conveyor (AFC) for transporting coal from coal face to outbye transport system, Stage Loader for transferring coal from AFC to outbye belt conveyor, 6 legged hydraulic Powered Supports of 240 te capacity for providing support against the roof, hydraulic power pack to generate high pressure hydraulic fluid to operate the powered supports and the electrical switch gears for supplying power to all these machines. Moreover, there are sensors installed to monitor the environmental condition like flow of air, concentration of CO, O2, CH4 etc. as required in actual underground coal mines to identify and assess the hazards due to presence of these gases in underground mines.

The equipment have been overhauled and repaired and maintained in perfect working condition. The students and participants of Executive Development Program are taken to the gallery for demonstrating the operations of the machines and the total system, without going to a longwall mine in the gallery and exposed to the hazardous conditions of a mine.

LTG as in-house test facility for Technology Development

Now as it is proposed to develop sensors for monitoring the mine atmosphere through the program of Technology development under TIH in mining, it is very much required to develop a testing set up for evaluating the performance of the developed products. Any technology development process requires an in-house testing facility for continuously evaluating the performance and upgrading the same through modification in the design of the product. This is a continuous process till the product attains the standard quality or performance requirement. As per the prevailing mine safety laws in the country, no such safety equipment can be used in the mines until and unless approval of Chief Inspector of Mines is obtained based on test results and field performance.

For successful implementation of technology for improving safety standard in mines, it is highly essential that the CoE under TIH in Mining at IIT(ISM), Dhanbad should establish an in-house performance evaluation & calibration facility for the developed products under CPS systems such as sensors, data loggers, monitoring instruments etc. The regulatory authority, Directorate General of Mines & Safety requires a complete performance report of the setups/prototype/equipment/component to be permitted for field trails in mines.

In view of the above it is also proposed that the existing facility of Longwall training Gallery would be converted into an in-house technology development test centre. The current facilities of the LTG will be upgraded and equipped suitably keeping in mind the requirement of Technology Development Centre under the CoE.

Following major upgradation and creation of additional facilities will be undertaken under the CoE in IIT(ISM):

1. Smart class room for the students and research scholars
2. Mine Automation Gallery for demonstration of latest technologies and advanced systems in Mine Automation, Robotics in mining, 3D Visualization, etc.
3. Establishing modern mine environmental monitoring system like static gas sensors, airflow sensors, Tele-monitoring System, Tube bundle system, Gas Chromatograph with Analytical software and intelligent system
4. Installation of mechanical Ventilator in the LTG
5. Structural modification of the LTG with gallery walls coated with coalcrete
6. Communication system and interlocking system of the machines in the LTG
7. Installation of additional modern mining equipment for updation of the LTG

The upgraded Longwall Training Gallery with the proposed modification will serve as a unique facility for demonstrating best practices in mining and for testing of developed technology like sensors, expert system etc. This facility may also be used as an accredited test house, after obtaining necessary statutory approval, for testing the products, which is pre-requisite for obtaining statutory approval.

6 HRD, SKILL DEVELOPMENT & INTERNATIONAL COLLABORATION

Skill of the workforce plays a very important role in achieving the primary objectives of Mining 4.0. The large population of youth in this country need to be transformed into a pool of skilled work force in India as well as abroad and thereby driving the economic growth of the country. Development of super speciality skill centre for providing skilled work force to the mining and mineral processing industry is the need of the hour. Though the NM-ICPS focuses on skill development of upper level of pyramid however, there is a dearth of skilled manpower at bottom level of pyramid with skill set at Diploma / ITI level in mining sector. To realise our future aspirations of smart, safe and sustainable mining, a vocational and university educational system is needed that can equip future employees the skills needed for a future industry.

6.1 Need for Rapid Growth in Skilled Manpower in Mining Industry

Skill Development is an essential prerequisite for sustainable and inclusive growth. Hon'ble Prime Minister while launching the National Skill Development Policy 2015 reminded that, "Skilling is building a better India. If we have to move India towards development then skill development should be our mission."

Honourable Prime Minister, Shri Narendra Modi launched the Skill India Mission in 2015 with a vision to make India the "skill capital" of the world. The aim was to impart skills training to 400 million people by 2022 through flagship schemes such as Pradhan Mantri Rojgar Prohatsan Yojana, the Deen Dayal Upadhyaya Grameen Kaushalya Yojana.

As emphasized in the National Mineral Policy 2019, development of human resources is the mainstay to improve the competitive edge of the national mining industry with a focus on improving gender balance in mining industry. Emphasis are being laid on mechanisation, computerisation, automation and adoption of state-of-the art technology of the existing and new mining units. The productivity gains in the mining sector would be achieved through greater use of innovative practices and technology in the sector.

6.2 Skill Development as an Objective of TexMin

Basic objective of Govt. of India through the mission of establishing TIH in mining is to make the existing and future mines smart, safe, sustainable and globally cost competitive through the intervention of disruptive technologies like automation, digitization, cyber technology and application of artificial intelligence, machine learning etc. Indian mining industry is way behind in these areas of automation and driven by expert system based on cyber technologies and AI, compared to other advanced countries like Australia, USA. In the past 10-15 years, Australia has taken lot of initiatives in making their mines smart by high level of automation and expert system driven. Mines of Rio Tinto, BHP Billiton etc. are highly automated through use of Automated Trucks and Drills, Mine Automation System (MAS), 3D visualization tools etc. However, one of the basic elements for successful automation of such high standard is skill development of workforce as per the changing need of future mining.

6.3 Skill Gap- Employment Trends in the Mining Sector

The report on "Mapping of Human Resources and Skills for the Mining Industry in India" report by Confederation of Indian Industry in association with ICRA Management Consulting Services Limited (IMaCS) listed out several key forces affecting the human resource and skills requirement in the Indian Mining Industry:

- Technology upgradation
- Increasing growth of mining output
- Retaining and attracting talent
- Ageing profile of the workforce
- Increase in productivity
- Long gestation period for skill acquisition
- Equity issues relating to relating to local population acquiring necessary skills

It reported an estimated 1.2 million total employment in the mining & exploration of coal, metallic and non-metallic, minor & other minerals by the year 2025. Successful adaptation to a new working environment will depend on the learning evolution of the labour force, meaning the extent to which workers are able to acquire new skills and adapt their competencies to remain fit to perform more sophisticated tasks. This is still an uncertain and unknown variable in many countries.

To adapt to the coming changes, governments and mining industries will need to have a profound understanding of the gaps and future skills needs. Today, it is estimated that there is a limited pool of people who have the requisite skills, in fields such as data science, analytics, predictive modelling and mechatronics (EY, 2018). Training programs, curricula and institutions will have to be adapted to respond to those changes. Social protections programs will have to been revised to take care of the most vulnerable workers who might fall out of the system (World Bank, 2019).

In relation to one of the objectives of TIH mining as Skill Development, other than skilling through conventional methods of UG and PG students, it is very important to address the skill development in the focus area of mine automation for the general workforce associated or to be associated in the process of automation and digitization of mines.

A list of possible advanced courses to be developed are listed below:

- ☐ Advanced airborne gravity gradiometer technology for mineral exploration.
- ☐ 3D imaging technologies such as 3D laser scanning and Drone Based Surveying including 3D visualisation and analysis software solutions.
- ☐ The application of automation & robotic technology in drilling, blasting, loading, hauling, bolting mine roofs as well as ore sampling and rescuing trapped miners.
- ☐ Internet of Things, convergence of wireless technologies, micro-electromechanical systems (MEMS) and their applications in connecting machines, fleet and people with unique identifiers based on radio frequency identification device (RFID) and sensor technologies.
- ☐ Remotely operating, monitoring and controlling the mining processes and operations.

- GIS & Remote Sensing Applications.
- Other Certification Programmes:
  - Surface Internship Certification.
  - Simulation Based training to understand the surface mining process including the best mining practices and mine safety standards.
  - Underground Internship Certification.
  - Simulation Based training to understand the underground mining process including the best mining practices and mine safety standards.
  - Mine Foreman Training.
  - Simulation Based training to operate and maintain HEMMs

6.4 Manpower Skilling

A. CHANAKYA- GI Fellowships (for 10 months): UG fellowship for a period of 10 months i.e., during final year project duration will awarded to a maximum of 220 students spread over five years. The fellowship will be Rs. 10,000/- per month for 10 months. The total estimated cost per unit is Rs 1,00,000 under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

B. Development fund for Projects done by UG Students undergoing the CHANAKYA- GI: When needed, a grant of Rs. 1,00,000 per two students can be given for Projects done by UG Students Undergoing the CHANAKYA-GI. The total estimated cost is Rs 1,00,000 per unit under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

C. Infrastructure Support linked to CHANAKYA-GI: One time Grant of Rs. 1,00,00,000 for infrastructure support for Under-graduate labs in CPS and Allied areas to institution where GI is offered. The total estimated cost per unit is Rs 1,00,00,000 under Non-Recurring and no Capital expenditure involved under this component.

D. CHANAKYA- PG Fellowships (for 2 years): PG fellowship for a period of 2 years i.e., during M. Tech./ M.S./ M.E will be awarded to 42 students spread over four years. The fellowship will be Rs. 12,400/- per month for 2 years. The total estimated cost per unit is Rs 2,97,600 under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

E. Development fund for Projects done by PG Students undergoing the CHANAKYA-PG Fellowships: When needed, a grant of Rs. 2,00,000 can be given for Projects done by PG Students Undergoing the CHANAKYA-GI. The total estimated cost is Rs 2,00,000 per unit under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

F. Infrastructure Support linked to CHANAKYA- PGF: One time Grant of Rs. 1,00,00,000 for infrastructure support for Post-graduate labs in CPS and Allied areas to institution where GI is offered. The total estimated cost per unit is Rs 1,00,00,000 under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

G. CHANAKYA- DF Doctoral Fellowships (duration 3 years to 4 years): Doctoral fellowship for a period of 3 to 4 years i.e., during PhD. will be awarded to 25 students spread over three years. The fellowship will be Rs.25,000/- + HRA per month for First 2 years, after that the fellowship will be Rs 28,000/- + HRA for remaining duration under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

H. CHANAKYA- Faculty Fellowships (for 3 years) (On the lines of INSPIRE faculty award Scheme): In line with INSPIRE Faculty fellowships, faculty/ young researchers with Ph.D will be awarded fellowship for a duration of 3 years and will be attached to the CoE/ institute. The fellowship will be Rs.80,000 per month for five faculty positions with all-inclusive under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

I. CHANAKYA- Chair Professor Fellowships (for 3 years) (On the lines of National Geospatial Chair Professor Scheme): Chair Professor Fellowship for a period of 36 months i.e., during the duration of guidance of project in CoE will be available for 5 positions. The fellowship will be an honorarium of Max. Rs. 80,000/- per month for 3 years, the annual contingencies/ Travel/ Miscellaneous costs of Rs.1.20 Lakh for travel to various institutions for attending conferences; review meetings etc. and to propagate the technologies in CPS and institutional overhead @ of 10% subject to maximum of Rs.1.00 lakh per annum under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

J. CPS-Upgrading PG Programme: One-time Grant of Rs. 5,00,00,000 for Upgrading PG programmes in CPS and Allied areas. The Grant will be a onetime grant of Rs.5,00,00,000/-. The total estimated cost per unit is Rs.5,00,00,000.

K. CPS-PSDW (Professional Skill Development Workshop):

S No	Budget Head	Amount in Rs Lakhs
A.	**Recurring**	
	1. Contingencies	0.40
	2. Travel, honorarium to experts etc.	2.50
	3. Miscellaneous	0.20
	Sub-Total	**3.10**
B.	**Non-Recurring**	
	1. Teaching Material	0.90
	2. Used case studies, Books, Journals etc.	1.00
	Sub-Total	**1.90**
C.	**Capital**	**0.00**
	Grand Total	**5.00**

L. CHANAKYA- CPS-Advanced Skill Training Institute: A grant of total Rs 10.00 lakhs is requested in 2 years. The total estimated cost per unit is Rs 10.00 lakhs.

6.5 International collaboration

Development of Mining Sector is essential for a country's development in industrial sector. India is deficient in many important minerals and India also needs capacity building in geosciences, transfer of technology in mining sector as well as acquisition of mining assets abroad by public and private sector.

A joint statement was made on 18.11.2014 by Honourable Prime Ministers of India and Australia to explore opportunities for partnership between Australian Institutions and IIT (ISM)

Dhanbad in the area of Clean Coal and Energy Technologies. The statement is reproduced below:

"Energy is a central pillar of the economic relationship. Prime Minister Abbott and Prime Minister Modi agreed to expedite approvals for key mining investment projects. They agreed to cooperate on clean coal technologies and welcomed the intention to explore opportunities for partnership between Australian institutions and the Indian School of Mines in Dhanbad."

There is a wider scope of carrying out Collaborative R&D projects in collaboration with countries like Canada, Australia, Russia and African. At present several collaborative activities are ongoing with the Universities and research organizations in Australia and other countries. Table 2.1 lists the ongoing international collaborations in Mining and Allied Sectors.

Table 6.1: Ongoing international collaborations of IIT (ISM) in Mining and Allied Sectors in top 10 QS world university rankings.

Organisation/Lab	Nature of Interaction
Curtin University of Technology, Australia	Collaborative Ph.D. Programme & AISRF joint R&D Project
University of New South Wales, University of Wollongong, CSIRO	MoU signed with Australian Universities and Organisations for academic and research excellence in Mining and Allied Areas
SIMTARS, Govt. of Queensland	CIL Funded R&D project on Mines Safety
JKMRC, University of Queensland	CIL Funded R&D project on Multiple layer trial blasting for better recovery with less diluted coal
NIER, University of New Castle	Design of cost-effective process flow sheet for improved washing efficiency of Indian Coking & Non-coking coals
Monash University, Australia	Endeavour Faculty Exchange programme and joint R&D programme.
Curtin, Melbourne and Monash Universities	High ash coal gasification and associated upstream and downstream process

7 INNOVATION, INCUBATION & ENTREPRENEURSHIP ECOSYSTEM

In an increasingly technological society, it is essential to identify and foster innovative solution to complex challenges is critically important, to create an ecosystem where ideas leads to innovation and entrepreneurship. Technology Innovation Hub (TIH) is a not for profit centre at Indian Institute of Technology (Indian School of Mines), Dhanbad initiated by DST which dedicated to promote Innovation Research and Entrepreneurship in the field of Mining Engineering, Earth Science, Geo Physics and advanced technologies like Robotics, AI, Internet of Things, Cyber Security, Block chain etc. Innovation, Incubation and Entrepreneurship (IIE) is one of the important verticals of TIH at IIT (ISM) which has been mandated to promote new Venture creations through providing incubation and host of other support to the start-ups such as Physical Infrastructure, Fully furnished offices, Laboratory Facilities of Incubation Labs, Business plan assistance, Mentoring support etc. Mining is still an unknown sector for many people. This industry provides basic materials whose demand increases just as much its industrial clients (automotive sector, electronics, energy, construction, etc.). Apart from the safety challenges that may come to mind, this sector has other great challenges regarding productivity and sustainability. However, innovation in mining has traditionally been difficult to achieve due to the very complexity of the challenges, even when the technological progress is going faster lately. There is a wider scope of promoting start-ups in the mining companies with main concerns of improving productivity and safety. Table 7.1 lists a typology of technological innovation relevant to the Mining Sector.

Technology and innovation is key to the step changes required to make Indian Mining Industry sustainable, safe and productive. The adoption of technology and innovation goes beyond the headlines on artificial intelligence (AI) used in the automation of driverless trucks, drills and trains for transport.

The Innovation, Entrepreneurship & Start-up Ecosystem at TIH will be setup with the following mission.

"To motivate, build and promote out of box thinking, development of innovative ideas. To build an environment that will facilitate the creation of social enterprise knowledge through research and empower students to apply their entrepreneurship abilities to develop solutions for greater social impact through academia."

Major Activities Proposed

- Creating a collaborative environment between industry and academia through joint research projects and consulting assignments, Training and awareness programs in Entrepreneurship (EAC, EDP, and FDP).
- Community Training Programs, Workshops / Ideathons / Hackathons/Bootcamps and other activities round the year will help in identify and address the local industrial problems including community issues.
- Tech driven R&D projects to be given to young entrepreneurs will certainly help in

resolving the problems faced by society.

- Networking, Mentoring and collaboration with institutions / Labs / industries / Academia, Patent facilitation, Consultancy and technical support for R & D activities will drive the innovation culture in Mining Industry.
- Sectorial Priorities of Innovation, Incubation & Entrepreneurship of TIH will be mining industry, sustainability and improvement of environment, and water resource management for general consumption and irrigation purposes to achieve SDGs.
- Incubating early stage technology based innovative entrepreneurial ventures.
- Encouraging and enabling the alignment of R&D activities to potential needs of the industry.
- Competitive events, lectures and workshops on soft skill development, case studies, bplan competitions, innovators camps etc.
- Promoting Innovations in Individuals, Start-ups and MSMEs (PRISM).
- New Venture Creation through providing incubation and host of other support in the areas of Mining Engineering and application of CPS in Mining and Allied domain.
- Technology Commercialization, targeted at providing a much needed platform for speedy commercialization of technologies developed in the academic and R & D institutions to reach the end users.
- Interfacing and Networking between academic, R & D institutions, industries and financial institutions.
- Value Addition through its services provided to its incubatees as well as to the existing technology dominated SMEs, TBI aim at value addition.
- Creating value added jobs & services, fostering the entrepreneurial spirit.
- Identifying technologies/innovations which have potential for commercial ventures.
- Physical infrastructure and support systems creation for business incubation activities. Foster and promote entrepreneurship spirit.
- Facilitate knowledge creation, innovation and entrepreneurship activities.
- Facilitate networking with professional resources, which include mentors, experts, consultants and advisors for the incubate companies.
- Enabling development of high quality personnel and motivating researchers to grow professionally within organizations through part time Masters and PhD Programs.

The Tier II city Dhanbad lacks innovation & entrepreneurship ecosystems. The livelihood are mainly dependent on surrounded mining companies and organizations which needs innovative and specialized skill sets. There is a tremendous scope of innovation & entrepreneurship ecosystems development in the entire mining value chain (exploration, exploitation and eco-restoration). IIT (ISM) Dhanbad has its unique strength in earth sciences/mining/oil and gas sector with an excellent lab facilities and industrial connects. The same will drive the successful innovation and entrepreneurship.

Table 7.1: A Typology of Technological Innovation Relevant to the Mining Sector (IGF, IISD, 2019)

Type of technological innovation	Characteristics	Key applications	Wider impacts
1. Enablers of big data			
Sensor technologies	Sensors are elements that convert physical quantities into electrical signals transferred to the Controller. They can be: inductive, capacitive, optical, magnetic, ultrasonic, etc. Their function is to detect presence, level, pressure, temperature, flow, pH, etc., and communicate it to the system.	• LIDAR (Light detection and ranging) sensor technology in autonomous vehicles • Remote operations and precision planning: Smart sensors connected to automated vehicles/helmets and a range of other tools can better help control/remotely monitor equipment and infrastructure; identify obstacles • Predictive maintenance: Smart sensors combined with algorithms can help predict breakdowns; detect anomalous conditions/ installations and maintenance • Sensors to detect the grade, hardness and size of ore coming into the processing facilities.	Ensures accurate and cost-effective manufacturing. Using digital twin applications, companies can perform simulations to determine efficiency and productivity of a future mine. Perform probability modelling—a major advantage when time is a decision factor. Help save time and money because weather and physical conditions are no longer obstacles
Connected smart portable devices	Allows interface between machines and humans to enhance productivity Designed to interact with humans in a shared workspace	• Personal protective equipment (PPEs) with built-in tag • Co-bots: Characterized by small size, versatility and are affordable in price • Touch technology • Captive pads • Helps detect fatigue and stress levels • Supervisory control and data acquisition	Specialized connected devices used by operators to provide real time information; to observe, intervene and monitor operations Aimed at corrective, preventive and predictive maintenance Control and supervise operations from a distance Advantages: precision, strength and resistance
Drones (UAVs)	An unmanned aerial vehicle that can navigate autonomously, without human control or beyond the line of sight Equipped with GPS navigation systems and sensors to perform in-situ scanning, measurement and assessment	• Stockpile inventory and management • Mine monitoring and operation planning • Assessment before and after drilling and blasting • Hazard identification and mitigation • Geological mapping and surveys • 3D data output	Can reap significant productivity enhancements. Improves the overall efficiency of mines Provide accurate and comprehensive data of site conditions in a very short time Support better coordination among teams onsite and internationally, offering dynamic oversight of all operations Operate much faster than

Type of technological innovation	Characteristics	Key applications	Wider impacts
			labour at lower costs. Potentially more beneficial for remote extraction activities
GPS	A satellite-based navigation system that provides information, including the position of the satellite, velocity and the precise time of transmission. GPS technology works in almost any conditions and is accurate to within 3 to 15 metres.	Helps in navigation, surveying, tracking. Frequently used in: • Control of heavy machinery • Control of bucket wheels and dozers • Drill guidance • Road grading and maintenance • Fleet management systems for haul trucks and other vehicle tracking and dispatch • Access and zone control for visiting vehicles • Detecting dangerous driver behaviour • Collision avoidance applications	Enhances overall productivity (incl. by streamlining Operations) Lengthens assets lifetime (less wear and tear due to optimized asset management; early maintenance reminders etc.) Reduces fuel budget
2. Users of big data			
Machine learning (ML)	Use large data sets, artificial neural networks and algorithms to detect patters, process data and learn autonomously how to make decisions A type of machine learning that processes a wide range of data resources (that may be too large to be processed by humans) to produce more accurate results Also includes universal quantum computers	Those analytical techniques can be applied to solve real-life problems, i.e., • Descriptive: Identify patterns of behaviour • Predictive: Anticipate what will happen • Prescriptive: Provide recommendations on what to do to achieve objectives • Clustering: Individual data sets with common characteristics—or with ability to create synergies—are assembled Applications include: • Image classification • Facial recognition • Voice recognition Quantum computers augment data crunching capabilities by orders of magnitude.	Value of ML lies in organizational abilities to harness it Biggest impact likely to be in supply chain management and in particular on activities such as: • Maintenance and service intervention • Smart CAPEX • Procurement and spend analytics • Inventory and parts optimization • Yield optimization • Logistics networks and warehouse optimization • Sales and demand forecasts

