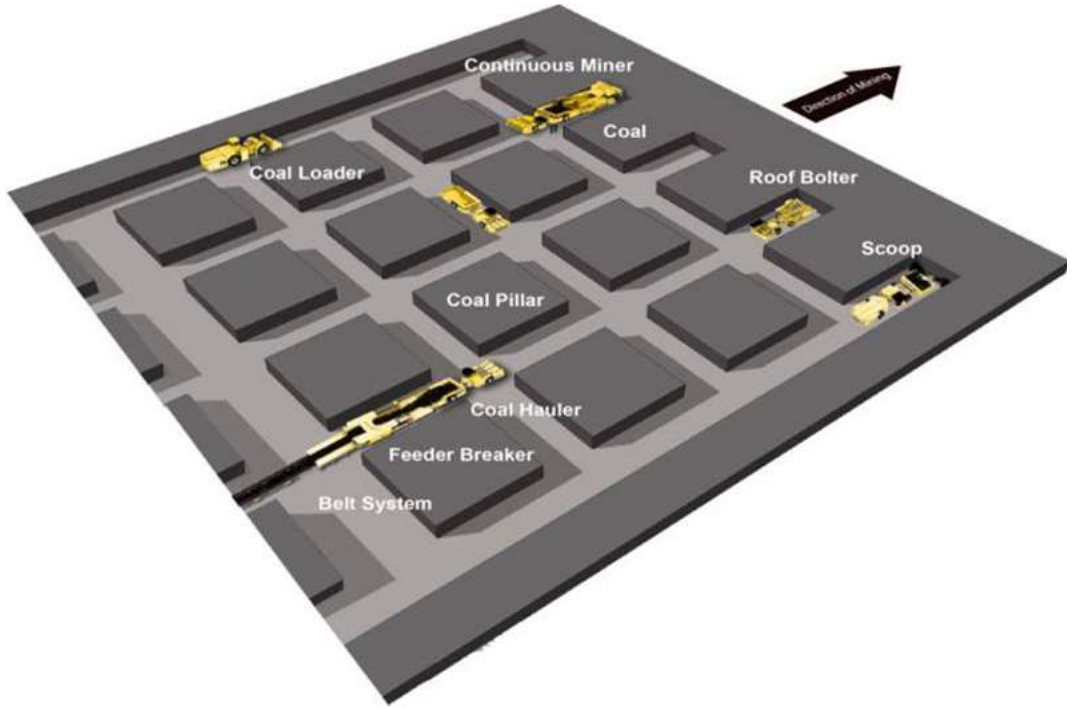
Implementing Mining 4.0 through Cyber Physical Systems (CPS)

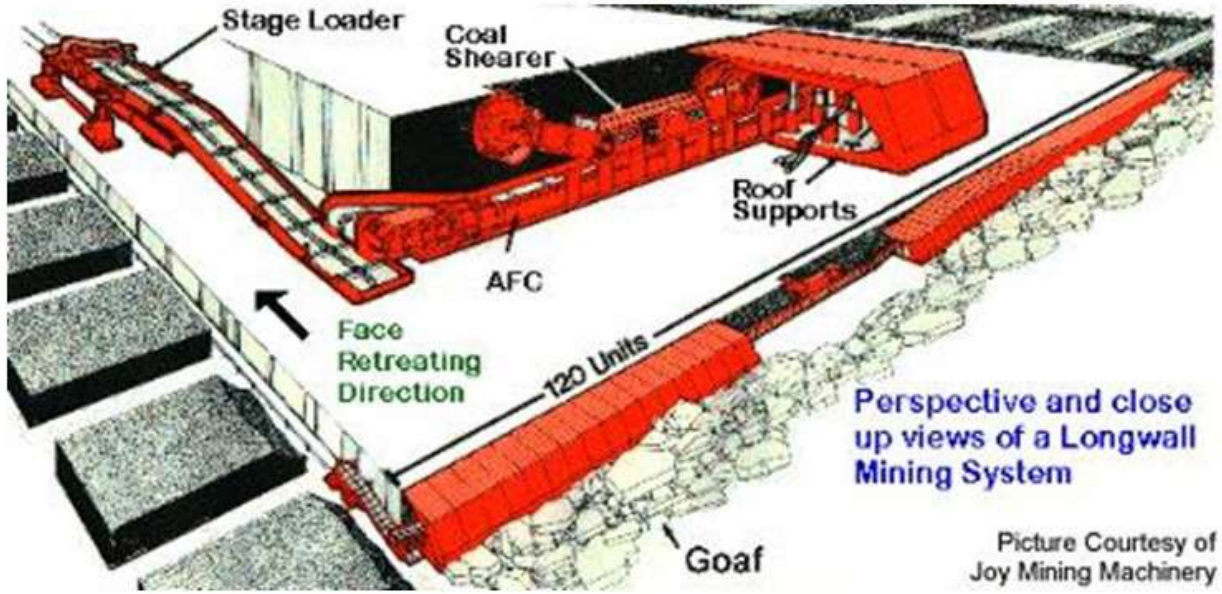
A typical Manual Coal Mining in India
late 1970 (live mint)

Semi-robotic mining
(http://www.ambriefonline.com/)

Mining Value Chain

Locate the Deposit → Establish Mine → Operate Mine → Mineral Processing → Eco-restoration





Perspective and close up views of a Longwall Mining System

Picture Courtesy of Joy Mining Machinery