Type of technological innovation	Characteristics	Key applications	Wider impacts
Advanced analytics	Objectives to be achieved: decisions and actions based more on data analysis and less on experience and intuition. Four key characteristics of big data: Volume: Treatment of large volumes of data Range: Different forms and sources of data Speed: Allows real time analysis Accuracy: The information will facilitate decision making	• Enable end-to-end tracking and communications and real-time supply and demand management • Descriptive analytics • Predictive analysis: Can pinpoint requirements; address bottlenecks; determine output • The data collected (geological; metallurgical; operational) will allow the use of 3D visualization and digital twinning • 3G/4G connectivity can send data in real time	Will dramatically reduce costs across the value chain, from exploration to logistics. Improve efficiency: Can create simulations to precisely prepare plan and schedule operations
Automation: Hardware automation/ Autonomous assets	Predicted to redesign traditional occupations such as drill operators, surveyors, field geologists; increase the demand for remote vehicle operators with greater skills in contemporary data and digital technologies	• Autonomous haulage systems • Operators remotely controlling multiple rigs simultaneously • Mine automation system • Telematics (condition monitoring) to avoid downturn • Vehicles without drivers and monitored from a distance	Improved efficiency and drilling precision, reduced human error in transport
Robotic process automation (RPA)	A combination of artificial intelligence and automation that is able to sense and synthesize vast amounts of information and can automate entire processes or workflows, learning and adapting as it goes	• Process automation and configuration • Graphical user interface (GUI) automation • Advanced decision systems	It makes mining processes more accurate, more liable and more consistent. It improves productivity of mining operations because process cycle times are much faster compared to manual operations.
Software automation	Machines match and outperform human beings in a range of activities, including those requiring cognitive capabilities	• Software guiding remote controlled excavators, tele-operated vehicles etc. • Software to guide drivers toward most optimal routes to reduce transportation time	Software automation tools help mining operators maintain real-time control over operations for better safety and efficiency.
Digital twin	A digital twin is a virtual simulator of mining operations. It is a carbon copy of the digital world.	❑Management can use the simulator to manipulate a huge number of variables over a given ❑time period to see how changes will ❑affect both up- and downstream processes	It is an optimization tool that allows for improved efficiency. It facilitates decision making in an objective way to optimize production processes. It incorporates data and digital information into the real-world environment.
Cloud computing	Technological model that allows firms and individuals to access a set of computer resources on demand and in a personalized manner	• Data management • Collaborative platforms and virtual workspace • Requires strong cyber security	Storage makes information accessible from anywhere Advantages: Cost savings; storage and security; easy access; automatic updates and customization

Type of technological innovation	Characteristics	Key applications	Wider impacts
3. Integrators/ trackers of big data			
Internet of things (IoT) and Industrial Internet of Things (IIoT)	IoT is the connection of objects such as computing machines, embedded devices, equipment, appliances, and sensors to the Internet. The goal is to make all devices transfer data to a network without human intervention and, therefore, be more intelligent and independent. Industrial applications of IoT: IioT devices are more resistant since they have to work under extreme conditions without breaking down and are usually located in places that are difficult to access.	• Automate maintenance and operations of machines • Standardize processes • Improve traceability and visibility • Move from preventive to predictive maintenance • Get real-time data and analytics	Optimizes operations Increases safety Reduces costs Improves data and analytics
Block chain	A tamper-proof digital ledger that can document the provenance and characteristics of products, making information accessible to buyers at every stage	Areas where block chain might be used: • Engineering, construction and handover of the mine site: Can make transactions traceable during the complex processes of managing regulations and standards, ensuring trust and work compliance • Compliance and mining lease management: Approval of documents, contracts, audit, management of reserve flows • Supply chain management: can be used to track materials in the mining value chain from the blocks to the concentrate, to metal; manage procurement contracts, invoice reconciliation etc. • Mineral provenance and responsible sourcing	Guarantees quality and authenticity Ensures traceability Can help increase transparency along the mineral value chain Can support moves to improve mineral valuation

Type of technological innovation	Characteristics	Key applications	Wider impacts
Radio Frequency Identification (RFID) and Real-Time Location System (RTLS) tags	These are small devices, similar to a sticker, which can be attached or built into any object. They contain antennas which can receive and respond to requests by radiofrequency from a transceiver	RTLS tags are used to automatically identify and track location of people and objects, within a building or in an area. Types of technologies include: infrared and ultrasound	Efficiency gains: ❑This technology, combined with the electronic product code (a chip), can improve the tracking of products along the supply chain ❑Critical for logistics to monitor ❑stock and better manage supply chains
4. Process improvers			
Water-neutral processing/ water-saving technologies	Technologies meant to: • Minimize the use of water in mining operations • Minimize/ eliminate risk of pollution • Recycle water for mining and/or other uses	Types of technologies include: • Evaporation control • Closed-loop water recycling • Dry tailings water disposal • Dry separation • Non-aqueous processing	Impact on water usage (public good) Reduces footprint of the mining sector on the environment Conservation of water Potential to share benefits of saved water with communities or other economic sectors
Tailings management and recovery	Tailings management is a complex issue that encompasses the technology used to de-water the tailings, materials handling, and water management, as well as the design and risk management of the tailings storage facility	• Management and storage of tailings using concentrators • Tailings thickening, to reduce environmental risks and decrease seepage • Efficient recovery of process water • Reduction of slurry and water pumping • Dry tailing storage	Improved environmental footprint of industry Reduced emissions of effluents and dusts Reduced risks of accidental bursts and collapse Site rehabilitation and aftercare Metal recovery or reprocessing
Smart energy systems	Optimal energy management is key to increasing the competitiveness of industries in the face of increasing cost of supplies	• Renewable energy sources • Systems to manage energy generation (co-generation) • Systems to recover residual heat • Use of batteries	To optimize energy systems and efficiency
Electric mining equipment	Battery-powered vehicles and equipment to replace fuel and diesel equipment	• Trucks • Drillers • Battery-electric haulage	Improves environmental footprint of industry Reduce GHG emissions Better heat generation Less noise pollution Cost savings (fuel a large share of costs) Improved and cleaner mine site logistics

Type of technological innovation	Characteristics	Key applications	Wider impacts
Biological technologies	Genetically manipulated bacteria or nanobots that mine at the molecular Level	• Mines to look leaner and smarter, involving intelligent, mini-, micro-, and nano-machines • Use of fluids to dissolve rocks with more precision • Use of nano-robots	Precision mining Increased efficiency and productivity at lower costs Use less energy Produce less waste and less impact on the environment
Innovative bio-mining and biomineralization technologies	Technology based in the collection of microorganisms from hydrothermal vents	Applied to the extraction of lower grade ore deposits, mine by-products and recycling of man-made products (geologically uneconomical resources)	Allows for recycling of products Improves environmental footprint
5. Other technologies			
Additive manufacturing: 3D and 4D printing	A series of parts manufacturing technologies that fundamentally differ from conventional subtractive machining processes. The different additive processes each possess unique advantages in materials and applications.	The processes can broadly be categorized into the following eight groups: (i) Binder Jetting; (ii) Directed Energy Deposition; (iii) Direct Write; (iv) Material Extrusion; (v) Material Jetting; (vi) Powder Bed Fusion; (vii) Sheet Lamination; (viii) Hybrid Technologies. Different processes utilize different materials/forms and can result in different properties.	Possibility of manufacturing prototypes and to replace spare parts, at a relatively low cost (allows firms to save on time and shipment costs

Following are the activities to be undertaken under IIE at TIH, IIT(ISM)

7.1 IIT (ISM)-GCC

IIT (ISM)-Grand Challenges Competition (ISM-GCC) will strengthen the entrepreneurial ecosystem as well as deliver immense value to other Technology Business Incubators (TBI). ISM-GCC is a pre-incubation activity targeted mainly at scouting of innovations focused on mining, earth science and advanced technologies.

Objectives of ISM-GCC

- To find & nurture new and innovative solutions for major challenges being faced by the society that are viable and sustainable.
- To pickup ideas from untapped sources and convert them into start-ups.

- To create awareness about entrepreneurship amongst India's masses and reach out to aspiring and existing entrepreneurs through active media outreach
- To provide structured mentoring, guidance, prototyping grants, and seed-funding for ideas applying for such programmes
- To build a vibrant start-up ecosystem, by establishing a network between academia, financial institutions, industries and other institutions.

Scheme		**ISM-GCC - Grand Challenges and Competitions**
Objective		To motivate several aspiring entrepreneurs to take the plunge and convert their ideas into viable enterprises by scouting of innovations
Number		1 (Grand Challenge)
Intended/ Targeted Beneficiary	Category	Individuals with innovative ideas
	Numbers	20 (Idea Challenges)
Support Amount (per project) Maximum		Five @ Rs.5.00 lakhs per winner max.(Award) Five @Rs. 20.00 lakh per winner (for prototype development)
Project Duration		2 years (extendable by 6 months)
Funding (Nature/ Pattern)		**1 Grant Challenge Rs. 7.00 Crores**
Workplace		TIH / IIE IIT-ISM
Expected Outcomes		Innovative solutions to challenges faced in Mining and Earth Science Sector.
Performance Metrics		Innovative Solutions based on Problems faced by mining industries leads to sustainable development.
Jury		Academicians, Industry Experts, Experts from NRDC/MSME/Venture Capitals

7.2 ISM-PRAYAS

Pre-Incubation and Acceleration of Young and Aspiring technology entrepreneurs - Support from Idea to Prototype.

The ISM-PRAYAS programme focuses on addressing the idea to prototype funding gap. This programme would attract a large number of youngsters to come forward to try out their ideas without actually worrying about the failure. Eventually, such an approach would bring in a large number of potential ideas into the incubation programmes, thereby increasing the flow of quality incubate to the incubators. ISM-PRAYAS is positioned as a pre-incubation initiative.

Objectives of ISM-PRAYAS

- To enable translation of an innovative idea to a prototype.
- To provide a platform for faster experimentation and modify approaches in the idea to market journey.
- To generate innovative solutions relevant to the local and global problems.
- To attract a large number of youth who demonstrates problem solving zeal and abilities to work on their new technology/knowledge/innovation based start-ups.
- To enhance the pipeline in terms of quality and quantity of innovative start-ups to the incubators.
- To build a vibrant mining innovation ecosystem, by establishing a network between innovators, academia, mentors and incubators.

Scheme		**ISM-PRAYAS** Pre-Incubation and Acceleration of Young and Aspiring technology entrepreneurs - Support from Idea to Prototype.
Objective		To address the gap in the very early stage idea/ proof of concept funding
Intended/ Targeted Beneficiary	Category	Young Entrepreneur
	Numbers	1
Support Amount (per project) Maximum		Ten Projects (Ideas) @ Rs.10 Lakhs for Seed funding
Project Duration		2 years
Funding (Nature/ Pattern)		Total funding of **Rs. 3.70 Crores (Grant)**
Workplace		TIH / IIE IIT-ISM
Expected Outcomes		Innovators facilitated and enabled Ideas translated into prototype through funding support
Performance Metrics		Innovators facilitated and enabled Ideas translated into prototype
Project Evaluation & Monitoring Committee (PEMC)		Academicians, Industry Experts, Experts from NRDC/MSME/Venture Capitals

Activities:

1. Establishment of PRAYAS Center, Fabrication LAB
2. Industrial meet (To support in mining sector)
3. Converting young ideas into mature start up.
4. Support seed fund
5. Mentor support
6. Strategic Information Services for Entrepreneurship (Patent)
7. Quality enhancement through workshop/seminar.

7.3 ISM-EIR

To inspire the best talents to be entrepreneurs, minimize the risk involved in pursuing start-ups, and to partially set off their opportunity costs of high paying jobs, ISM-Entrepreneurs-in-Residence (EIR) Programme is introduced. The ISM-EIR programme provides tremendous opportunities for innovative entrepreneurs to expand their networks and get critical feedback on their ventures in order to promote their entrepreneurial career goals and aspirations. The opportunities under ISM NIDHI-EIR Programme include:

- Guidance from experienced, innovative and highly successful entrepreneurs on the business concept, strategy or venture and insight into specific industries or markets.
- Best practices for starting a business and broaden the professional network.
- Co-working spaces for developing the idea into a marketable product

Objectives of ISM-EIR

- To encourage graduating student to take to entrepreneurship by providing support as a fellowship
- To provide a prestigious forum for deserving and budding entrepreneurs to pursue their ventures without any additional risks involved in technology based businesses.
- To create, nurture and strengthen a pipeline of entrepreneurs for incubators
- To make pursuing entrepreneurship related to a technology business idea more attractive among options available career options.

- To enable creation of new start-ups by entrepreneurs and significant progress towards raising funding or investment.

The Programme thus encourages enterprising individuals to venture out and pursue daring entrepreneurial ideas as well as enhances the quantity and quality of start-ups.

Scheme		**ISM-Entrepreneur In Residence (ISM-EIR)**
Objective		To inspire the best talents to be entrepreneurs, minimise the risk involved in pursuing start-ups, and to partially set off their opportunity costs of high paying jobs
Intended/ Targeted Beneficiary	Category	enterprising individuals
	Numbers	100 (in 5 years)
Support Amount (per project) Maximum		30,000 per month as stipend
Project Duration		1 year
Funding (Nature/ Pattern)		**Total Grant of Rs. 3.60 Crores**
Workplace		Academic Institutions and/or B-Schools
Expected Outcomes		Conversion of at least 30 % of the support recipient's ideas into start-up companies. At least 10% support recipient raising funds or investment for his or her company within 18 months of NIDHI-EIR support.
Performance Metrics		Technologies commercialized Start-ups Revenue generated
Selection Panel / Jury		Academicians, Industry Experts, Experts from NRDC/MSME/Venture Capitals

7.4 ISM-Start-up

Through Innovation, Incubation and Entrepreneurship (IIE) in academic institutions; encouraging Students to promote start-ups

Objective of ISM-Start-up

- To take forward student innovations in programme to commercialization stage,
- To promote student start-ups,
- To accelerate the journey of idea to prototype by providing initial funding assistance

Through this programme TIH, IIT (ISM) would help the start-ups with initial / ignition funding and hence would be called Start-up-ISM.

Scheme		**ISM-Start-up**
Objective		To promote student start-ups, accelerate the journey of idea to prototype by providing initial funding assistance and take forward student innovations to commercialization stage.
Intended/ Targeted Beneficiary	Category	Student Start-ups
	Numbers	30 (in 3 years)
Support Amount (per project) Maximum		10 lakhs
Project Duration		3 years
Funding (Nature/ Pattern)		**Total Grant of Rs. 3.00 Crores**
Workplace		Academic Institutions and/or B-Schools
Expected Outcomes		Prototypes developed

	Technology commercialized Start-ups
Performance Metrics	Technologies commercialized, Start-ups
Selection Panel / Jury	Academicians, Industry Experts, Experts from NRDC/MSME/Venture Capitals

7.5 CPS-TBI

ICPS Division of the Department of Science and Technology, Government of India is supporting Technology Business Incubators primarily in and around academic, technical and management institutions to tap innovations and technologies for venture creation by utilizing expertise and infrastructure already available with the host institution.

Objectives of ISM-TBI

- To create jobs, wealth and businesses aligning with national priorities.
- To promote new technology/knowledge/innovation based start-ups.
- To provide a platform for speedy commercialization of technologies developed by the host institution or by any academic/technical/R&D institution or by an individual.
- To build a vibrant start-up ecosystem, by establishing a network between academia, financial institutions, industries and other institutions.
- To provide cost effective, value added services to start-ups like mentoring, legal, financial, technical, intellectual property related services.

7.6 ISM- DIAL

ISM-DIAL (Dedicated Innovation Accelerators) is a typically a 3-6 months' fast track structured programme helping ideas get accelerated to the next orbit. An accelerator aims at achieving one or more of the following objectives - introduction to entrepreneurial development to identify business opportunities (real problems that require real solutions), validate product ideas, engage with potential customers, build a scalable business model, build a product demonstration, manage team dynamics and pitch to investors. The Accelerators can be used to boost the Incubator's existing activities to build and attract high quality start-ups, and have a customer centric validation model which enhances investment readiness as well as worthiness. Entrepreneurs and start-ups undergoing an accelerator programme discover that their idea and product is just a small part of what makes up a successful, scalable start-up.

Objectives of ISM-DIAL

- To fast track the growth of potential start-ups through rigorous mentoring and networking support in a short span through existing TBIs
- To attract subject matter experts, mentors, and angel investors get associated with TBIs through the structured accelerator programmes
- To build a vibrant start-up ecosystem, by establishing a network between academia, financial institutions, industries and other institutions.
- To act as a hub for several incubators in the region, so that high-potential start-ups can be fast-tracked for increased exposure and validation

Accelerators should employ a "fail fast" mentality: ideas or prototypes that are not getting traction should be abandoned (or modified) quickly, allowing founders to redeploy resources to other projects or even new companies at a rapid pace.

Scheme		**ISM-DIAL (ISM- Dedicated Innovation Accelerators)**
Objective		Push innovations into commercial domain
Intended/ Targeted Beneficiary	Category	Academic Institutions and/or B-Schools/ Existing STEP/TBI
	Numbers	1
Support Amount (per project) Maximum		Rs.2.00 crores
Project Duration		3 -9 months
Funding (Nature/ Pattern)		Grant of Rs. 2.00 crores (to be released against targets) Equity stake of DIAL in start-up
Workplace		Academic Institutions and/or B-Schools
Expected Outcomes		Technology commercialized Start-ups
Performance Metrics		Technologies commercialized, Start-ups, Revenue generated
Project Evaluation & Monitoring Committee		Academicians, Industry Experts, Experts from NRDC/MSME/Venture Capitals

7.7 ISM-CPS-SSS

The sole objective of the CPS-Seed Support System (CPS-SSS) is to ensure timely availability of the seed support to the deserving incubate start-ups within an incubator, thereby enabling them to take their venture to next level and facilitate towards their success in the market place. The scheme also enables the STEP/TBI to widen their pipeline of start-ups and also share the success of their start-ups which would also result in ensuring their long term operational sustainability.

Scheme		**ISM- CPS-Seed Support System (CPS-SSS) for Start-ups in Incubators**
Objective		To provide financial assistance to potential start-ups with promising ideas, innovations and technologies
Intended/ Targeted Beneficiary	Category	Academic Institution
	Numbers	1
Support Amount		Rs 7 crore
Project Duration		3 years
Funding (Nature/ Pattern)		Grant
Site/ Workplace		Academic Institution
Expected Outcomes		Innovative technologies/products/services commercialized Start-ups (10 per year)
Performance Metrics		Innovative technologies/products/services commercialized, Start-ups, Revenue generated

Plans to Identify Aspiring Innovators

In order to identify aspiring innovators several events such as hackathons, grand challenges, innovators meet, annual technical fest, Annual Cultural Fest (Srijan and Basant) etc. will be organized in the following 5 stages.

Stage 1	**Announcement of the event**	An online brochure and format for proposal submission will be formed which includes information on the Title, Novelty and Innovation of the Idea, Proposed Solution and Methodology along with the outcome.
Stage 2	**Screening of proposals through presentation**	Applicants will give a 15 Minute presentation on their proposal. Presentations will be judged on the parameters such as Quality and Novelty of the solution, technical feasibility, significance and application potential of the solution, Cost Effectiveness, Societal Impact. Best proposals will be shortlisted
Stage 3	**Proof of Concept and Prototype**	Shortlisted teams or individuals will be asked to execute their proposed solution within 30 days of announcement of decision on selected proposals.
Stage 4	**Final Presentation**	Applicants will be asked to present proof of concept / prototype of their proposed solution.
Stage 5	**Announcement of results and support**	

8 TEXMIN FINANCES

8.1 Finance

The sources of financing for the scheme are public funds through Department of Science & Technology, Govt. of India. No external sources are intended. However, mining and other companies have shown their keen interests in supporting the TIH during its development phase as technology partner for field experimentations and commercialization through in-kind supports to begin with. The cost estimates are as per the guidelines available in the DPR of NP-ICPS. The TIH cost estimates for the scheme duration: both year-wise, component-wise segregated into recurring and non-recurring expenses are presented in subsequent sections in Table formats:

Table 8. 1: Financial Table of 5 years with Separate Recurring/Non-recurring cost

Budget Head	Budget in Rs Crores					
	1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
Recurring	11.00	20.00	35.00	8.00	4.38	78.38
Non-Recurring	7.00	15.00	8.00	1.00	0.62	31.62
Total	18.00	35.00	43.00	9.00	5.00	110.00

Table 8.2: TIH Cost Analysis sub-mission wise (in Rs. Crore)

S. No	Sub-Missions	Budget Head	1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr	Total
1	**Technology Development**	Recurring	4	12	21.97	3.55	0.25	41.77
		Non-Recurring	2.5	8	5.05	0.6	0.42	16.57
		Sub-Total	**6.5**	**20**	**27.02**	**4.15**	**0.67**	**58.34**
2	**Entrepreneurship Development**	Recurring	0.56	2.5	3.92	1.75	3.18	11.91
		Non-Recurring	0.7	2	1	0	0	3.7
		Sub-Total	**1.26**	**4.5**	**4.92**	**1.75**	**3.18**	**15.61**
3	**Human Resource Development**	Recurring	1.37	2.9	4.36	2.1	0.95	11.68
		Non-Recurring	1.27	2.65	0.7	0.4	0.2	5.22
		Sub-Total	**2.64**	**5.55**	**5.06**	**2.5**	**1.15**	**16.9**
4	**International collaborations**	Recurring	4	0	0	0	0	4
		Non-Recurring	1	0	0	0	0	1
		Sub-Total	**5**	**0**	**0**	**0**	**0**	**5**
5	**TIH Management Unit (TMU)**	Recurring	1.07	2.6	4.75	0.6	0	9.02
		Non-Recurring	1.53	2.35	1.25	0	0	5.13
		Sub-Total	**2.6**	**4.95**	**6**	**0.6**	**0**	**14.15**
	Total	Recurring	11	20	35	8	4.38	78.38
		Non-Recurring	7	15	8	1	0.62	31.62
	Grand Total in Rs Crore		**18**	**35**	**43**	**9**	**5**	**110**

Table 8.3: Estimated Expenditure (Rs crore) for Sub-Mission -Technology Development

S No	Major Components		Targets						Budget					
			Yr1	Yr2	Yr3	Yr4	Yr5	Total	Yr1	Yr2	Yr3	Yr4	Yr5	Total
1	No of Technologies (IP, Licensing, Patents etc)		2	3	5	5	5	**20**	1.25	3.25	4.75	1.95	0.12	**11.32**
2	Technology Products		1	2	2	5	5	**15**	2.25	7.85	7.85	1.25	0.1	**19.3**
3	Publications, IPR and other Intellectual activities		5	10	10	10	10	**45**	0.85	3.25	3.25	0.85	0.2	**8.4**
4	Increase in CPS Research Base		5	10	15	20	20	**70**	2.15	5.65	11.17	0.1	0.25	**19.32**
Total			**13**	**25**	**32**	**40**	**40**	**150**	**6.5**	**20**	**27.02**	**4.15**	**0.67**	**58.34**

Table 8.4: Estimated Expenditure (Rs crore) for Sub-Mission Entrepreneurship Development

Major Components		Targets						Budget					
		Target	Yr1	Yr2	Yr3	Yr4	Yr5	Yr1	Yr2	Yr3	Yr4	Yr5	Total
1	Technology Business Incubator (TBI)	1	1	0	0	0	0	0.45	0	0	0	0	**0.45**
2	Start-ups & Spin-off companies	35	5	10	10	10	0	0.11	2.25	4.92	1.75	0	**9.03**
3	GCC - Grand Challenges & Competitions	1	0	1	0	0	0	0	1.25	0	0	0	**1.25**
4	Promotion and Acceleration of Young and Aspiring technology entrepreneurs (PRAYAS)	1	1	0	0	0	0	0.12	0	0	0	0	**0**
5	CPS-Entrepreneur In Residence (EIR)	21	10	11	0	0	0	0.25	1	0	0	0	**1**

6	Dedicated Innovation Accelerator (DIAL)	1	1	0	0	0	0	0.15	0	0	0	0	**0**
7	CPS-Seed Support System (CPS-SSS)	1	1	0	0	0	0	0.18	0	0	0	0	**0**
	Job Creation	8750	150	1100	2000	2500	3000						
Total			**19**	**22**	**10**	**10**	**0**	**1.26**	**4.5**	**4.92**	**1.75**	**0**	**15.61**

Table 8.5: Estimated Expenditure (Rs crore) for Sub-Mission HRD & Skill Development

S No	Major Components	Targets						Budget					
		Yr1	Yr2	Yr3	Yr4	Yr5	Total	Yr1	Yr2	Yr3	Yr4	Yr5	Total
1	Graduate Fellowships	40	40	40	50	50	220	0.33	0.55	0.75	0.45	0.2	**2.28**
2	Post Graduate Fellowships	10	10	10	12	0	42	0.35	0.45	0.85	0.35	0.15	**2.15**
3	Doctoral Fellowships	5	8	10	0	0	23	0.5	0.75	0.95	0.4	0.15	**2.75**
4	Faculty Fellowships	0	2	1	0	0	3	0.21	0.65	0.75	0.25	0.2	**2.06**
5	Chair Professors	0	2	1	0	0	3	0.5	0.75	0.75	0.3	0.15	**2.45**
6	Skill Development	35	75	100	100	100	410	0.75	2.4	1.01	0.75	0.3	**5.21**
Total		**90**	**137**	**162**	**162**	**150**	**701**	**2.64**	**5.55**	**5.06**	**2.5**	**1.15**	**16.9**

Table 8.6: Estimated Expenditure (Rs crore) for Sub-Mission International Collaborations

Major Component	Unit cost	Targets						Budget in Rs Crore					
		Yr1	Yr2	Yr3	Yr4	Yr5	Total	Yr1	Yr2	Yr3	Yr4	Yr5	Total
1. International collaborations	5	1	0	0	0	0	1	5	0	0	0	0	5
Total		1	0	0	0	0	1	5	0	0	0	0	5

Table 8.7: Estimated Expenditure (Rs Lakh) for TIH Management Unit (TMU)

Major Component	Budget in Rs Crore					
	Yr1	Yr2	Yr3	Yr4	Yr5	Total
1. TIH Management Unit	2.6	4.95	6	0.6	0	14.15
Total	2.6	4.95	6	0.6	0	14.15

1. UNIT COST ESTIMATIONS FOR MAJOR COMPONENTS UNDER SUB-MISSION – TECHNOLOGY DEVELOPMENT

Table 8.7A: Expert Driven Research

S No	Budget Head	ESTIMATED COST IN Rs LAKHS			
		Ist Yr	2nd Yr	3rd Yr	Total
A.	**Recurring**				
	1. Project Staff	9.00	8.00	8.00	25.00
	2. Domestic Travel	1.50	2.00	1.00	4.50
	3. Contingencies	0.5	0.50	0.50	1.50
	4. Consumables	1.00	0.50	1.00	2.50
	5. Miscellaneous	0.50	0.50	0.50	1.50
	6. Over Heads	1.50	1.50	2.00	5.00
	Sub-Total	**14.00**	**13.00**	**13.00**	**40.00**
B.	**Non-Recurring**				
	1. Equipment	3.00	3.00	4.00	10.00
	Sub-Total	**3.00**	**3.00**	**4.00**	**10.00**
C.	**Capital**	0	0	0	0
	Grand Total	**17.00**	**16.00**	**17.00**	**50.00**

Table 8.7B: Development of Products/ Prototypes from Existing Knowledge

S No	Budget Head	ESTIMATED COST IN Rs. LAKHS					
		Ist Yr	2nd Yr	3rd Yr	4th Yr	5th Yr	Total
A.	**Recurring**						
	1. Project Staff	100.00	100.00	150.00	100.00	50.00	500.00
	2. Domestic Travel	6.00	6.00	6.00	6.00	6.00	30.00
	3. Contingencies	4.00	6.00	4.00	4.00	2.00	20.00
	4. Consumables	6.00	6.00	6.00	6.00	6.00	30.00
	5. Miscellaneous	2.00	2.00	2.00	2.00	2.00	10.00
	6. Over Heads	2.00	2.00	2.00	2.00	2.00	10.00
	Sub-Total	**120.00**	**122.00**	**170.00**	**120.00**	**68.00**	**600.00**
B.	**Non-Recurring**						
	1. Equipment	80.00	120.00	80.00	80.00	40.00	400.00
	Sub-Total	**80.00**	**120.00**	**80.00**	**80.00**	**40.00**	**400.00**
	Grand Total	**200**	**242**	**250**	**200**	**108**	**1000.00**

Table 8.7C: Development of Technology/ Product Delivery in Specific Sectors

S No	Budget Head	ESTIMATED COST IN Rs. LAKHS					
		Ist Yr	2nd Yr	3rd Yr	4th Yr	5th Yr	Total
A.	**Recurring**						
	1. Project Staff	50.00	50.00	75.00	50.00	25.00	250.00
	2. Domestic Travel	3.00	3.00	3.00	3.00	3.00	15.00
	3. Contingencies	2.00	3.00	2.00	2.00	1.00	10.00
	4. Consumables	3.00	3.00	3.00	3.00	3.00	15.00
	5. Miscellaneous	1.00	1.00	1.00	1.00	1.00	5.00
	6. Over Heads	1.00	1.00	1.00	1.00	1.00	5.00
	Sub-Total	**60.00**	**61.00**	**85.00**	**60.00**	**34.00**	**300.00**
B.	**Non-Recurring**						
	1. Equipment	40.00	60.00	40.00	40.00	20.00	200.00
	Sub-Total	**40.00**	**60.00**	**40.00**	**40.00**	**20.00**	**200.00**
C.	**Capital**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Grand Total	**100.00**	**121.00**	**125.00**	**100.00**	**54.00**	**500.00**

2. UNIT COST ESTIMATIONS OF MAJOR COMPONENTS UNDER SUB-MISSION – HRD AND SKILL DEVELOPMENT

A. CHANAKYA- GI Fellowships (for 10 months): UG fellowship for a period of 10 months i.e., during final year project duration. The fellowship will be Rs. 10,000/- per month for 10 months. The total estimated cost per unit is Rs 1,00,000 under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

B. Development fund for Projects done by UG Students undergoing the CHANAKYA- GI: When needed, a grant of Rs. 1,00,000 per two students can be given for Projects done by UG Students Undergoing the CHANAKYA-GI. The total estimated cost is Rs 1,00,000 per unit under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

C. Infrastructure Support linked to CHANAKYA-GI: One time Grant of Rs. 1,00,00,000 for infrastructure support for Under-graduate labs in CPS and Allied areas to institution where GI is offered. The total estimated cost per unit is Rs 1,00,00,000 under Non-Recurring and no Capital expenditure involved under this component.

D. CHANAKYA- PG Fellowships (for 2 years): PG fellowship for a period of 2 years i.e., during M. Tech./ M.S./ M.E. The fellowship will be Rs. 12,400/- per month for 2 years. The total estimated cost per unit is Rs 2,97,600 under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

E. Development fund for Projects done by PG Students undergoing the CHANAKYA-PG Fellowships: When needed, a grant of Rs. 2,00,000 can be given for Projects done by UG Students Undergoing the CHANAKYA-GI. The total estimated cost is Rs 2,00,000 per unit under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

F. Infrastructure Support linked to CHANAKYA- PGF: One time Grant of Rs. 1,00,00,000 for infrastructure support for Post-graduate labs in CPS and Allied areas to institution where GI is offered. The total estimated cost per unit is Rs 1,00,00,000 under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

G. CHANAKYA- DF Doctoral Fellowships (duration 3 years to 4 years): Doctoral fellowship for a period of 3 to 4 years i.e., during PhD. The fellowship will be Rs.25,000/- + HRA per month for First 2 years, after that the fellowship will be Rs 28,000/- + HRA for remaining duration. The total estimated cost per unit is Rs 14,00,000 to Rs.17,00,000 under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

H. CHANAKYA- Faculty Fellowships (for 3 years) (On the lines of INSPIRE faculty award Scheme): In line with INSPIRE Faculty fellowships, faculty/ young researchers with Ph.D. will be awarded fellowship for a duration of 3 years and could be attached to CoEs or research/ academic institutes. The fellowship will be Rs.80,000 per month with all inclusive. The total estimated cost per unit is Rs.30,00,000 under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

I. CHANAKYA- Chair Professor Fellowships (for 3 years) (On the lines of National Geospatial Chair Professor Scheme): Chair Professor Fellowship for a period of 36 months i.e., during the duration of guidance of project in CoEs. The fellowship will be an honorarium of Max. Rs.80,000/- per month for 3 years, the annual contingencies/ Travel/ Miscellaneous costs of Rs.1.20 Lakh for travel to various institutions for attending conferences; review meetings etc. and to propagate the technologies in CPS and institutional overhead @ of 10% subject to maximum of Rs.1.00 lakh per annum . The total estimated cost per unit is Rs.30,00,000 under Recurring cost. No Non-Recurring and Capital expenditure involved under this component.

J. CPS-Upgrading PG Programme: One-time Grant of Rs. 5,00,00,000 for Upgrading PG programmes in CPS and Allied areas. The Grant will be a onetime grant of Rs.5,00,00,000/-. The total estimated cost per unit is Rs.5,00,00,000 as detailed below

Table 8.8A: CPS-Upgrading PG Programme budget

S No	Budget Head	Amount in Rs Lakhs
A.	**Recurring**	
	Contingencies	20.00
	Miscellaneous	10.00
	Sub-Total	**30.00**
B.	**Non-Recurring**	
	Equipment	450.00
	Teaching Material	10.00
	Books, Journals etc	10.00
	Sub-Total	**470.00**
C.	**Capital**	**0.00**
	Grand Total	**500.00**

K. CPS-PSDW (Professional Skill Development Workshop):

Table 8.8B: Professional Skill Development Workshop

S No	Budget Head	Amount in Rs Lakhs
A.	**Recurring**	
	1. Contingencies	0.40
	2. Travel, honorarium to experts etc	2.50
	3. Miscellaneous	0.20
	Sub-Total	3.10
B.	**Non-Recurring**	
	1. Teaching Material	0.90
	2. Used case studies, Books, Journals etc	1.00
	Sub-Total	**1.90**
C.	**Capital**	**0.00**
	Grand Total	**5.00**

L. CHANAKYA- CPS-Advanced Skill Training Institute: A grant of total Rs 10.00 lakhs in 2 years. The total estimated cost per unit is Rs 10.00 lakhs as detailed below

Table 8.8C: CHANAKYA- CPS-Advanced Skill Training Institute

S No	Budget Head	Amount in Rs Lakhs		
		Year-1	Year-2	Total
A.	**Recurring**			
	Contingencies	0.50	0.50	1.00
	Travel, honorarium to experts etc	2.00	2.00	4.00
	Miscellaneous	1.00	1.00	2.00
	Sub-Total	**3.50**	**3.50**	**7.00**
B.	**Non-Recurring**			
	Equipment	**2.00**	**0.00**	**2.00**
	Teaching Material	0.30	0.30	0.60
	Used case studies, Books, Journals etc	0.20	0.20	0.40
	Sub-Total	**2.50**	**0.50**	**3.00**
C.	**Capital**	**0.00**	**0.00**	
	Grand Total	**6.00**	**4.00**	**10.00**

3. UNIT COST ESTIMATIONS OF MAJOR COMPONENTS UNDER SUB-MISSION – INNOVATION, ENTERPRENEURSHIP AND START-UP ECOSYSTEM

Table 8.9A: CPS-GCC - Grand Challenges and Competitions

S No	Budget Head	Amount in Rs Lakhs
A.	**Recurring**	
	I. All India Competitions (Operating Costs for 20 challenges under 1 GCC)	
	1. Human Resources	100.00
	2. Travel, honorarium to experts etc	200.00
	3. Miscellaneous	40.00
	4. Marketing, promotion and publicity	60.00
	5. Networking and training programmes	50.00
	6. Other administrative expenses including consumables, printing, publications, books, journals etc	100.00
	II. Awards	
	1. Reward @ Rs 5.00 lakhs per winner for 5 ideas	25.00
	Sub-Total	**575.00**
B.	**Non-Recurring**	
	I. Prototyping Grant/ Seed Fund @Rs 20.00 Lakhs each for 5 winners	100.00
	Sub-Total	**100.00**
C.	**Capital**	
	1. Competitions location specific arrangements like furniture, tables, chairs, dash boards, product development and demonstration arrangements etc	25.00
	Sub-Total	**25.00**
	Grand Total	**700.00**

Table 8.9B: CPS-Promotion and Acceleration of Young and Aspiring technology entrepreneurs (CPS-PRAYAS)

S No	Budget Head	Amount in Rs Lakhs
A.	**Recurring**	
	1. Prototyping Grant/ Seed Fund @Rs 10.00 Lakhs each for 10 ideas	100.00
	2. Travel, honorarium to experts etc	10.00
	3. Miscellaneous	5.00
	4. Other administrative expenses including consumables, printing, publications, books, journals etc	5
	Sub-Total	**120.00**
B.	**Non-Recurring**	
	1. Raw material, Spare parts, consumables etc	25.00
	2. Fabrication/ Synthesis charges of working model development or process that includes design engineering/ Consultancy/ Testing/ Experts costs etc	25.00
	Sub-Total	**50.00**
C.	**Capital**	
	1. Establishment of PRAYAS Center, Fabrication LAB, location specific arrangements like furniture, tables, chairs, dash boards, product development and demonstration arrangements etc	100.00
	2. Operation and maintenance of Fab lab @ Rs 20.00 lakhs per year for 5 years	100.00
	Sub-Total	**200.00**
	Grand Total	**370.00**

C. CPS-Entrepreneur In Residence (CPS-EIR): A grant of maximum Rs.30,000 per month for a period of 12 months. The total estimated cost per unit is Rs 3.60 Lakhs under recurring

D. CPS-Start-up: A onetime grant of Rs 10.00 Lakhs to each selected student start-up. The total estimated cost per unit is Rs 10.00 Lakhs under recurring.

E. CPS- Dedicated Innovation Accelerators (DIAL) The budget includes Human resource, logistics, travel, mentoring, infrastructure, training etc. The overall budget for running accelerators shall be Rs 1.5 crore per year with participation of 10-15 start-ups. Rs 1.00 crore as soft loan and Rs.2.00 lakh per technology as project handling charges, as grant to DIAL. The total estimated cost per unit is maximum Rs 2.00 crore under recurring.

F. CPS-Seed Support System (CPS-SSS): Given to eligible TBI's under recurring Head with a maximum cap of Rs 7.00 crore. However, the support should be utilised in 2-3 years. It is given as investment or debt to incubate with a maximum support of Rs 70 lakhs. The total estimated cost per unit is Rs 7.00 crore under recurring.

4. UNIT COST ESTIMATIONS OF MAJOR COMPONENTS UNDER SUB-MISSION – INTERNATIONAL COLLABORATIONS

A. INTERNATIONAL COLLABORATIVE RESEARCH PROGRAMME: International collaborations will be based on existing International co-operation modalities. Each collaboration will have around 10 projects and will be on 50:50 cost sharing basis between India and participating country/ Int. Institutions. Thus, the unit cost for India is as per cost details given below

Table 8.10: International Collaborative Research Programme

S No	Budget Head	ESTIMATED COST IN Rs. LAKHS			
		Ist Yr	2nd Yr	3rd Yr	Total
A.	**Recurring**				
	1. Project Staff	50.00	50.00	50.00	150.00
	2. Contingencies	10.00	10.00	10.00	30.00
	3. Consumables	10.00	20.00	5.00	35.00
	4. Miscellaneous	10.00	10.00	10.00	30.00
	5. International travel/ exchange programmes	40.00	50.00	0.00	90.00
	6. International workshops/conference s/meetings		50.00		50.00
	7. Over Heads	5.00	5.00	5.00	15.00
	Sub-Total	**125.00**	**195.00**	**80.00**	**400.00**
B.	**Non-Recurring**				
	1. Equipment	50.00	50.00	0.00	100.00
	Sub-Total	**50.00**	**50.00**	**0.00**	**100.00**
C.	**Capital**	0.00	0.00	0.00	0.00
	Grand Total	**175.00**	**145.00**	**80.00**	**500.00**

5. UNIT COST ESTIMATIONS OF MAJOR COMPONENTS UNDER SUB-MISSION – TIH MANAGEMENT

Table 8.11: NM – ICPS TIH Management Unit (TMU)

S No	Budget Head	ESTIMATED COST IN Rs Crore					
		IstYr	2nd Yr	3rd Yr	4th yr	5th yr	Total
A.	**Recurring**						
	1. Project staff salaries & wages	1.30	1.30	1.30	1.30	1.30	6.50
	2. expenses towards conducting of Apex committee, executive committee and Sub-missions co-ordination meetings	0.10	0.10	0.10	0.10	0.10	0.50
	3. Travel	0.05	0.05	0.05	0.05	0.05	0.25
	4. Miscellaneous	0.05	0.05	0.05	0.05	0.05	0.25
	5. Contingencies	0.10	0.10	0.10	0.10	0.10	0.50
	Sub-Total	**1.60**	**1.60**	**1.60**	**1.60**	**1.60**	**8.00**
B.	**Non-Recurring**						
	TIH Office expenses	0.10	0.10	0.10	0.10	0.10	0.50

	Cloud Technology Platform for Mission, Portal development, Services, databases etc	0.05	0.10	0.10	0.05	0.05	0.35
	Sub-Total	**0.15**	**0.20**	**0.20**	**0.15**	**0.15**	**0.85**
C.	**Capital**	**0.88**	**0.00**	**0.00**	**0.00**	**0.00**	**0.88**
	Grand Total	**2.63**	**1.80**	**1.80**	**1.75**	**1.75**	**9.73**

8.2 Time Frame

Implementation of the project will involve, apart from the many administrative actions, the following major activities:

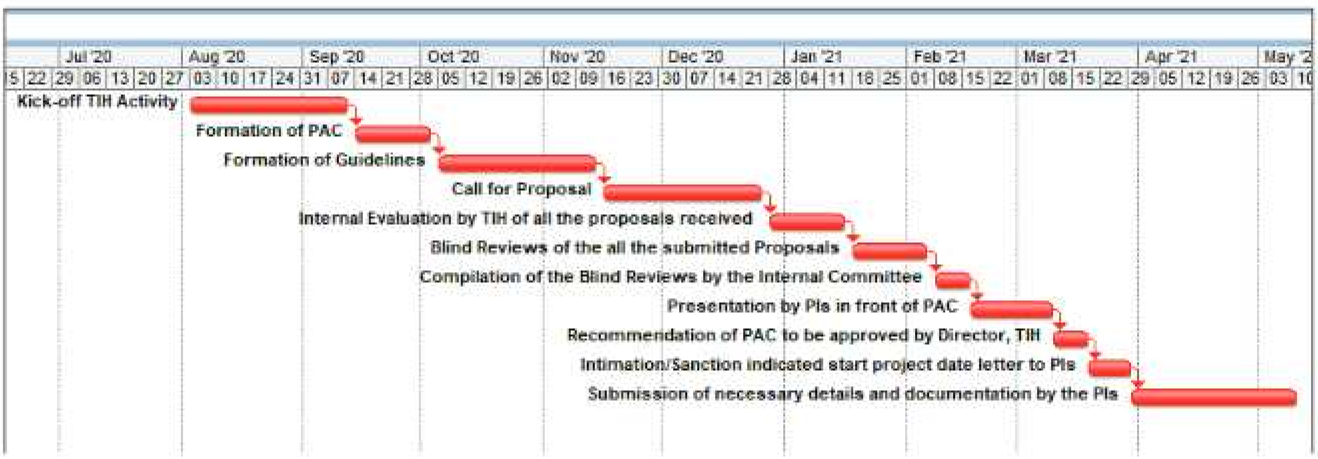
- Registration of Section 8 Company in the Name of TIH IIT (ISM)
- Signing of MoU between IIT (ISM), TIH and DST
- Setup of Infrastructure
- Establishment of TMU
- Recruitment of Manpower
- Preparing Guidelines
- Kick-off of all the Activities under verticals of TIH
- Calling for TD Project proposals & Seeking Applications for Fellowships
- Establishment of CoE & CAFE
- Assigning/sanctioning projects
- Monitoring and Review

As evident some of the activities are one time, however the remaining activities need to be carried out on periodic or as the need be basis. The Project Head will undertake the activities in time so that the aims of the project are achieved. Considering the major activities, an action plan for the implementation of the project is as given below in **Table 8.13.**

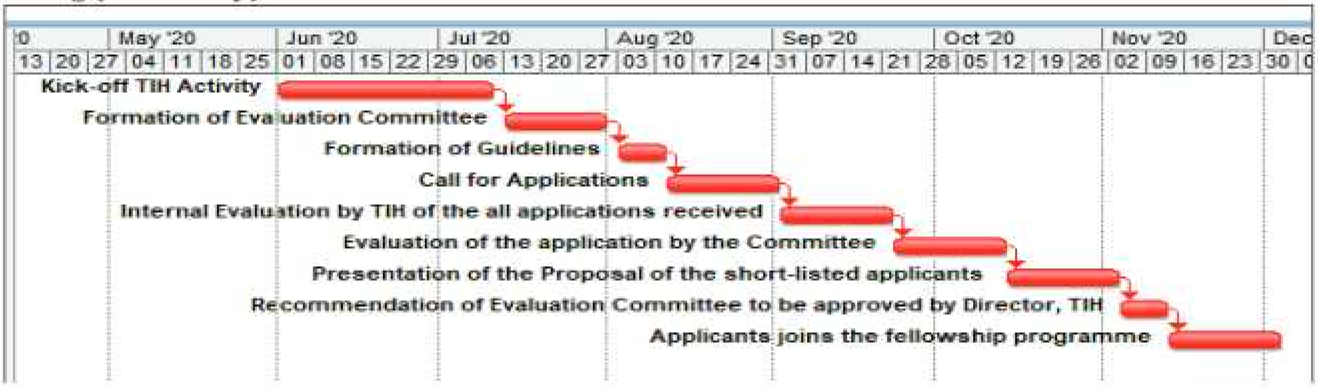
8.2.1 CPM Activity Wise

The activity-wise Gantt charts for R&D Projects, Hiring of students and hiring of faculty including chair are presented below.

Projects:



Hiring (Fellowship):



Hiring (Faculty):

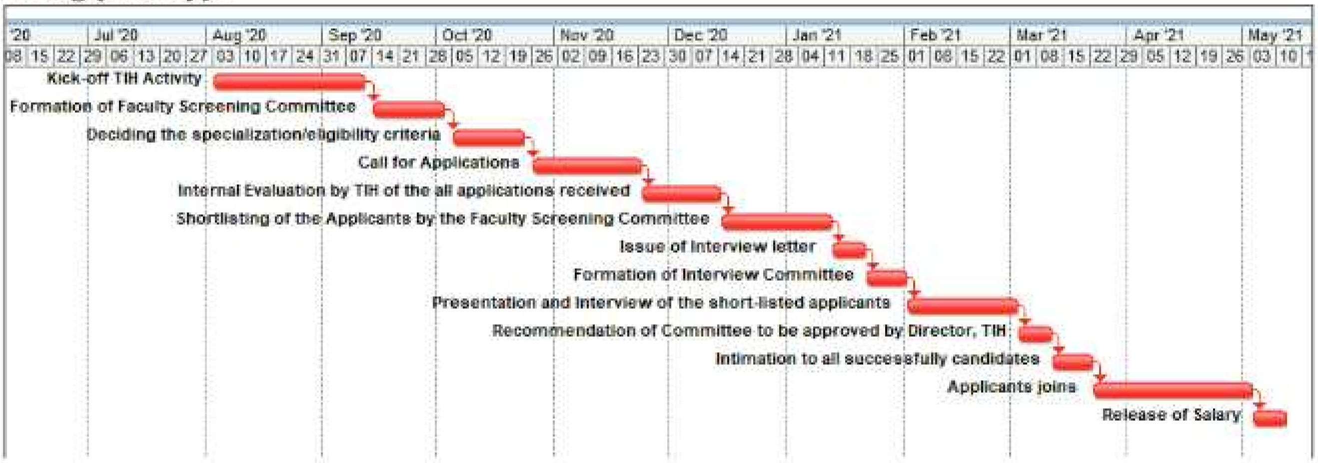


Table 8.12: Tentative Implementation Action Plan for TIH

	YEAR 1 6 MONTHS												YEAR 2				YEAR 3				YEAR 4				YEAR 5			
MAJOR ACTIVITY	1	2	3	4	5	6	7	8	9	10	11	12	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Section 8 Company																												
MoU with DST & IIT (ISM)																												
Infrastructure Setup																												
Establishing TMU																												
MANPOWER Recruitment																												
Publishing Guidelines																												
Activities of TIH																												
Project Proposals																												
COE																												
CAFE																												
Innovation Idea Challenge																												
Review and Monitoring																												

8.3 Cost Benefit Analysis (CBA)

Mining Companies like Rio Tinto, BHP Billiton etc. have already taken initiatives for making mining smarter using cyber technologies like machine learning, IoTs, Artificial Intelligence etc. for improving efficiency in each unit operations. However, before applying CPS technologies, technology of mining had to be improved by designing and planning the mine with latest technologies leading to large scale automation and optimization of machine capacities to reduce operational cost. But such technological up gradation also reached its plateau and there was not much scope of further optimization of cost and making it globally competitive. Then came the Mining 4.0, i.e. smart and safe mining adopting further automation and application of CPS technologies wherever applicable. The process started 10-15 years back and the impact of introduction of cyber technologies is visible today. As per an estimate, there had been 15 to 25 % reduction in cost of production of such mining projects with large scale implementation of CPS technologies in terms of autonomous machines, 3D visualization of mining operations, optimization of assets through real time analysis of machine deployment, idle time, etc.

However, Indian mining industry is not matured enough compared to the globally advanced countries in terms of introduction of mass production technologies, automation and introduction of CPS technologies in improving unit operations in exploration and exploitation. Indian mines have to go a long down the lane to reach the technological status suitable for further optimization through CPS technologies. Though, nothing stops Indian mining industry to reach the stage of Mining 4.0, simultaneously improving technological status using state of the art modern technologies in planning, designing and scheduling, automation etc. and also introducing the CPS technologies through a comprehensive integrated approach based on the global knowledge through international collaboration and creating a suitable ecosystem for successful introduction of CPS technologies in mining under TIH in Mining. A pictorial representation of direct and indirect benefits of CPS Technologies in Mining 4.0 is shown in Figure 8.1.

Fig. 8.1: A pictorial representation of direct and indirect benefits of CPS Technologies in Mining 4.0

8.3.1 CBA of CPS in Exploration

Table 8.14 shows the cost benefit analysis of CPS application in Exploration. Cost Benefit Analysis of the exploration component has been carried out based on a few major parameters such as feasibility study for geological and geophysical survey, geological and geophysical (G&G) survey, drilling, drilling-related chemical Analysis and operating Expenditure. Initially, 16.67 MMUSD (based on available analogue data) has been considered as a total exploration cost for this analysis.

The exploration project has been run for the period of 20 years where the initial 10 years are considered under Greenfield exploration and from 11th year onwards it has been considered as brownfield. We have considered 10% cost escalation during brownfield development whereas we are anticipating enhancing the 50% return valuation from brownfield.

After using AI (Artificial Intelligence) the exploration cost has been reduced. The data shows that the current success of mineral exploration in India is 0.327. After using AI technology in exploration this success ratio has been projected to 0.67 which is a global average. Drilling and drilling-related cost have been mostly reduced after using AI. However, the technology cost of AI has been considered during the cost-benefit analysis. We can achieve 19% more target after using AI in the exploration. After incorporation of all cost, we have observed considerable techno-economic analysis for exploration inform of conservative return.

The analysis is depicted that NPV (net present value) 38.75 MMUSD where IRR (internal rate of return) is 25% and the discount rate has been considered as 10%.

Table 8.13 : Cost Benefit Analysis of CPS application in Exploration

Current Estimation		
Line items for conducting Exploration Survey	**Cost in INR**	**Exploration Cost in Million USD @ 75 INR conversion rate**
Geological and Geophysical (G&G) Survey	250,000,000.00	3.33
Drilling	600,000,000.00	8.00
Drilling Chemical Analysis	100,000,000.00	1.33
Feasibility Study Geotechnical, Groundwater etc.	100,000,000.00	1.33
Operating Expenditure	200,000,000.00	2.67
	Total Exploration Cost	16.67

Cost Benefit Analysis after using AI				
Year	**Exploration Cost in Million USD**	**Estimated Value of Discovery in Million USD**	**Success Ratio**	**Assumption for parameter consideration**
Initial Cost	16.67	5.45	0.327	Success ratio for rest of the world
Revised Cost based on uses of AI		**Revised Benefit**		
1st Year 1. 5% of G&G Survey 2. Operating Expenditure	2.83	13.065	0.67	Global Success Ratio
2nd Year to 5th Year 1. Drilling Cost 2. Drilling Chemical	11.68	13.065	0.67	Achieve Target 6%

Analysis 3. Operating Expenditure				
4th Year	11.68	13.065	0.67	Achieve Target 6%
5th Year	11.76	13.065	0.67	Achieve Target 7%
6th Year to 10th Year 1. Operating Expenditure	2.67	13.065	0.67	
7th Year	2.67	13.065	0.67	
8th Year	2.67	13.065	0.67	
9th Year	2.67	13.065	0.67	
10th Year	2.67	13.065	0.67	
11th Year 1. G&G Study 2. Drilling 3. Drilling Chemical Analysis 4. Feasibility Study 5. Operating Expenditure	14.05	19.59	0.67	10% hike for Brown Field & 50% estimated value addition
12th Year to 14th Year 1. Drilling Cost 2. Drilling Chemical Analysis 3. Operating Expenditure	12.88	19.59	0.67	Achieve Target 6%
13th Year	12.88	19.59	0.67	Achieve Target 6%
14th Year	12.96	19.59	0.67	Achieve Target 7%
15th Year to 20th Year 1. Operating Expenditure				
15th Year	2.93	19.59	0.67	
16th Year	2.93	19.59	0.67	
17th Year	2.93	19.59	0.67	
18th Year	2.93	19.59	0.67	
19th Year	2.93	19.59	0.67	
20th Year	2.93	19.59	0.67	

Improvement after using AI	**Quantification**
Uses of AI will enhance technology cost	5%
Usages of AI will improve G&G study which will reduce Drilling cost	10%
New Target will be generated after using AI	19%
Target Achieve after using of AI based on global average	0.67

Brown Field Cost Enhancement	**10%**
Brown Field Estimated Value estimation Enhancement	**50%**

Cost Benefit Analysis					
Year	**Costs**	**Benefits**	**Total Benefits**	**Discount Factors**	**Present Value**
0	16.67	0	-16.67	1	-16.67
1	2.83	5.45	2.62	0.91	2.38
2	11.68	13.06	1.39	0.83	1.14
3	11.68	13.06	1.39	0.75	1.04
4	11.68	13.06	1.39	0.68	0.95
5	11.68	13.06	1.39	0.62	0.86

6	2.67	13.06	10.40	0.56	5.87
7	2.67	13.06	10.40	0.51	5.34
8	2.67	13.06	10.40	0.47	4.85
9	2.67	13.06	10.40	0.42	4.41
10	2.67	13.06	10.40	0.39	4.01
11	14.05	13.06	-0.99	0.35	-0.35
12	12.88	19.59	6.72	0.32	2.14
13	12.96	19.59	6.64	0.29	1.92
14	12.96	19.59	6.64	0.26	1.75
15	2.93	19.59	16.67	0.24	3.99
16	2.93	19.59	16.67	0.22	3.63
17	2.93	19.59	16.67	0.20	3.30
18	2.93	19.59	16.67	0.18	3.00
19	2.93	19.59	16.67	0.16	2.72
20	2.93	19.59	16.67	0.15	2.48

Discount Rate	10%
Net Present Value (NPV)	38.76
IRR (Internal Rate of Return)	25%

8.3.2 Cost of Occupational Injury (CDC. NIOSH)

Direct cost in *Safety Pays in Mining* is the cost of workers' compensation claims (medical expenses and indemnity payments for wage loss, both paid and reserved)

Indirect cost estimates can include:

- Any benefits paid to injured workers for absences not covered by workers' compensation
- The wage costs related to time lost through work stoppage associated with the worker injury
- The overtime costs of other workers necessitated by the injury
- Administrative time spent by supervisors, safety personnel, and clerical workers after an injury
- Training costs for a replacement worker
- Lost productivity related to work rescheduling, new employee learning curves, and accommodation of injured employees
- Clean-up, repair, and replacement costs of damaged material, machinery, and property
- Increased workers' compensation insurance premiums

Indirect cost estimates generally do not include:

- The costs of MSHA fines and any associated legal action
- Worker pain and suffering
- Loss of good will from bad publicity

To estimate the indirect costs of injuries, *Safety Pays in Mining* uses an indirect cost multiplier of 2.12.* The indirect cost is calculated by multiplying the direct cost of an injury and the indirect cost multiplier.

Therefore, Indirect cost = Direct cost × Indirect cost multiplier

Cost of single fatal accident in India

Direct cost

- Compensation cost: 40% of monthly wages X Factor based on age (workmen's compensation Act 1921) i.e. 0.4 x 80000 x 185 = Rs. 60 00 000 (assuming monthly wage of Rs 80000 and average age of deceased 40 yrs)

- Exgratia : Rs. 15 00 000
- Medical Treatment: Rs. 10,00,000

Indirect Cost

- Loss of production: 6000 tpd x 3 days x Rs. 2000 / te = Rs. 360 00 000
- Loss of working hours: (1000 man / day) x 3 days x (Rs. 5000 / day) = Rs. 15 000 000
- Loss of Machine hours (Assuming 3 days loss of working per fatal accident)
  Capital expenditure: Rs 30000 000 000
  Interest / depreciation: Rs. 6000 000 000 / yr = Rs. 20,000,000 / day
  Total loss due to machine idle time – Rs. 20 000 000 x 3 = Rs. 60 000 000
- Training of replacement workers: 21days x Rs. 5000 /day (Wages of trainees) + 21 x Rs 2000/ day (training cost per day per person) + Rs. 50000 (other cost) = Rs. 200000 (approx...)
- Cost of inquiry: 200 mandays x Rs. 10000 per manday (manday cost) + 30 days x Rs.10000 (Logistical expenses)+ Rs. 200000 (Misc. Exp) = Rs. 25 00 000
- Legal cost: Rs. 10 00 000 / fatal accident

Total Estimated cost: 1200 00 000 / fatality

Cost of serious injury

- Compensation: 50% of monthly wages X Factor based on age x % disablement
  0.5 x Rs. 80000 x 185 x 0.5 = Rs. 40 00 000
- Cost due to reduced productivity:
  20 yrs x Rs. 10 00 000 (annual salary) / yr x 0.5 (% disablement) = Rs. 10 000 000
- Exgratia: Nil
- Medical Treatment / per person injured: Rs.10,00,000
- Loss of production : 6000 tpd x 0.5 days x Rs. 3000 / te = Rs. 9, 000 000
- Loss of working hours: 1000 man / day x 0.5 day x Rs. 5000/ man = Rs. 25 00 000
- Loss of Machine hours:
  - Capital expenditure – Rs 30000 000 000
  - Interest / depreciation – Rs. 6000 000 000 / yr = 20,000,000 / day
  - Total loss due to machine idle time – 20 000 000 x 0.5 = Rs. 10 000 000
- Training of replacement workers: Rs. 1 00 000
- Cost of inquiry : Rs. 5 00 000
- Legal cost:

Total Estimated cost: Rs. 40, 000 000 /injury

Cost of disasters: Direct cost same as fatal accident

Additional Indirect cost

- Rescue & Recovery cost
  Rescuers: 30 teams /day, 20 days / rescue work of days, 6 persons in each team
  30x6x20x10000 per day =Rs. 36,000,000
  Logistics: Rs. 100,00,000
  Additional resources: Rs. 200,00,000
  Worker's mandays lost: 1000 x 30 x 5000 = 150 000 000
  Production loss : 1000 te / day x 30 days x Rs.3000/ Te = Rs. 90 000 000
  Estimated average of total cost of rescue or recovery: Rs. 320 000 000 / disaster

1 disaster / 3 yrs
Average cost of disaster / yr – Rs. 110 000 000
Average cost in mining accidents in India
100 fatalities + 200 serious injuries per year+ cost of disaster:
120,000,000 x 100 + 350 00 000x 200 + 110 000 000= 20,000 000 000 / yr
Assuming 15 % reduction in fatality and serious injuries / year due to smart and safe mining, amount of savings on account of mining injuries
15% 0f 20000 000 000 = Rs.3,000,000,000 / year i.e. Rs 300 crores per year

8.3.3 Cost benefit Analysis of Optimizing Mining Operation

Planning and management of equipment productivity is critical for success of large scale surface mining operations. Poor equipment availability, utilization, reliability and productivity can endanger the performance of mining operation. Mining plan and production schedule should be so designed to optimize equipment productivity and utilization. Key operational parameters that affect the productivity of equipment in surface mine are the pit geometry, production planning, digging conditions, mining methods, dig-dump schedules, and operator's efficiency. The productivity of Indian open cut coal mine is very low compared to global operations due to poor equipment productivity. The major factor is insufficient technical improvement in mining methods and application of technology over the period of time.

Removal of overlaying waste or overburden material in surface coal mining accounts for over 60% of the mining cost. It is therefore, important for open cut mine operators to focus on overburden removal for possible reductions in the mining cost. Dragline has emerged as the dominant overburden removing machine in surface coal mining world-wide due its very high productivity and low cost. Large surface coal mines of USA and Australia deploy draglines to produce up to 70-80Mt. coal from one mine. In India over 120 Mt. of coal is produced annually from dragline operated coal mines. Singrauli coalfields of India which produces over 100Mt coal deploys more than 25 small size draglines for overburden removal.

Draglines are large weight (3000 – 4000 metric tons), capital intensive ($ 40 – 100 million per unit) overburden mining equipment which generally works 24 hours a day and all days of the year. Studies have shown that that 1 % improvement in the productivity of a medium size dragline operation will be valued around USD 0.75 – 1.00 million per annum. Productivity of dragline operation depends on a number of factors such as geological and mining parameters, mining methods, digging sequence, dragline operating level, and pit geometry etc. Application of technology for capturing data and processing them through computer aided simulation could provide effective tools to optimize operation for enhanced productivity and cost reduction.

A typical dragline operated coal mine of Singrauli coalfields deployed 4 draglines, each costing approximately $40.00 – 45.00 million with a coal production target of 8.00 million tons per year. The mine used traditional systems and methodologies for planning, simulation and operation large equipment. There are opportunities to use modern technologies for data capturing and data processing which could yield significant gain in equipment productivity of and cost reduction. A cost-benefit analysis on application of modern technologies was done with following simulated outcomes (Table 8.15):

Table 8.14: Cost benefit analysis of applying modern technology

Parameters	***Existing*****	***With Technology***	***Difference***
Coal exposed (Mt) - Annual	8.07	8.17	0.10
Total overburden removed (Mm³) - Annual	**15.24**	**15.24**	**0.00**
Dragline system			
Dragline System (Mm³) - Annual	9.23	11.32	2.09
Annual dragline hours (hr.)	20400	20400	0
Dragline hourly operating cost (₹/hr)	***37188***		
Dragline annual operating cost (₹. Cr./year)	***75.86***	***75.86***	***0***
Dragline productivity (m³/hr)	***1810***	***2220***	***210 (11.60%)***

Shovel-Dumper System			
Shovel-dumper system (Mm³)	6.01	3.92	-2.09
Annual Shovel hours (hr.)	13356	6533	6823
Shovel hourly cost (₹/hr)	29927		
Shovels annual operating cost *(₹. Cr./year)*	39.97	19.55	20.42 (51.08%)
Shovels productivity *(m³/hr)*	450.00	600.00	150.00 (37.50%)
Dumpers annual working hours (hr.)	63936	40833	23103 (36.13%)
Dumper hourly operating cost (₹/hr)	14350		
Dumpers annual operating costs *(₹. Cr./year)*	91.70	77.55	14.15 (15.40%)
Dumper productivity *(m³/hr)*	94.00	96.00	2.00 (2.12%)
Costs & Benefits			
OPEX Benefits			
Total annual opex of dragline system (₹. Cr.)	75.86	75.86	0
Total annual opex of shovel dumper system (₹. Cr.)	131.70	97.10	34.60 (26.30%)
Total annual opex for overburden removal (₹. Cr.)	***207.56***	***172.96***	***34.60 (16.66%)***
CAPEX Benefits			
Dragline system (₹. Cr.)	NIL		
Shovel-Dumper System (₹. Cr.)	53.00	Equipment fleet size reduced by 1 shovel (@₹35.00 cr.) and 6 Dumpers (@₹3.00 cr.)	
Total annual capex benefits (₹. Cr.)	***6.36***	***@ 12% cost capital***	
Cost of Technology			
Dragline system (₹. Cr.)	Existing	4.00 (Additional)	4.00
Shovel-Truck System (₹. Cr.)	Existing	5.00 (Additional)	5.00
Total cost of technology			***9.00***
Environmental Benefits			
Reduction in green-house gases (GHGs) emission – te of CO_2 equivalent			
Dragline system	17397	17397	-

Shovel-Dumper System	15618	9611	6007 (38.46%)
Total	***33015***	***27008***	***6007(18.19%)***
Reduction in Fugitive Dust Emission (TSP and PM_{10})			
Dragline System (TSP)	881.64	1132.80	-251.16 (-28.48)
Shovel-Dumper System(TSP)	1732.74	1130.18	602.56(34.77)
Total TSP	***2614.38***	***2262.98***	***351.4 (13.4 %)***
Dragline System (PM10)	113.76	132.16	-18.4 (16.1%)
Shovel-Dumper System(PM10)	583.81	380.79	203.02 (34.77 %)
Total (PM10)	***697.57***	***512.95***	***184.62 (26.4%)***

**: Numbers arrived from the data collected from the mine site of Northern Coalfields Limited.

Following inferences can be drawn from the above cost-benefit analysis:

- The analysis is based on simulated outcome of mining operation on the real field data. Accuracy of simulation model is above 90%.
- There is an annual saving of **₹ 40.95 cr.** against an additional investment of **₹ 9.00cr** in technology**.** The investment in technology will be recovered within 3 months of successful implementation.
- There will be an additional coal production of 0.1 Mt. At a nominated coal price of about **₹ 1500 per tons,** would result into an additional revenue of **₹ 15.00 cr.**
- An increase of annual productivity of dragline system by 2.09 million m^3 (11.6%) have been reported based on simulated outcome of dragline operation. This is even a conservative estimate which has the potential to go up further.
- An increase in productivity of shovels by over 37.50% and dumpers by over 2%. With optimization of shovel-dumper fleet, resulted gain in capex would be **₹ 6.36 cr.** per year.
- Two types of technologies have been considered, - i) technology for data capturing, and ii) technology for data processing;
    - For dragline equipment system, Pegasys system for monitoring and data capturing, and DragSim system for data processing have been considered.
    - For shovel-dumper equipment system, Track-Dispatch System (TDS) for monitoring and data capturing, and TALPAC – 3D or HAULSIM system for data processing have been considered. The cost of TDS has not been considered in the analysis as this system is in place for many large mines without much benefits derived from it. Being merely used to facilitate supervision.
- There would be significant associated environmental benefits to promote sustainable mining. Operational Efficiency will positively contribute to Environmental Efficiency due to efficiency in energy consumptions per unit of material mined and equipment fleet optimization. This in turn will reduce emissions of green -house gases (GHGs) and fugitive dust (TSP & PM_{10}) due to mining as committed by our prime minister to UN convention on climate change. Using IPCC – 2006# and USEPA## methodology for estimating the emissions, modern technology would also result into the following benefits in the present case study:

  A reduction in GHGs emission by 6007 te. *of CO_2 equivalent* (18.7%).

  Equipment fleet size optimization would result into reduction in fugitive dust emissions of TSP and PM_{10} by 351.4 (13.4 %) and 351.4 (13.4 %) respectively.

#: UN Convention of Inter-Governmental Panel on Climate Change, 2006a and 5th Assessment report 2014: Climate change 2014: Synthesis report.
##: United States Environmental Protection Agency, 2006, 2006a and 2008.

In absence of actual data of performance improvement due to CPS technologies in mining, while making an attempt to do cost benefit analysis or impact analysis of CPS technologies in mining, it is assumed that there is potentiality of reduction in cost at up to 15% through incremental steps of 5% and 10 % within next 10-15 years. An exercise has been done to estimate the financial gain by estimating the cost with 85% and 100% achievement from the project performance report of few opencast and underground coal mines in India. The financial performance of Opencast and Underground Coal Mines are shown in Table 8.16 and Table 8.17.

The gain per million te of annual production has been calculated at 15%, 10% and 5% performance over 85% performance data. It is also assumed that India is planning to achieve 1000 Million Te production of coal by 2022 from the existing level of round 730 M Te. Out of this 1000 M Te, 900 M Te is assumed to be produced from opencast mines and 100 M Te from underground mines. On the basis of that assumption, it is estimated that the annual financial gain for Indian coal industry may be around Rs. 4161.2 crores, Rs. 8322.4 Crores and 12483.60 crores, with 5%, 10% and 15% performance improvement per year due to introduction of CPS Technologies in mining. However, this is to be noted that this exercise is an indicative assessment of the benefit of CPS technologies based on the experience of global mining companies.

BHP Billiton has reported that, through its Maintenance Centre of Excellence initiative, it expects to save $1.2 billion across the business by FY2022, with a corresponding reduction in downtime of 20 per cent. The company also reports that unit costs have reduced by 15 per cent over the past two years.

Anglo American increased its production by 9 per cent, at a 26 per cent lower cost per unit, and its volume target for 2017 by $1.1 billion. It attributed these successes to its improved mine planning and the simplification of its operating structure.

Table 8.15: Financial Performance of Opencast Coal Mines

Summary

Sl. No.	Particulars	**Mine X** (Large Opencast Project)	**Mine Y** (Medium Opencast Project)	**Mine Z** (Mega Opencast Project)
1	Annual Production (M Te)	16.0	6.0	50
2	Capital Expenditure - HEMM (Rs. In crores)	2049.43	664.49	7227.2
3	Total Cost per Te (in Rs.) at 100% of production capacity	677.29	912.82	445.88
	at 85% of production capacity	747.84	1099.04	506.31
4	Selling Price (Rs/t)	877.82	1045.15	898.00
5	Profit / Loss (Rs.) at 100% of production capacity	200.53	132.33	452.12
	at 85% of production capacity	129.98	- 27.49	391.69

Detailed analysis of Profit and Gain

	Opencast Project								
Mine	**Production in Mty at 100% capacity**	**Production in Mty 85%**	**Profit Rs/T at 85%**	**Profit Rs/T at 100%**	**Profit (Rs. In crores) at 85%**	**Profit at 100% (Rs. in Crores)**	**Net gain due to increase in performance by 15 %(Rs in Crores)**	**Net gain due to increase in performance by 10 %(Rs in Crores)**	**Net gain due to increase in performance by 5 %(Rs in Crores)**
Mine X	50	42.5	391.69	452.12	1664.6825	2260.6	595.9175	397.2783333	198.6392
Mine Y	6	5.1	-53.89	132.33	-27.4839	79.398	106.8819	71.2546	35.6273
Mine Z	16	13.6	129.98	200.53	176.7728	320.848	144.0752	96.05013333	48.0251
Total	72	61.2	467.78	784.98	1813.9714	2660.846	846.8746	564.5830667	282.2915333
Average gain per million te of annual production (Rs in crores)							11.7621	7.8414	3.9207
Assuming 900 Mt production out of total 1000 Mt production by opencast method							10585.9325	7057.2883	3528.6442

Table 8.16: Financial Performance of Underground Coal Mines

Sl. No.	Particulars	Mine M (Medium capacity UG Coalmine)	Mine N (Medium capacity UG Coalmine)
1	Annual Production (M Te)	0.76	0.43
2	Total Cost per Te (in Rs.) at 100% of production capacity	1331.11	799.07
	at 100% of production capacity	1496.24	894.85
3	Selling Price per Te (Rs)	1808.00	1262.45
4	Profit / Loss per Te (Rs.) at 100% of production capacity	476.89	463.38
	at 85% of production capacity	311.76	367.60

Detailed analysis of Profit and Gain

Underground Project									
Mine	**Production Mty at 85 % capacity**	**Production in Mty at 100% capacity**	**Profit Rs/T at 85% performance**	**Profit Rs/T at 100 % performance**	**Profit (Rs in Crores) at 85 % performance**	**Profit (Rs in Crores) at 100% performance**	**Net gain due to increase in performance by 15% (Rs in Crores)**	**Net gain due to increase in performance by 10% (Rs in Crores)**	**Net gain due to increase in performance by 5 % (Rs in Crores)**
Mine M	0.3825	0.45	367.6	463.38	14.0607	20.8521	6.7914	4.5276	2.2638
Mine N	0.6715	0.79	311.76	476.89	20.9347	37.6743	16.7396	11.1598	5.5799
Total		1.24	679.36	940.27	34.9954	58.5264	23.5310	15.6874	7.8437
Average gain per million te of annual production (Rs in crores)							18.9766	12.6511	6.3255
Assuming 100 Mt production out of total 1000 Mt by underground method							1897.6634	1265.1089	632.5545
Assuming 900 Mt production out of total 1000 Mt by opencast method							10585.9325	7057.2883	3528.6442
Total production of 1000 M Te per year							12483.5959	8322.3972	4161.1987

8.4 Risk Analysis

The global mining leaders find 10 most business influencing risks in mining industry of the future. Figure 8.2 presents the rankings as carried out by EY in 2019-20 through consultation of stake-holders. Effective application of digital transformation across mining value chain will lead to the successful application of CPS technologies in Mining 4.0. There is a need of top-bottom approach in this endeavour. In order to maximize the output of the CPS in Mining 4.0, the companies are required to have significant increase in investment on technological innovations. Presently around less than 5% of their budgets are being invested on digital technologies across various companies in India. They need to enhance their investment by 20-25% initially for feeling a visible impact of digital technologies. Societal change, new technologies and the race to transform business models are driving a whole range of disruption for mining and metals companies. Cyber security threats of digital technologies are also quite high in worldwide mineral sectors. More than 50% of mining and metals companies worldwide have had a significant cyber security incident in the year 2018-19. The pace at which mining companies are required to grow remains uncertain globally as the mining companies are totally demand driven and governed by commodity pricing across the globe. There is a global concern on greenhouse gases. The mining companies, particularly coal companies will have a tough competition with the producers of renewal and other non-conventional energy. The digital enablement may attracts increased technological skill and specialization among employees and opportunity for business disruption. However, there will be job fear at shop floor workforce owing to their non-performance due to knowledge gap in CPS technologies. At the same time these workforce in India may not be easily transformed to adopted disruptive technologies.

The above possible risks in mining of future may also influence the performance of TIH in Mining 4.0. However, the global experts opines that "Digital innovation will be a key tool, but the industry must overcome a poor track record of technology implementations. If mining companies are to survive and thrive in a new energy world, they must embrace digital to optimize productivity from market to mine". The era of disruption has begun in mining industry from several horizons such as job disruption, customer disruption, asset disruption, economic disruption etc. Out of the possible disruptions, it is felt that technology is leading the disruption in mining sector, followed by the workforce. TIH at IIT (ISM) is being setup keeping in view the above possible risks and disruptions.

Table 8.18 presents critical parameters/risk of implementations, their impacts and mitigation strategy for achieving the desired objectives of TIH in Mining 4.0 at IIT (ISM)

Graphical representations are made through Figures 8.3 and 8.4. Figure 8.3 shows the probability – impact matrix of technical risk parameters, whereas figure 8.4 depicts the matrix of all the parameters. It may be seen from these figures that technical risks are not that severe as compared to financial and project management risks.

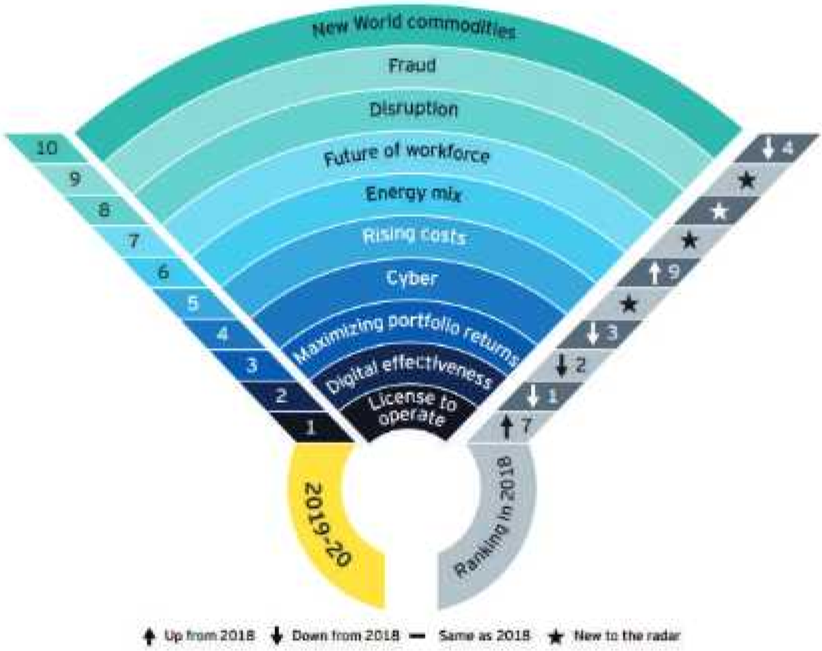


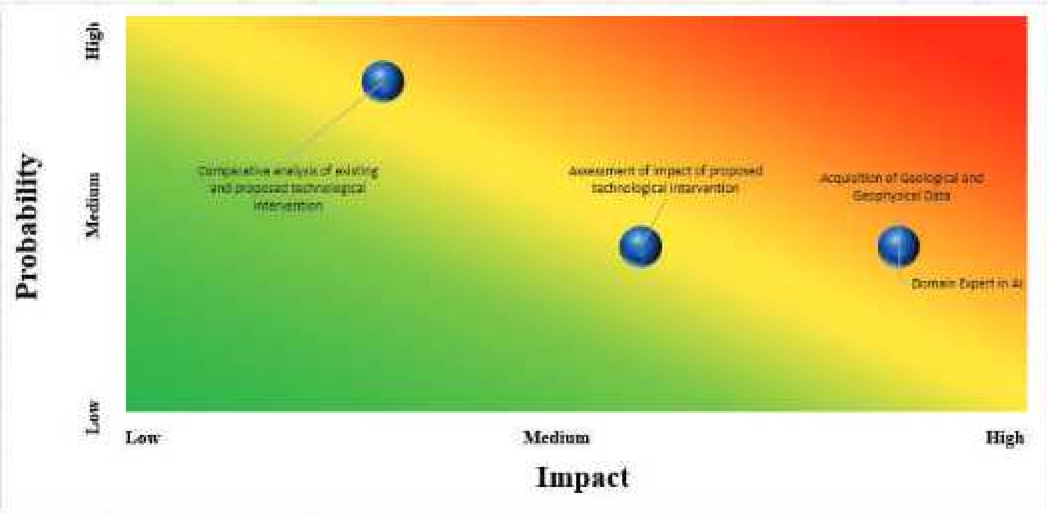
Fig. 8.2: 10 most business influencing risks in mining industry of the future (EY 2019-20)

Table 8.17: Critical parameters/risk of implementations, their impacts and mitigation strategy for achieving the desired objectives of TIH in Mining 4.0

Risk Items	Impacts	Critical Parameter / Risk of implementation	How to Mitigate
Technical Risks	High	Acquisition of Geological and Geophysical Data	All existing data acquired by different agencies be available online similar to portal BHUKOSH of GSI
			Extensive Data acquisition programme viz., NAGPM, NGPM, NGCM to be completed at the earliest. Collaborate with other agencies to complete this exercise. NGPM must include seismic and magneto-tellurics as done by Australia
	High	Domain Expert in AI	Collaborate with Industry and Academics
			With their association a skill development programme, be initiated
			The under graduate students need to take as an undergraduate project for four years
	Medium	Assessment of impact of proposed technological intervention	Impact assessment of proposed technological intervention on production, productivity, cost, safety and environmental sustainability to be carried out while selecting options for technological interventions.
			Prioritise options based on level of impact.

	Low	Comparative analysis of existing and proposed technological intervention	List out existing technologies for achieving the project objectives.
			Analysis of advantages or disadvantages of existing one with proposed technology.
			Specific advantages or gains of the project proposal comparing with the existing one, which may include cost of equipment and spares, availability of service, long-term availability, forex requirement, import policy and excise duty, scope of domestic employment, capability development etc.
Social Risks	Low	Community Resistance	Community to be taken in confidence and to ensure that their living condition and safety to improve and is not as an attempt towards reducing manpower, In fact this thought must take the front seat
			Need to work with the community to generate employment opportunities, for example, along the supply chain related to the mine or in alternate fields.
People Risk	High	Mining not a first-choice career option	The mining industry can attract and retain the much-needed diversified talent by adopting more technologically driven solutions and encourage innovation in everyday operations.
			Technology can also ensure a safe and comfortable environment to attract the interest of women to the industry, thereby ensuring that the mining industry is able to attract a well-rounded diverse workforce.
Financial Risks	High	Losing Revenue to Foreign Players	Govt. Initiative is towards digital India, skill development and promotion of innovation
			Collaborate with Industry and Academics
Regulatory Risks	Medium	Requirement of statutory approval / permissions for testing / trial and implementation	☐ To discuss with regulatory authorities before formulation of a project and preparing a protocol for testing / trial and implementation. ☐ Representatives of statutory authorities may be included in project evaluation and monitoring committee
Project Management Risk	Medium -High	User industry's consent for trial and implementation of developed technology	☐ User industry to be involved while formulating project objectives and prior consent for trial / testing and implementation to be obtained

Contract Management Risks	Medium – High	Partnership with manufacturing industries	□ Project-wise industry partner to be identified based on capability, credibility, MoUs and specific commitment on deliverables □ Project-wise Contract agreement with technology partner with clearly defined terms & conditions on IPR and commercial issues □ Exploring alternative partners as contingency measures
Safety & Environment Risk	Low - Medium	Assessment of safety and environmental risk of proposed technological intervention	□ Every project to be risk assessed on its safety and environmental impact while implementation □ Specific mitigating measures against each risk element to be incorporated in the project report □ Project monitoring committee to review the



Risk Factors	Impact	Probability
Acquisition of Geological and Geophysical Data	3	0.25
Domain Expert in AI	3	0.25
Assessment of impact of proposed technological intervention	2	0.25
Comparative analysis of existing and proposed technological intervention	1	0.5
Low - 1		
Medium - 2		
High – 3		

Fig 8.3: Probability – impact matrix of technical risk parameters

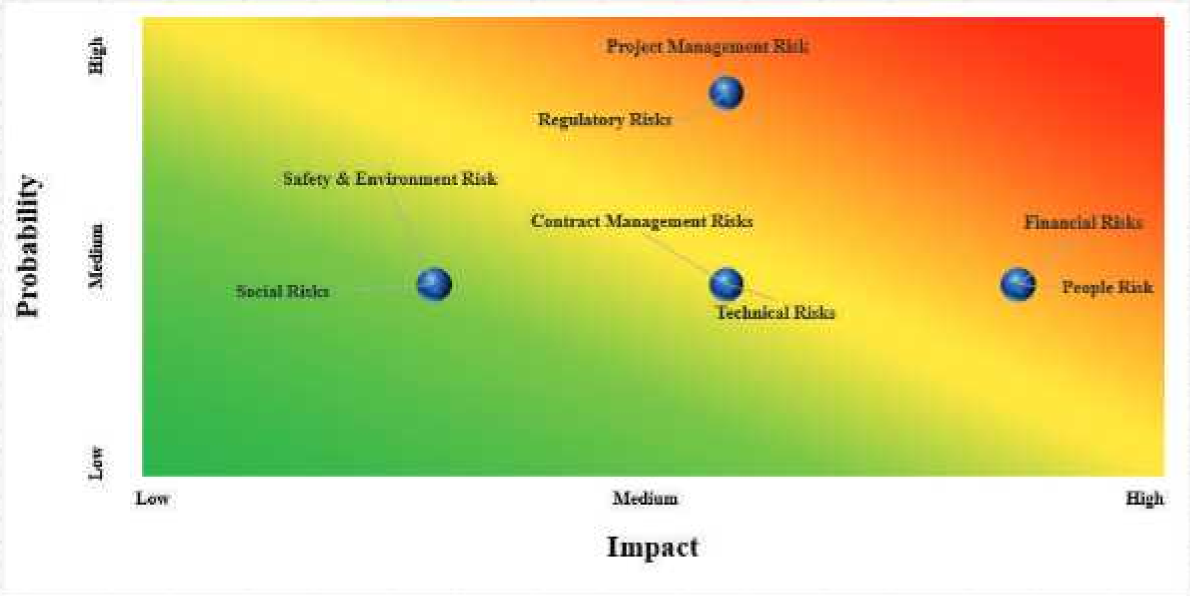


Fig. 8.4: Probability – Impact matrix of all the parameters

Risk Factors	**Impact**	**Probability**
Technical Risks	2	0.25
Social Risks	1	0.25
People Risk	3	0.25
Financial Risks	3	0.25
Regulatory Risks	2	0.5
Project Management Risk	2	0.5
Contract Management Risks	2	0.25
Safety & Environment Risk	1	0.25

Low - 1
Medium - 2
High - 3

8.5 Sustainability Model

IIT (ISM) has been contributing for up-gradation of knowledge and expertise of executives of different companies by offering executive development programmes and also solving real-life problems of the Industry in its core areas of competence. Over the years, it has established excellent credentials in this area of activity. The due recognition of IIT (ISM) in earth sciences and mineral sector will certainly prove to be blessings for TIH in building confidence among its stakeholders.

Needless to say that the scope of the institute as loomed from primarily a mining institute into a fully grown technology institute wherein all conventional streams of science and technology got added out during its journey of 90 years. The TIH will generate revenues from the following activities and will become self-sustained after passing through the incubation stage within 5 years of its establishment.

Following activities will help in self-sustaining of the TIH. Annexure 3 shows sustainability model of the TIH.

- Industrial/Executive Training/Development Programs, Consultancy / Calibration Services, Industrial Projects etc.
- Revenue sharing through transfer of Technology, Products and Processes
- The TIH will have financial stakes through equity in all the incubated start-ups from the centre which will provide financial sustainability in the long run.
- Revenue generation through participation of stake holders and relevant industries.

8.6 The Benefits of Being a Partner

It is also hope that TIH will attract active industrial partners and will claim stakes. The partners will be allied with TIH under various schemes of sustainability of TIH. A brief of the same is presented below:

TIH would be collaborating with mining and exploration companies along with academicians at a national/international level. The problems identified in the DPR have been discussed and finalised in consultation with the eminent academicians and industry personnel worldwide (Annexure 1). All of them agreed to be a part of the expert team. This helps to build a team of world-class researchers with a wealth of knowledge and experience, and a focus on end-user driven outcomes.

The intention is to provide the partners the access to state-of-the-art facilities at TIH. The TIH team will have the ability to tailor research projects to meet their individual requirements.

Major benefits of an alliance with TIH will include:

- Opportunities to focus research activities where they will have maximum impact for your organisation.
- Early-mover advantage when implementing research outcomes to enhance discovery potential and optimise existing reserves.
- One-on-one research projects tailored to company requirements.
- Access to world-class facilities.
- Facilitated engagement with our domain/international experts and practising researcher.
- Access to a comprehensive range of industry-focussed training courses -tailored to your requirements.
- The facilities are NABL accredited

It's understandable that the minerals industry is cyclical by nature, and operating conditions can vary greatly, often through unforeseen circumstances. For this reason, we offer partnership opportunities on a five-year basis, which gives you the flexibility to adjust your involvement in line with your circumstances. Companies may sign up at either the Platinum, Gold, Silver or Copper level, depending on their planned level of involvement with the Centre. These partnership funds are used to support TIH in the conduct of research, administration and external communications, ensuring valued funding for specific industry projects is directed solely into activities related to those studies. Each level has a series of escalating benefits, which are:

Platinum

- Domain/International Experts Guidance
- Facilities available as an Internal User of TIH
- Tailor Made Training Programme
- Tailor Made Research Programme
- Become a part of the Board of TIH

Gold

- Domain/International Experts Guidance
- Use of Facilities at 50% of the existing rates for an external user
- Tailor Made Training Programme
- Tailor Made Research Programme

Silver

- Domain Experts Guidance
- Use of Facilities at 65% of at the existing rates for an external user
- Can opt only from the Existing Training Programmes of TIH
- Tailor Made Research Programme

Copper level

- Domain Experts Guidance
- Use of Facilities at 75% of the existing rates for an external user
- Can opt only from the existing Training Programmes

8.7 Infrastructure

Unfurnished Multi-storey building of total area of approx. 30,000 square feet, centrally air conditioned, with uninterrupted quality power supply is presently available to be allotted to TIH. It will have sufficient space to accommodate the Instruments including space for the TMU and various activities of TIH. Provision of a Conference room and two Syndicate rooms in each floor with office space for TMU will be available in the allotted space.

9 TIH MANAGEMENT

9.1 Management

In order to effectively implement the NM-ICPS mandated TIH programmes, the process of registration of TIH in Mining in the name of TIH IIT (ISM) under Section 8 of the Indian Companies Act, 2013 has already been initiated. Memorandum of Association (MOA) and Article of Association (AOA) of the Company has already been prepared. The TIH will have its Hub Governing Body (HGB) having full authority, delegated with administrative, technical and financial powers and will be assisted by TIH Advisory Council for the smooth function of the TIH. The HGB headed by the Director, IIT (ISM) Dhanbad as the permanent Chairman will have functional autonomy to realize the goals and objectives of TIH in Mining. Chairman, HGB will approve and release the funds on the recommendation of TIH Advisory Council. Figure 9.1 provides the organogram of the TIH. The HGB will have representations from Academic, Industry and DST with Director, IIT (ISM) as the Chairman of the HGB and Project Director as ex-officio Member-Secretary of the TIH.

Structure of Hub Governing Body:

Director, IIT (ISM) Dhanbad	Chairman
Academic representatives including Project Coordinators	Members
Industry representatives	Members
Mission Director (or representative), Mission Office, DST	Member
Project Director, TIH	Member – Secretary

TIH Executive Council will be chaired by Project Director with the following Structure:
Structure of TIH Executive Council

1. Project Director	Chairperson
2. Academic Experts (Domain Specific)	Member
3. Industry Experts (Domain Specific)	Member
4. CEO	Member Secretary

9.1.1 Technology Management Unit (TMU)

The implementation of the TIH activities will be made through a section 8 company, TexMin under the leadership of the **Board of Directors of TexMin Foundation. The Hub Governing Body (HGB) of this Hub will guide and monitor the activities of the TexMin as per the mandate of DST**. TMU will be headed by the Project Director and will be supported by a full-time CEO and sectional heads (CTO, CIO, and CBDO) in each vertical of the TIH as shown in the organogram at figure 9.1. The board of Directors will be empowered and may delegate powers to Project Director and CEO to approve and sanction funds for carrying out DST mandated activities of TexMin Foundation in accordance with the company law.

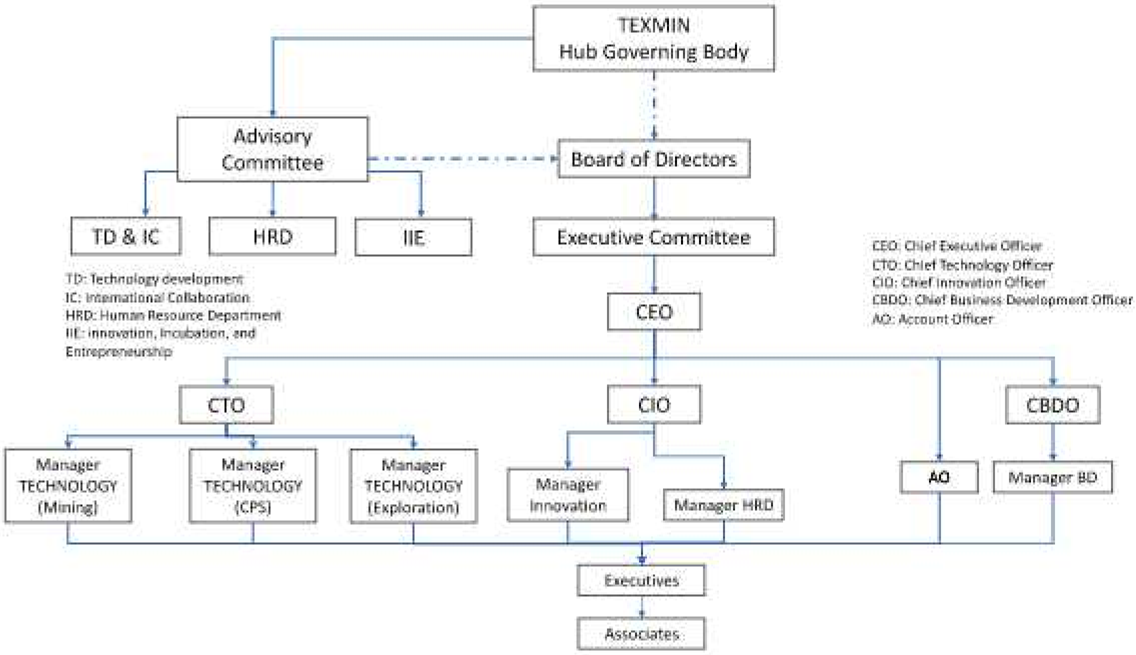


Fig. 9.1: Organogram of the TIH

The major functions of the TMU would be:

(i) To work as the nodal agency of the Government of India for ICPS Mission and to coordinate with all the stakeholders.

(ii) Selecting components and activities included in the TIH from time to time and preparing annual action plans.

(iii) Developing and fine-tuning the final delivery contents, mechanisms, and performance measurement criterion of each of the components/activity of TIH.

(iv) Developing and finalizing the guidelines & terms and conditions of the grants and various other formats and documents needed for making requests to participate in the project activities, submitting periodic reports, funds utilization statements etc.

(v) Seeking proposals for undertaking the various components and activities selected to be included in the TIH from time to time.

(vi) Monitoring all the aspects of the delivery of the TIH components and activities and ensuring the quality of delivery.

(vii) To ensure effective coordination with implementing agencies together with collection of information pertaining to implementation and progress.

(viii) Overseeing and Management of the TIH funds, preparation of budget statements, utilization and re-appropriation etc.

Under each of the 5 Programmes, there will be sub-missions or components. Implementation of these Programmes will be overseen by Chiefs, who by being part of TMU will ensure synergy and cohesion among the components. The components will cover the complete spectrum of technology life cycle stages on one hand, addressing the development of human resource, skills, entrepreneurship and international linkages on the other.

Figure 9.2 shows the schematic diagram of synergy across the part of the verticals of TIH. Work done under various sub-processes of technology innovation hub will feed into the work of other sub-processes. For example, students awarded fellowships under HRD and skill development sub-process may be assigned work under projects and studies conducted under Technology Development (TD) and CASTLE (COE). International collaboration and innovation and entrepreneurship too will be an integral part of this web of interlocking ideas and work.

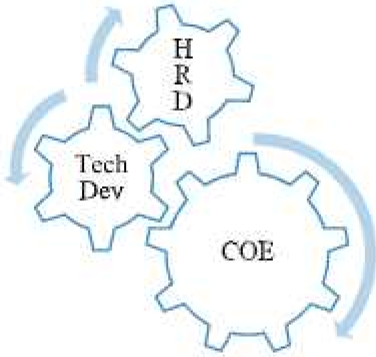


Fig. 9.2 : Synergy across the part of the vertical of TIH

9.1.2 TIH Project Monitoring Committee (TPMC)

For effective evaluation & monitoring of the projects/activities, TIH shall constitute Project Monitoring Committee (TPMC). The members of the TPMC would be drawn from stakeholders, such as Government, academia, research institutions, end-users organizations and industry. The TPMC would meet as and when required, at least once in a year. The broad functions of TPMC would be to review and monitor the various activities of TIH for achieving desirable goals and deliverables.

9.1.3 Human Resources at TMU

The roles and responsibility of Human Resources at TMU are listed in Table 9.1

Table 9.1: The roles and responsibility of HGB, TAC and PD/EC

Designation	Roles and Responsibilities
Hub Governing Body	☐ Overall supervision, control, directions and mid-course correction in the implementation of Hub. ☐ Monitoring the activities of TexMin ☐ Approving key guidelines for implementation of the Hub. ☐ Providing guidelines for implementation and operating the Hub..
TIH Advisory Committee (TAC)	☐ Brainchild for facilitating research, technology development, skill development and collaboration through TIH in various functional areas of mining ☐ Facilitating synergies between various sub-processes in TIH ☐ Monitoring progress in key performance indicators of various initiatives taken under TIH ☐ Suggesting mid-courses correction for various initiatives, if needed ☐ Monitoring adherence to timeline of various projects and TIH initiatives ☐ Monitoring utilization of funds and auditing of financial transactions ☐ Advising Project Director in the effective and efficient functioning of TIH

Project Director / TIH Executive Committee (EC)	□ Providing leadership to the initiatives for sub-domains of TIH □ Developing, designing and implementation of various schemes in accordance with the TIH objectives including the fund management. □ Selecting components and activities included in the TIH from time to time and preparing annual action plans. □ Developing and fine-tuning the final delivery contents, mechanisms and performance measurement criterion of each of the components/activity of TIH. □ Developing and finalizing the guidelines & terms and conditions of the grants and various other formats and documents needed for making requests to participate in the project activities, submitting periodic reports, funds utilization statements etc. □ Seeking proposals for undertaking the various components and activities selected to be included in the TIH from time to time. □ Monitoring all the aspects of the delivery of the TIH components and activities and ensuring the quality of delivery in time. □ Ensuring effective coordination with implementing agencies and collection of information pertaining to implementation and progress. □ Overseeing and Management of the TIH funds, preparation of budget statements, utilization and re-appropriation etc.

The Human Resources in TIH in terms of Number of positions, Eligibility Criteria, Remuneration (Tentative) etc. are listed in Table 9.2.

Table 9.2: Positions and eligibility criteria etc. of Human Resources at TMU

Chief Executive Officer (CEO)

Job Description	□ Chief Executive of the company will be responsible for effective implementation of the TIH activities through TexMin Foundation. □ CEO will be responsible for the following: o Developing, designing and implementation of various schemes in accordance with the TIH objectives including the fund management. o Coordinating among the host institute i.e., IIT (ISM), the HGB and TexMin Foundation (the company). o Providing continued support to faculty, students and research collaborators for their day-to-day research requirements and facility developments including their management. o Planning and executing events related to research and startup funding, investments, workshops etc. o Interacting with outside collaborators for promoting the hub activities, focusing on research translation and commercialization activities, generating funds for making the hub self-sustainable. o Monitoring and implementation of statutory norms and legal compliance of the hub. o Building and nurturing innovation and start-up ecosystem. □ CEO will be assisted by a dedicated team of professionals in the company and will report to the Project Director of TIH.
Essential Qualifications	□ First Class Bachelor's degree in Engineering/Technology preferably in Mining/CSE/Electronics/Mechanical/Mining Machinery from a leading engineering

	institute (preferably from IITs/similar institutions). ❑ First class Master's degree in Business Administration (MBA) or Engineering from recognized university/institute of repute with good track record (preferably from IIMs/ IITs/similar institutions). ❑ At least 08 years of working experience in technology business sectors for technology development, commercialization, and implementation.
Essential Experience	❑At least 08 years of working experience in Technology Business development sector.
Desirable Profile	❑ International degree and work experience shall be added advantage. ❑ Prior experience in translational research work into product development and deployment preferably in the areas of Industry 4.0 applicable to Exploration and Mining. ❑ Good understanding of Industry – Academia ecosystem. ❑ A successful senior level innovative executive looking for a change for contributing to the mission of Atmanirbhar Bharat. ❑ Effective communication, inter-disciplinary skills, Collaboration/Partnership, Organizational Development and Planning. ❑ Commanding respect, ability to interact comfortably with eminent and senior academicians, professionals, students, collaborators, and other stakeholders. ❑ Should be willing to travel extensively.
Maximum Age limit	50 years
Salary	Rs. 1,50,000-2,00,000 per month with 3-5% increment based on performance.

Chief Innovation Officer (CIO)

Job Description	CIO of TexMin will be responsible for the following: ❑ Building nurturing innovation and start-up ecosystem. ❑ Identifying opportunities for providing capacity building, training and financial support to promising talent and start-ups ❑ Facilitate new initiatives for incubation service offerings to entrepreneurs and start-ups. ❑ Interacting with outside collaborators for promoting the Innovation & Entrepreneurial activities, focusing on commercialization of technologies and processes developed by start-ups. ❑ Planning and organizing symposiums, workshops, hackathons, boot camps, Ideation challenge, grand challenges etc. ❑ Facilitating identification and selection of suitable students/candidates for various fellowships, sponsorships and grants under TIH ❑ Facilitating liaisons between academia and industry for curriculum development, trainings etc. ❑ Undertaking documentation for preparation of various reports ❑ Putting in appropriate project management systems for various projects ❑ Maintain account of inflows and outflows in various projects ❑ Executive Director will report to the CEO of TexMin/Project Director
Essential Qualification	❑ First Class undergraduate Engineering/Technology degree preferably in Mining/CSE/Electronics/Mechanical/Electrical Engg. from a leading engineering institute. ❑ Master's degree in Engineering/Technology from recognized university/institute of repute with good track record (preferably from IITs/similar institutions).

	☐ At least 8 years of working experience in technology business sectors in Incubation, and entrepreneurship related activities.
Desirable Profile	☐ Experience in entrepreneurship promotion, and commercialization ☐ Good understanding of Industry – Academia ecosystem ☐ A successful senior level innovative executive looking for a change for contributing to the mission of Atmnribhar Bharat. ☐ Effective communication, inter-disciplinary skills, Collaboration/Partnership, Organizational Development and Planning. ☐ Commanding respect, ability to interact comfortably with eminent and senior academicians, professionals, students, collaborators, and other stakeholders. ☐ Should be willing to travel extensively. ☐ Good at multitasking and working with diverse teams
Age limit	Preferably below 50 years
Salary	Consolidated pay of INR 15 - 18 Lakhs per year. There may be performance link payment.

Chief Technology Officer (CTO)

Job Description	Chief technology officer of TexMin will be responsible for the following: ☐ Identifying experts and collaborators and facilitating research towards technology development ☐ Putting in appropriate project management systems for various projects ☐ Maintain account of inflows and outflows in various projects ☐ Assisting CEO and residential experts for success of initiatives under TIH ☐ Developing linkages with R&D institutions, industry, technology business incubators, international institutions, MMU /ministries, other centres of excellence ☐ Working with residential experts and CEO to identify opportunities for domain-specific research, translational research, innovation, entrepreneurship development and capacity building ☐ Preparing detailed timelines for various activities to be undertaken in various years CTO will report to the CEO of TexMin
Essential Qualification	☐ First Class undergraduate Engineering/Technology degree preferably in Mining/CSE/Electronics OR MSc Tech in Applied Geophysics / Applied Geology from a leading engineering institute. ☐ Master's degree in Engineering/Technology from recognized university/institute of repute with good track record (preferably from IITs/similar institutions). ☐ At least **8** years of working experience in **technology business sectors for technology development, commercialization and implementation.**
Desirable Profile	☐ Prior experience in translational research work into product developments and deployments preferably in the areas of **Industry 4.0** applicable to Exploration and Mining. ☐ Good understanding of Industry – Academia ecosystem ☐ A successful senior level innovative executive looking for a change for contributing to the mission of Atmnribhar Bharat. ☐ Effective communication, inter-disciplinary skills, Collaboration/Partnership, Organizational Development and Planning.

	☐ Commanding respect, ability to interact comfortably with eminent and senior academicians, professionals, students, collaborators, and other stakeholders. ☐ Should be willing to travel extensively.
Age limit	Preferably below 50 years
Salary	☐ Consolidated pay of INR 15 - 18 Lakhs per year (negotiable). There may be also be performance link payment.

Chief Business Development Officer (CBDO)

Job Description	☐Develop a highly scalable outreach strategy and work with teams toward common goals of revenue generation ☐Develop and implement business development strategies and execution plans for assigned business lines ☐Develop and actively maintain relationships with key industry contacts, including current, potential clients, and industry experts ☐Work with marketing manager to identify target markets and develop a strategy to build a list of prospective clients that fit within an ideal client profile ☐Form new partnership programs ☐Develop, monitor and refine Business Development team targets and KPI's, and continually manage team activities to drive results ☐Direct and guide the team to engage in proposal writing, contract negotiation, sales presentations, and support of client relations ☐As a part of the leadership team, participate in formulating and reshaping strategies that govern TexMin's growth, operations and future plans ☐Market update of all the government initiatives and international schemes relevant to Hub's mission
Essential Qualifications	☐ Preferably First-class Graduate in Engineering/ Commerce/ Business Administration/ Economics ☐ MBA in Marketing, Business Development, and related fields from a recognized Institute
Essential Experience	☐At least 8 years of working experience in Technology Business development sector.
Desirable Profile	☐ Experience with the governments and ministries grants and funding is highly preferred ☐ Experience in developing marketing strategies for a diverse audience in multi-functional disciplines ☐ Experience of working with reputed multinational companies, preferably with hands-on international experience ☐ Effective communication, interdisciplinary skills, Collaboration/Partnership, Organizational Development and Planning
Maximum Age limit	50 years
Salary	Rs. 1,25,000-1,50,000 per month with 3-5% increment based on performance.

Manager (Technology)

Job Description	☐ Innovation in electronics & control systems for underground/open cast mines, market research to determine technology field trends, patentability and licensing opportunities ☐ Assisting technical projects and proposals to deliver competitive edge ☐ Draft provisional and non-provisional patent applications in India, USPTO and

	EPO ☐ Implementation of Cyber Physical Systems in mining and Exploration
Essential Qualifications	☐ First class B.E/B.Tech. preferably from a leading institute with a minimum 3 years of relevant experience **OR** First class Master's degree in M.E./M.Tech. from a leading institute with a minimum 2 years of relevant experience ☐ Preference will be given to the candidates having experience in Mining, sensor technology, and its implementation
Essential Experience	☐ Experience in Mining technology and its applications ☐ Experience in Cyber Physical Systems ☐ Knowledge of using software like Primavera & MS Project
Desirable Experience	☐ Having knowledge of IPR and patenting research in the field of mining. ☐ Good at multitasking and working with diverse teams
Maximum Age limit	40 years
Salary	Rs. 50,000-60,000/- per month (consolidated) with 3-10% increment based on performance

Manager (Innovation)

Job Description	☐ Develop new initiatives for incubation and entrepreneurial service for start-ups under TexMin TBI ☐ Planning and executing events related to innovations, start-up funding, boot camps, hackathons, workshops etc. ☐ Collaboration with the external source for funding, mentoring, and promoting the Innovation & Entrepreneurial activities ☐ Commercialization of technologies through various sources. ☐ To facilitate TexMin TBI with state of art R&D environment for the start-ups and existing entrepreneurs ☐ Planning and organizing overall development of the company. ☐ Facilitating identification and selection of suitable ideas for various fellowships, sponsorships, and grants under TIH ☐ Building nurturing innovation and start-up ecosystem ☐ Identifying opportunities for providing capacity building, training, and financial support to promising talent and start-ups through investors and various govt schemes ☐ Implementing and introducing latest technologies within the company for better outcomes
Essential Qualifications	☐ First Class B.Tech./ BE in Mining/Electronics/ Mechanical/Robotics & Automation/ Computer Science/ Mechatronics degree, preferably from a leading institute OR ☐ First Class Master's degree in Engineering/Technology from a leading institute. ☐ Preference will be given to the candidates having experience and expertise in Innovation, Product Development, Start-ups, and CPS Technologies.
Essential Experience	☐ At least 3 years of working experience in technology business sectors in Innovation, incubation, and entrepreneurship related activities. ☐ Having experience in such Technology Hub or Research Park for overall technological development.
Desirable Experience	☐ Expertise in CPS Technologies like IoT, Robotics, Automation, Cloud, and Sensor Technologies. ☐ Having innovative mind-set looking for a change for contributing to the mission

	of Atmanirbhar Bharat. □ Effective communication, inter-disciplinary skills, Collaboration/Partnership, Organizational Development and Planning. □ Commanding respect, ability to interact comfortably with eminent and senior academicians, professionals, students, collaborators, and other stakeholders. □ Good at multitasking and working with diverse teams
Maximum Age limit	45 years
Salary	Rs. 50,000-60,000/- per month (consolidated) with 3-10% increment based on performance

Account Executive

Job Description	To perform various accounting, budgeting, finance and auditing. The Account Executive will require to undertake a variety of activities in the office ranging from filing audit and account related works. The Account Executive will have the ability to work diligently to help maintain smooth accounting operations. You must be reliable and hardworking with great accounting skills. The ideal candidate will also be familiar with GFR, GST, 80G and other tax related work.
Responsibility	□ Maintain accounts and records so they remain updated and easily accessible. □ Undertake finance tasks and issue invoices, checks etc. □ Assist in office management and organization procedures. □ Perform auditing and finance duties as assigned.
Essential Qualification	□ CA/ICWA
Desirable Experience	□ **Proven experience of minimum 3 years** as accountant or other financial position □ Familiarity with office procedures and basic accounting principles □ Working knowledge of GST Portal and Tax related work. □ Very good knowledge of MS Office and Accounting softwares □ Excellent communication skills □ Very good organizational and multi-tasking abilities
Maximum Age limit	50 years
Salary	Rs. 40,000/- per month plus 5% increment per year (consolidated)

Executive (Business Development)

Job Description	□Assess and evaluate mining/mineral exploration market growth and revenue potential □Develop and manage relationships with key stakeholders to promote market outreach and business development □Develop and implement new ideas that will achieve team and organization-wide goals □Develop new relationships in an effort to grow business and help organization expand □Conduct face to face meetings including presentations, webinars and product demonstrations □Support funding opportunities and formalizes business development plans and presentations □Responsible for ensuring delivery timelines and adherence to customer quality and standards and customer relationship management
Essential Qualification & Experience	□First class Bachelor's degree in Engineering from a leading institute with minimum 3 years of experience in technology sector business development **OR** □First class Master's degree in Business Administration/ Economics/Geo-

	informatics from a leading institute with minimum 2 years of experience in technology sector business development ☐ Preference will be given to the candidates having experience in working with international clients
Desirable Profile	☐ Experience working with institutions and other external partners to create longstanding relationship ☐ Demonstrated knowledge of academic and business relations through taking ownership and resolving each concern or problem as appropriate, exhibiting professionalism and expertise in every interaction ☐ Demonstrated knowledge of consulting methods, techniques, and practices ☐ Experience in a sales, proposals or procurement environment is an asset ☐ Experience in dealing with PSUs ☐ Excellent customer service focus with the ability to quickly build strong working relationships with clients, business partners, and other colleagues
Maximum Age limit	40 years
Salary	Rs. 40,000-45000/- per month (consolidated) with 3-10% increment based on performance

Executive (Operations)

Job Description	☐ Manage various schemes in accordance with the TIH objectives in consultation with the senior management ☐ Monitor project management, content writing, preparing newsletters, and data management ☐ Preparing smooth office operation, designing contents for reports, blogs etc. ☐ Social Media marketing – cross platform awareness – FB, Insta, Koo, YouTube, etc.
Essential Qualifications	☐ First class Graduate in Arts/Science/Commerce from recognized institute. ☐ First class PG in Arts/Science/Commerce from recognized institute.
Essential Experience	☐ Minimum 3-year Experience in Operational and management skills
Desirable Profile	☐ Skilled in effective communication, building organizational development. ☐ Expertise in MS Office and fluent in English
Maximum Age limit	40 years
Salary	Rs. 40,000-45,000/- per month (consolidated) with 3-10% increment based on performance

Associate (Marketing)

Job Description	☐ Conduct market research and identify new opportunities ☐ Writing detailed technical documentation and support CBDO in preparing proposals ☐ Assist with drafting presentations, reference material, and other documents as required ☐ Form new client relationships and strengthen existing client relationships to create new opportunities
Essential Qualifications	☐ First class Bachelor's degree in Engineering from a leading institute with minimum 1 years of experience in technology sector business development **OR** ☐ First class Master's degree in Business Administration/ Economics/Geo-

	informatics from a leading institute
Required Experience	☐ Experienced in Business development for mining, Geospatial Technologies, Exploration, and related areas
Desirable Profile	☐ Demonstrated knowledge of working in global business network ☐ Ability to interact comfortably with students, collaborators, and other stakeholders ☐ Experience of working in client facing positions ☐ Experience of working with govt proposals is added advantage
Maximum Age limit	30 years
Salary	Rs. 25,000-35000/- per month (consolidated) with 3-10% increment based on performance

Associate (IT)

Job Description	☐ To develop/manage online/web portals for activities and related webpages, manage online data and to develop the company's project management system using PHP, MYSQL, Node.js, React, CodeIgniter etc. ☐ To maintain overall IT services in the company.
Essential Qualifications	☐ MCA/M.Sc.(CS)/B.Tech (CSE/IT) with minimum 60% marks from a recognized institution.
Essential Experience	☐ Having at least two (02) years' experience in Software development using CI/AJAX/JavaScripts/CSS/PHP/MySQL/JQuery, Motion UI, any responsive Framework, NodeJS, React etc. in a Govt. Dept/Autonomous Bodies/Private Sector Organization of repute.
Desirable Profile	☐ Skilled in Graphics Designing. ☐ Expertise in MS Office
Maximum Age limit	40 years
Salary	Rs. 35,000 – 40,000 per month (consolidated) with 3-10% increment based on performance.

Depending on further requirements, several other positions such as Account Officers, Research Officers, Executives, and Associates will be hired in TexMin. The qualifications, experiences, and salaries will be at par with other equivalent positions.

9.1.4 Cloud based Technology Platform for the TIH

Towards effective implementation of the activities of TIH in Mining 4.0, third-party Cloud based technology platform will be created. This will have both computational and storage facility, accessible to all projects. It will also have centralized Web Portal for TIH Management which will provide collective information of running status of all the activities under the TIH. Such portal will be a dynamic repository of information on all activities/components, resources and outputs, associated with the Mission. This will be continuously updated for monitoring the progress of the TIH by the TMU. The information will be used for periodic review of the HGB, The information will be shared with all the stakeholders and participants in the mission to ensure synergy. The funding to set up Web portal and its maintenance will be drawn from the TMU.

9.2 Evaluation

TIH, in general, will follow the DST guidelines in evaluation/review and monitoring of projects along with policy of Conflict of Interest.

The Conflict of Interest applies to all the six activities of TIH in particular with Technology Development and with Technology Development and International Collaboration. However, if domestic country requires some other guideline for Policy of Conflict of Interest then that should be followed for foreign PI.

Policy on Conflict of Interest for Reviewer & Committee Member or Applicant or TIH Officer associated/ dealing with the Scheme/ Program of TIH

Issues of Conflicts of Interest and ethics in scientific research and research management have assumed greater prominence, given the larger share of Government funding in the country's R & D scenario. The following policy pertaining to general aspects of Conflicts of Interest and code of ethics, are objective measures that is intended to protect the integrity of the decision-making processes and minimize biasness. The policy aims to sustain transparency, increase accountability in funding mechanisms and provide assurance to the general public that processes followed in award of grants are fair and non-discriminatory. The Policy aims to avoid all forms of bias by following a system that is fair, transparent and free from all influence/ unprejudiced dealings, prior to, during and subsequent to the currency of the programme to be entered into with a view to enable public to abstain from bribing or any corrupt practice in order to secure the award by providing assurance to them that their competitors will also refrain from bribing and other corrupt practice and the decision makers will commit to prevent corruption, in any form, by their officials by following transparent procedures. This will also ensure a global acceptance of the decision-making process adopted by TIH.

Definition of Conflict of Interest

Conflict of Interest means "any interest which could significantly prejudice an individual's objectivity in the decision making process, thereby creating an unfair competitive advantage for the individual or to the organization which he/she represents". The Conflict of Interest also encompasses situations where an individual, in contravention to the accepted norms and ethics, could exploit his/her obligatory duties for personal benefits.

Coverage of the Policy

a) The provisions of the policy shall be followed by persons applying for and receiving funding from TIH, Reviewers of the proposal and Members of Expert Committees and Programme Advisory Committees. The provisions of the policy will also be applicable on all individuals including Officers of TIH connected directly or indirectly or through intermediaries and Committees involved in evaluation of proposals and subsequent decision making process.

b) This policy aims to minimize aspects that may constitute actual Conflict of Interests, apparent Conflict of Interests and potential Conflict of Interests in the funding mechanisms that are presently being operated by TIH. The policy also aims to cover, although not limited to, Conflict of interests that are Financial (gains from the outcomes of the proposal or award), Personal (association of relative / Family members) and Institutional (Colleagues, Collaborators, Employer, persons associated in a professional career of an individual such as Ph.D. supervisor etc.)

Specifications as to what constitutes Conflict of Interest

Any of the following specifications (non-exhaustive list) imply Conflict of Interest if,

(i) Due to any reason by which the Reviewer/Committee Member cannot deliver fair and objective assessment of the proposal.

(ii) The applicant is a directly relative# or family member (including but not limited to spouse, child, sibling, parent) or personal friend of the individual involved in the decision making process or alternatively, if any relative of an Officer directly involved in any decision making process / has influenced interest/ stake in the applicant's form etc..

(iii) The applicant for the grant/award is an employee or employer of an individual involved in the process as a Reviewer or Committee Member; or if the applicant to the grant/award has had an employer-employee relationship in the past three years with that individual.

(iv) The applicant to the grant/award belongs to the same Department as that of the Reviewer/Committee Member.

(v) The Reviewer/Committee Member is a Head of an Organization from where the applicant is employed.

(vi) The Reviewer /Committee Member is or was, associated in the professional career of the applicant (such as Ph.D. supervisor, Mentor, present Collaborator etc.)

(vii) The Reviewer/Committee Member is involved in the preparation of the research proposal submitted by the applicant.

(viii) The applicant has joint research publications with the Reviewer/Committee Member in the last three years.

(ix) The applicant/Reviewer/Committee Member, in contravention to the accepted norms and ethics followed in scientific research has a direct/indirect financial interest in the outcomes of the proposal.

(x) The Reviewer/Committee Member stands to gain personally should the submitted proposal be accepted or rejected.

Regulation

The TIH shall strive to avoid conflict of interest in its funding mechanisms to the maximum extent possible. Self-regulatory mode is however recommended for stake holders involved in scientific research and research management, on issues pertaining to Conflict of Interest and scientific ethics. Any disclosure pertaining to the same must be made voluntarily by the applicant/Reviewer/Committee Member.

Confidentiality

The Reviewers and the Members of the Committee shall safeguard the confidentiality of all discussions and decisions taken during the process and shall refrain from discussing the same with any applicant or a third party, unless the Committee recommends otherwise and records for doing so.

9.3 Code of Conduct

A. **To be followed by Reviewers/Committee Members**

(a) All reviewers shall submit a conflict of interest statement, declaring the presence or absence of any form of conflict of interest.

(b) The reviewers shall refrain from evaluating the proposals if the conflict of interest is established or if it is apparent.

(c) All discussions and decisions pertaining to conflict of interest shall be recorded in the minutes of the meeting.

(d) The Chairman of the Committee shall decide on all aspects pertaining to conflict of interests.

(e) The Chairman of the Committee shall request that all members disclose if they have any conflict of interest in the items of the agenda scheduled for discussion.

(f) The Committee Members shall refrain from participating in the decision making process and leave the room with respect to the specific item where the conflict of interest is established or is apparent.

(g) If the Chairman himself/herself has conflict of interest, the Committee may choose a Chairman from among the remaining members, and the decision shall be made in consultation with Member Secretary of the Committee.

(h) It is expected that a Committee member including the Chair-person will not seek funding from a Committee in which he/she is a member. If any member applies for grant, such proposals will be evaluated separately outside the Committee in which he/she is a member.

B. To be followed by the Applicant to the Grant/Award

(a) The applicant must refrain from suggesting referees with potential Conflict of Interest that may arise due to the factors mentioned in the specifications described above in Point No. 2.

(b) The applicant may mention the names of individuals to whom the submitted proposal should not be sent for refereeing, clearly indicating the reasons for the same.

C. To be followed by the Officers dealing with Programs in TIH

While it is mandatory for the program officers to maintain confidentiality as detailed in point no. 6 above, they should declare, in advance, if they are dealing with grant applications of a relative or family member (including but not limited to spouse, child, sibling, parent) or thesis/ post-doctoral mentor or stands to benefit financially if the applicant proposal is funded. In such cases, TIH will allot the grant applications to the other program officer.

Sanction for violation

a. For a) Reviewers / Committee Members and b) Applicant

Any breach of the code of conduct will invite action as decided by the Committee.

b. For Officers dealing with Program in TIH

Any breach of the code of conduct will invite action under present provision of CCS (conduct Rules), 1964.

Final Appellate authority:

Project Director, TIH / Chairman, HGB shall be the appellate authority in issues pertaining to conflict of interest and issues concerning the decision making process. The decision of **Director, TIH** in these issues shall be final and binding.

Call for Proposals projects aim to impact the society by the translation of knowledge into technology (product or process). The two major activities of the hub which would be inviting proposals for research and development are (a) Technology Development and (b) International Collaborations.

The Technology Development is classified into three categories depending upon Technology Readiness Level (TRL):

1. Expert-driven new knowledge generation /Discovery (TRL 1-3)
2. Development of products/prototypes from existing knowledge (TRL 4-6)
3. Technology /product delivery in specific sectors, i.e., projects that involve knowledge generation and also conversion to technology, demonstration of full working technology (by experts or teams) (TRL 7-10).

International Collaborations aims to establish and strengthen international collaborative research for cross-fertilization of ideas.

The projects based on Expert-driven new knowledge generation /Discovery (TRL 1-3) and International Collaborations would primarily be governed by the conventional schemes of DST such as Core Research Grant. In contrast, the IMPRINT Guidelines of DST would primarily govern the projects leading to TRL 4-6 and TRL 7-10.

Broad General Guidelines for Technology Development Projects

- The scheme provides research support to an individual researcher or a group of researchers working in collaborative mode. TexMin may also identify such groups and carry out in-house Technology Development through engagement of such a group.
- Proposals from applicants belonging to National Laboratories/Research Institutions, in-line with the mandated research work of the lab/institution can also be entertained in TexMin.
- Applicants [Principal Investigator (PI) and Co-Principal Investigator(s) (Co-PI(s))] should be Indian citizens. Foreign nationals (including OCI and NRI) are also eligible to apply.
- **Plagiarism:** Proposals submitted must be original in ideation and content. Applicants are requested to pre-check their proposals for plagiarism before uploading. Plagiarism in any form will not be acceptable. All submitted proposals would be subjected to a third-party similarity check and proposals are liable to be rejected if found plagiarised. Any text taken verbatim from other source needs to be identified using quotation marks and proper reference. Proposals found containing plagiarised content will be rejected. Additionally, the Committees may carry out plagiarism checks and ask the proposers to modify / or rebut the similarities that may arise in such checks. In the event of the latter being not submitted, the proposal shall be deleted by the PAC

- Intellectual Property (IP) generated under these projects shall be governed under the terms and conditions laid in tri-partite agreement between HI, TexMin and DST.
- The research grant is provided for equipment, manpower, consumables, travel and contingency. "Overheads" may also be provided to the implementing institution as per prevailing norms of the National Mission-Interdisciplinary Cyber-Physical System.
- **Cyber-physical Social Responsibility (CpSR):** TIH has adopted **Cyber-physical Social Responsibility (CpSR)** Policy to imbibe a culture of social commitment among TIH Grantees. The policy intends to effectively utilize scientific infrastructure and expertise of TIH grantees to benefit other stakeholders especially the less-endowed researchers and the society. CpSR activities need to be chosen after approval and depending on the activities chosen additional budget would be provided under separate head to carry out the chosen activities. TIH Grantees need to undertake the proposed CpSR activities during their project period. The expenditure will be met from the miscellaneous head of the Project. **For International Projects CpSR should be conducted during the visit of Foreign PI.**
- The projects for above TRL 4 would be in collaboration with Industry Partners. The industry partners would be providing minimum support in the form of kind.
- Duration of Project:
    - Three Years for Expert-driven new knowledge generation /Discovery (TRL 1-3) and International Collaboration
    - Five Years for Development of products /prototypes from existing knowledge (by experts or teams) (TRL 4-6) and Technology /product delivery in specific sectors, i.e., projects that involve knowledge generation and also conversion to technology, demonstration of full working technology (by experts or teams) (TRL 7-10), 3 Year/Five Years

Some Specific Guidelines for International Collaboration

With existing mechanisms of DST (IC Divisions), International Collaborations dedicated to Cyber-Physical Systems will be built at the levels of researchers and thematic domain areas to leverage international best practices in India. HRD will be the one of the main focus in such activities. Projects will be governed by the norms and rules prescribed under the S&T Agreements with the particular country. DST S&T agreement in general would be followed.

Facilities Developed

All the facilities developed in TIH will be the property of TIH. After the completion of the project the facilities developed would be the property of the TIH. During the execution of the project the equipment lying idle may be used on rental basis.

HRD& Skill Development

Applications will be invited across the country for various fellowship under the scheme. The broad evaluation criteria would be based on the academics and a one-page focused research projects and push their intellectual abilities beyond those driven by the classroom. The research proposal would focus on the application of CPS for technology innovation in mining. The applicants needs to choose one mentor from the available domain experts in TIH.

The evaluation process will consider:

1. Compliance to the formal criteria
2. Scientific quality and originality of the project idea
3. Feasibility of the project
4. Innovative potential for industrial application (prospects for commercial success / commercial exploitability). It will help in deciding the support for Development fund under various activities under HRD & Skill Development.

After initial screening specific committees for different fellowships would be at scrutinize the application. The recommendation would of it would be put up to the Director, TIH for approval.

CHANAKYA-GI (Graduate Internships)

Guidelines: The candidate selection is based on the CGPA, publications, awards, research proposal, the student's college and letters of recommendation.

Following minimum CGPA criterion will apply a. CGPA ≥ 7.5 for IITs/IISc b. CGPA ≥ 8.0 for NITs/ IISERs/ NISER/IIEST c. CGPA ≥ 8.5 for students of other institutes.

Students with backlog and/or disciplinary action are not eligible.

The recipients may stay in the Campus of IIT (ISM) during summer and winter vacations of the Institute. The expenses for the stay may be borne by the candidates as applicable to the students and project fellows of the institute.

CHANAKYA Post-Graduation Fellowships (CHANAKYA-PGF) (24 months)

This is primarily open for students taking admission in the PG programme initiated or upgraded with the support of TIH.

The candidates would be governed by the IIT (ISM) rules viz., eligibility criteria, disciplinary, continuation of fellowship, termination etc. applicable for other M Tech Programmes.

Doctoral Fellowships (CHANAKYA-DF) (36 months extendable by another 12 months)

The candidates would be governed by the IIT (ISM) rules viz., eligibility criteria, disciplinary, continuation of fellowship, termination etc. applicable for other PhD Programmes.

CHANAKYA Faculty Fellowships (CHANAKYA-FF) (Tenure track of 3 years term)/ CHANAKYA Chair Professors (CHANAKYA-CP) (3 year term)

The application received will be scrutinised and evaluated by the TIH Faculty Screening Committee. The same would be put up to the TIH Central Faculty Screening Committee for further recommendation, The short listed candidates application will be further reviewed by two to three eminent academicians at country level, Once their recommendation is received the candidates would appear for interview. The interview committee would be chaired by Director, TIH.

The selected candidates will be a domain expert for TIH and would be governed by the existing rules and guidelines of IIT (ISM) applicable for faculty members of the Institute.

9.4 Legal Framework

9.4.1 Dispute Resolution

Any disagreement/ difference of opinion/ dispute between the various stakeholders regarding the activities undertaken by the TIH shall be resolved by mutual consultation, under the leadership of the Chairman, TEXMIN HUB or their nominee. For any dispute unresolved for a period not exceeding thirty (30) days, reference shall be made under the provisions of the Arbitration and Conciliation Act, 1996 or any statutory modification / re-enactment thereof and rules made there under. The place of arbitration shall be Dhanbad and the proceedings shall be conducted in English or Hindi language. The award of the arbitrator shall be binding on all stakeholders.

9.4.2 Governing Law

The TIH policies shall be governed by and construed in accordance with the Laws of India and the Parties submit to the exclusive jurisdiction of the Competent Courts of India.

9.4.3 Modification

TexMin reserves the right to amend and modify this DPR at any time. Any such updates shall be consulted with DST/HGB/BOD and shall be governed by the tripartite agreement and the Companies Act 2013.

10 CONCLUSION

India is endowed with great mineral wealth. Properly tapped, it can help propel India's GDP growth, generate additional employment, and mitigate fiscal and forex challenges. The TIH plays a vital role in ensuring that the industry reaches its high potential. To ensure some of ambitious government initiatives like "Make in India", "Start-Up-India', "Skill Development", "Digital India", "Stand-Up India", and "National Skill Quality Frame work" becomes a reality, it is imperative to grow the mining sector. Further, it also helps to meet the ever-growing demand of the downstream industries such as manufacturing and infrastructure.

The DPR is in line with the sub-missions or, programmes under the NM-ICPS which includes (i) Technology Development, (ii) HRD & Skill Development, (iii) Innovation, Entrepreneurship & Start-up Ecosystem, and (iv) International Collaboration.

The problems to be tackled at TIH in Mining 4.0 have been formulated in consultation with the stakeholders, government vision documents, recommendations of various conferences, strategic meetings of various committees, recent literatures, white papers etc.

CPS technologies in Mining 4.0 will help in eliminating the age old drudgery of mining by improving the working condition and keep the work force away from the hazardous work place.

Traditionally, mining sector is dominated by male because of its requirement for physical strength in a harsh working environment but with introduction in CPS technologies there would be equal opportunity for other gender.

The NM-ICPS focusses on creating an army of Indians who can implement CPS technologies in Mining 4.0 with the Chanakya Scheme at various levels for students in undergraduate or above degrees. In addition, for building synergies among all stakeholders in our scientific knowledge community and also about developing linkages between science and society, Cyberphysical Social Responsibility (CpSR) in line with Scientific Social Responsibility of DST has been mandated in all Technology Development and International Collaboration Projects.

The strategy developed for the TIH in Mining and the programmes/ projects proposed under five verticals of NM-ICPS and its cost has been estimated to be Rs. 110.00 Crores.

The TIH will become self-sustainable after successful completion of mandated objectives within 5 years of its establishment.

LIST OF TABLES

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80. https://www.gsi.gov.in/webcenter/portal/OCBIS/pageaboutus/pagemissions?_adf.ctrl-state=64evzuame_26&_afrLoop=26832283831397860#!%40%40%3F_afrLoop%3D26832283831397860%26_adf.ctrl-state%3D64evzuame_30.

ANNEXURES

Annexure-I

Response of Stakeholders on the draft problems defined in the DPR for Exploration & Mining

Name	Are the identified problems relevant?	Is the scope of the work clearly defined for the identified problems	If No, then please give your inputs by adding to/modifying the problem (in 1000 characters)	Can the proposed problems result in economically viable products?	Can these products be easily deployed?	Please mention two industry partners (National/ International)	Please mention two academic partners (National/ International)	Would you like to be associated with the TIH?	If yes, then please mention your role in the TIH
Dr V M Tiwari, Director, NGRI	Yes	No		Yes	Yes	NGRI		Yes	
Prof B B Bhattacharya, FNAE	Yes	No	The crosswell project is very broad, focus it to seismic or radio or radar or other methods. The UAV project is also very broad. This is tricky as the vehicle might be different for different methods (magnetics is light; electromagnetics heavy). If you work with a specific partner they may limit your options and flexibility. Spend time defining the scope. Do not spread yourself to broad. Pick a specific geological problem or area and focus on the geological, geophysical and drilling problems of that area.	Yes	Yes		CET, University of Western Australia, MERC Laurentian University	Yes	advisor
Prof Andre Revil, Université Savoie Mont-Blanc EDYTEM, France	Yes	Yes	No Suggestion	Yes	Yes		EDYTEM USMB A. Revil	Yes	Induced polarization technology (geophysics) for

									mineral localization and discrimination
Prof V P Dimri, Ex-Director, NGRI	Yes	Yes	No Suggestion	Yes	Yes			Yes	
Prof Michael Dentith, University of Western Australia	Yes	No	The problems are only defined in a very general sense. I think what is described is valid. In my view there should be greater emphasis on facilitation of collecting new geoscience data - there are vast areas to be explored. This is implied by the UAV mentioned of course but what is needed is a vehicle with significant range/endurance.	Yes	Yes		There are numerous research centres in universities around the world. there are at least 3 in Australia - I am part of the Centre for Exploration Targeting at the Univ of Western Australia. Internationally I would recommend the Colorado School of Mines and the MetalEarth initiative at Laurentian Univ in Ontario, Canada.	Yes	I am happy to be involved in an advisory capacity - I have 30 yrs expereince in geophysical research related to mineral exploration
Terry Barclay, Member Geological Society of Australia and the AUSIMM - Aust.	No	Yes	The key mining countries in the world that are discovering orebodies annually have ready access to exploration ground. This ground comes with a number of responsibilities such as: - tenure time frame with Exploration Licences covering 100 sq km. Multiple Licences may be	No	No	AMD were undertaking some very interesting exploration programs for uranium very similar to what has been undertaken in Australia. There are a	Universities in Perth and Brisbane are the best Australian candidates. I would expect there are several candidates in Canada.	Yes	Able to provide international experience in mineral exploration for a wide range of commodities. Furthermore, having spent +10 years working in India I have a very

			granted at any one time. - expenditure commitments - selected drill core to be sent to a State storage centre - strict reporting time frames - environmental commitments - compulsory commitments to provide ongoing communication to the land owners In all of the key mining countries there are strong links between the State agencies and the Mining Industry. The reason for this linkage is that the Mining Companies, in Australia at least, generated $Aus290b in sales in 2019 and paid SAus31b in taxes and royalties. In addition, the Mining Industry being rural based, also employs and supports a wide range communities and their inhabitants. Universities and Research Centres also provide high quality students and undertake State of the Art research projects that enhance exploration discovery, mining efficiency			Government Agencies such as are in Australia and Canada that may be able to provide assistance etc.			comprehensive knowledge of Indian prospectivity for a wide range of mineral commodities.

			and metal recovery.						
Dr. S. Ravi. Director (G), RTI-SR. GSITI, Hyderabad	Yes	Yes	Prioritization of mineral commodities is governed by various factor like, countries resource position, import cost, metal/ ore value trends, industrial demand, defence demand, geological scarcity, Production, Reserves to resource ratio, recycling rate, availability of substitutes, governance, countries relationship with producing/ reserve holding countries, availability of technology for utilizing leaner grade ore and many more. The demand-supply in respect of various mineral commodities is dynamic. From the foregoing, it can be stated that the prioritization of exploration depends on the following factors: (i) Mineral potential of the country (ii) Demand and supply scenario (iii) Criticality of a mineral The following mineral commodities also needs to be taken into consideration apart from REE and PGE in the project. (a) There is high import dependency on fertilizer minerals due to its	Yes	Yes	Indo -Australian Resources,Bangalore and Rio Tinto Limited,Australia	Geological Survey of India and Geoscience Australia	Yes	With my 26 years' experience in Mineral Exploration domain spanning field/research/policy aspects I am willing to contribute both in research &technical arena and policy areas.

			geological shortage in the country as well as high demand and need for the agronomy. (b) The critical commodities especially high import of gold to meet the domestic consumption and complete import dependency of PGE metal also needs a due attention. (c) India is world's largest exporter of cut and polished diamonds, which is mostly met with the import of raw diamonds. To keep the diamond industry alive in the country, exploration of diamondiferous formations needs to be taken up more comprehensively. (d) The basemetals (copper, lead and zinc) are essentially required for almost all industries producing the finished products for consumption in the country. Again, large quantities of copper concentrate is being imported to meet the local demand. Hence, concerted efforts are required for basemetals exploration. (e) As per the criticality studies done by IDSA for the defence requirement, Antimony, Boron, Cobalt,						

			Fluorite, Gallium, Germanium, Lithium, Molybdenum, Nickel, Niobium, Selenium, Tin, Tungsten, indium, beryllium, tantalum, bismuth etc. are strategic commodities (Critical). These occur usually in very low concentrations in rocks and therefore, these mineral commodities need to be explored with modern concepts and tools for possible breakthrough. This would require high investments in sophisticated survey and spatial data management technologies.						
Dr Dinesh Gupta, Director General, GSI, Retd.	Yes	Yes	Huge data with GSI, AMD and other exploring agencies should be brought at one platform and should be freely available to all stakeholders to plan further exploration which can give quantum jump to exploration activities and attract FDI in Mining Sector	Yes	Yes	1. Geological Survey of India 2. Geoscience Australia	NGRI and Geoscience Deptt of University of Adelaide Australia	Yes	Technical member either in hierarchy or board of TIH

Ajay Kumar Singh, Director, DMT Consulting Pvt. Limited	Yes	No	(a) Mineral Discrimination: the concept and philosophy needs to be explained in more generic form (b) Concealed deposits, though not very deep, is another focus area Examples being SK Mines, 2nd load	Yes	Yes	Hindustan Zinc Limited, India DMT GmbH & Co. KG, Essen, Germany	Indian School of Mines, Dhanbad & IIT Kharagpur Tuev Nord Academy, Germany	Yes	Industry collaboration and testing/calibrating the results/tool
Dr. Nabarun Bhattacharyya, CDAC Kolkata	Yes	Yes		Yes	Yes	A number of start-up's and MSME's are associated with CDAC. Appropriate names may be provided later.	1. Jadavpur University, kolkata, India 2. ITMO University, St. Petersburg, Russia	Yes	CDAC is an R&D Organization under Ministry of Electronics & IT (MeitY), Government of India. CDAC pursues R&D in the fields of IoT, AI & ML, Big data analytics etc. and CDAC would like to play the role of R&D partner in all the proposed activities under the TIH.
Prof. Y. P. Chugh, Southern Illinois University, Carbondale	Yes	No	See my comments in a separate e-mail to you.	No	No	Coal India, Singreni Collieries, Australian Coal Industry, Large surface mines in the Western USA	NIOSH and MSHA in the USA; West Virginia University, University of New South Wales, Colorado School of Mines, IIT Kharagpur, IIT-	Yes	I can assist with research program development and implementation. I can also work with faculty as research associate on

							BHU		several projects.
Simit Raval, Program Director - Undergraduate Mining Engineering Degree. Co-Director, Laboratory for Imaging of the Mining Environment (LIME) University of New South Wales	Yes	Yes	There will be a need to further clarify scope and deliverable at each research project level	Yes	Yes	National: Coal India International: METS (Mining Equipment, Technology and Services) Sector	National: IIT Kharagpur International: UNSW Sydney	Yes	Advisory for over wholeTIH and solution provider for targeted critical areas in the technology development
Ashis Dash, CEO, Sustainable Mining Initiative, **FIMI** (Policy Advocacy & Sustainability).	Yes	Yes		Yes	Yes	Tata Steel, Coal India, Rio Tinto	IISc., IIT Madras, MIT	Yes	Support from Industry side
Simon Askey-Doran, General Manager, Business Development-Advisory at RPM Global Holdings Ltd	Yes	Yes		Yes	Yes	RPM Global		Yes.	
Umesh K Mahato, Project Director, Reliance Power	Yes	Yes		Yes	Yes	Relaince Power		Yes	
Sri Sudhanshu Singh . Director , Global	Yes	Yes	They are planning to establish a base India as Innovation Centre in Mining	Yes	Yes	Caterpillar		Yes	

Mining Product Design and Validation at Caterpillar Inc			Equipment at IIT (ISM). Intend to establish small problems to the student						
Shri. Binay Dayal, Director - Technical, Coal India Limited	Yes	Yes	2D/3D Seismic Exploration for Coal. Problems are pertaining to the scope of Coal India. A task force has been formed at CIL for implementing Mining 4.0.	Yes	Yes	Coal India Limited			To carry the joint activities, CIL desires to sign an MoU with IIT (ISM)/TIH.
Vinod Shukla, CEO, PMT InfraScience	Yes	Yes	Detailed mail attached	Yes	Yes	PMT InfraScience		Yes	Industry Collaborator

Annexure II: TIH Advisor/Collaborator/Adjunct Professor

Sl. No	Name	Email	Specialization
1	Dr V M Tiwari, Director, NGRI	director@ngri.res.in	Mineral Exploration
2	Prof B B Bhattacharya, FNAE	bimalism@gmail.com	Mineral Exploration and Petrophysics
3	Prof Andre Revil, Université Savoie Mont-Blanc EDYTEM, France	andre.revil@univ-smb.fr	Mineral Discrimination
4	Prof V P Dimri, Ex-Director, NGRI	vpdimri@gmail.com	Mineral Exploration
5	Prof Michael Dentith, University of Western Australia	michael.dentith@uwa.edu.au	Mineral Exploration, Petrophysics
6	Terry Barclay, member of Geological Society of Australia and the AUSIMM - Aust.	geologist_terry@yahoo.com.au	Mineral Exploration
7	Dr Dinesh Gupta, Director General, GSI, Retd.	dineshguptagsi@yahoo.co.in	Mineral Exploration

8	Ajay Kumar Singh, Director, DMT Consulting Pvt. Limited	AjayKumar.Singh@dmt-group.com	Mineral Exploration
9	Prof. Y. P. Chugh, Southern Illinois University, Carbondale	siu681@siu.edu	Sustainable Mining
10	Simit Raval, Program Director - Undergraduate Mining Engineering Degree. Co Director, Laboratory for Imaging o the Mining Environment (LIME] University of New South Wales	simit@unsw.edu.au	Digital Mining
11	Ashish Dash. Head, Corporate Affairs Vedanta Resources.	ashis001@gmail.com	Sustainable Mining and Policy Framewirk
12	Simon Askey-Doran, Genera Manager, Business Development Advisory at RPMGlobal Holdings Ltd	saskeydoran@rpmglobal.com	Business Development
13	Umesh K Mahato, Project Director, Reliance Power	umesh.mahato@relianceada.com	Mine Operations
14	Sri Sudhanshu Singh. Director Global Mining Product Design and Validation at Caterpillar Inc	sudhanshu.singh8@gmail.com	Automation in Mining Equipment

15	Vinod Shukla, CEO, PMT InfraScience	vinodshukla@pmtpl.com	Sensor Technologies and Artificial Intelligence
16	Sanjeev C Kumar VP- Automation Sandvik Mining and Rock Technology India Pvt Limited	sanjeev.c.kumar@sandvik.com	Mine Automation and Data Analytics
17	Sanjay K Prasad, PhD CTO & Distinguished Engineer Industrial Products (Adjunct Professor, TexMin)	sanprasa@in.ibm.com	Digital technologies in Mines
18	Dr. Nabarun Bhattacharyya Sr. Director & Centre Head CDAC,Kolkata	nabarun.bhattacharya@cdac.in	Sensor technologies
19	Mr. Arun Misra Chief Executive Officer Hindustan Zinc Limited Yashad Bhawan Udaipur - India	arun.misra@vedanta.co.in	Innovative Mining Technologies (Metal)
20	Mr. Binay Dayal Director (Technical) Coal India Limited	dt.cil@coalindia.in	Innovative Mining Technologies (Coal)
21	Dr. S. Ravi Director (Geology) National Centre for Mineral Targeting GSI	s.ravi1@gsi.gov.in	Mineral Exploration
22	Mr. Rajiv Aramadaka India Public Sector Director Global Affairs	Rajiv.armadaka@3ds.com	AR/VR and Digital Technologies

Annexure -III
Collaborator Details

S.No.	Industry	Type	Activities to be covered under Support in Kind
1	PMT InfraScience Pvt. Ltd. 565KA/49, Amrudahibag, Alambagh, Lucknow (UP), India, PIN-226005; Ph. No - 915452220479	Design and Manufacturing of geotechnical sensors	Contribution in Kind: Reducing Risk in mining and civil engineering projects by providing Sensors. (List activities)
2	Nvidia Graphics Pvt Ltd. Nvidia Graphics Pvt Ltd., C1, Jacaranda, A Wing, Manyata Embassy Business Park, Bangalore 560045	Graphic Card Developer	Technical inputs, technical expertise, and research assistance for the proposed collaborative research Activities.
3	Sandvik Mining and Rock Technology India Pvt Limited	Mine Automation	Centre for Mine Automation and Learning
4	Coal India Limited	Mining Technologies	CIL Centre for Innovation and Incubation
5	Dassault Systems India Pvt. Ltd.	Innovative Digital technologies	Dassault Centre (Proposed)
6	Centre for Development of Advanced Computing (C- DAC)	AI and Sensor Technologies	In-kind support for joint development of technologies for mining

PROPOSED BUDGET PLAN & SUSTAINABILITY MODEL FOR TECHNOLOGY INNOVATION HUB (TIH), IIT (ISM) DHANBAD (Rs. Crores)														
1	Total TIH grant requested (5 Years)			Rs. 110.00 Crores					1	Total Spending post incubation				39.13
2	Total expected funding from IRG, Funding Partners and other sources during this incubation period			Rs. 74..50 Crores					2	Total expected funding from IRG, Funding Partners and other sources during this incubation period				52.90
S.No	Items **	Amount (Rs. Crores)							3	Net Surplus /Deficit				13.77
		Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL		Year 6	Year 7	Year 8	Year 9	Year 10	TOTAL
A.	Item-wise Non-Recurring Expenditure													
1	Technology Development	2.5	8.0	5.05	0.6	0.42	16.57		0.63	2.75	3.25	0.00	0.00	6.63
2	HRD and Skill Development	1.27	2.65	0.7	0.4	0.2	5.22		4.25	0.03	0.03	0.03	0.02	4.36
3	Innovation, Entrepreneurship, and Start-ups Ecosystem	0.7	2	1	0	0	3.7		0.22	0.34	0.09	0.09	0.09	0.83
4	International collaborations	1.0	0	0	0	0	1		0.25	0.50	0.50	0.00	0.00	1.25
5	TIH Management Unit	1.53	2.35	1.25	0	0	5.13		0.04	0.04	0.04	0.04	0.04	0.19
	Total A	7.0	15.0	8.0	1.0	0.62	31.62		6.13	4.91	4.66	0.90	0.40	17.00
C.	Operating / Recurring Expenditure													
1	Technology Development	4	12	21.97	3.55	0.25	41.77		0.63	2.38	2.75	0.00	0.00	5.75
3	HRD and Skill Development	1.37	2.9	4.36	2.1	0.95	11.68		0.36	0.63	0.87	0.85	0.64	3.35
4	Innovation, Entrepreneurship, and Start-ups Ecosystem	0.56	2.5	3.92	1.75	3.18	11.91		0.43	1.55	0.79	0.66	0.26	3.69
5	International collaborations	4.0	0	0	0	0	4.0		0.50	1.00	1.00	0.00	0.00	2.50
6	TIH Management Unit	1.07	2.6	4.75	0.6	0	9.02		0.27	0.27	0.27	0.27	0.27	1.35
	Total B	11.0	20.0	35.0	8.0	4.38	78.38		2.93	6.58	6.74	2.53	1.60	20.39
D.	Total Project Grants													
	Total C (A+B)	18.0	35.0	43.0	9.0	5.0	110		9.73	11.80	11.68	3.71	2.20	39.13
E.	Projected Revenue													
1	Consultancy / Testing & Calibration Services /Industrial Projects		2.00	3.00	5.00	7.00	17.00		2.00	2.00	3.00	5.00	7.00	19.00

2	Technology Development & Transfer, Transfer of Processes, Idea, Patents etc.								2.00	3.00	3.00	5.00	5.00	**18.00**
3	Equity in the Start-ups graduating to full-fledged company								0.25	0.50	0.50	0.50	0.50	**2.25**
4	Contributions from Stakeholders, Shareholders etc.			10.00	10.00	10.00	**30.00**							**0.00**
5	R&D Projects			2.00	2.00	2.00	**6.00**		**3.00**	2.00	2.00	2.00	2.00	**11.00**
6	Industrial/Executive Training/Development Programs & Other Capacity Building Programmes			0.40	0.50	0.60	**1.50**			0.40	0.40	0.50	0.60	**1.90**
7	Corporate CSR Funding		5.00	5.00	5.00	5.00	**20.00**		**2.00**	2.00	2.00	2.00	2.00	**10.00**
	Total D		**7.00**	**20.40**	**22.50**	**24.60**	**74.50**		**9.25**	**9.90**	**10.90**	**15.00**	**17.10**	**62.15**
F.	**Projected Surplus/Deficit, if any =(D-B) (considering Revenue Expenses)**	**-11.00**	**-13.00**	**-15.00**	**14.50**	**20.22**	**-4.28**	**Projected Surplus /deficit = D-C (Considering total expenses)**	**-0.48**	**-1.90**	**-0.78**	**11.29**	**14.90**	**23.03**

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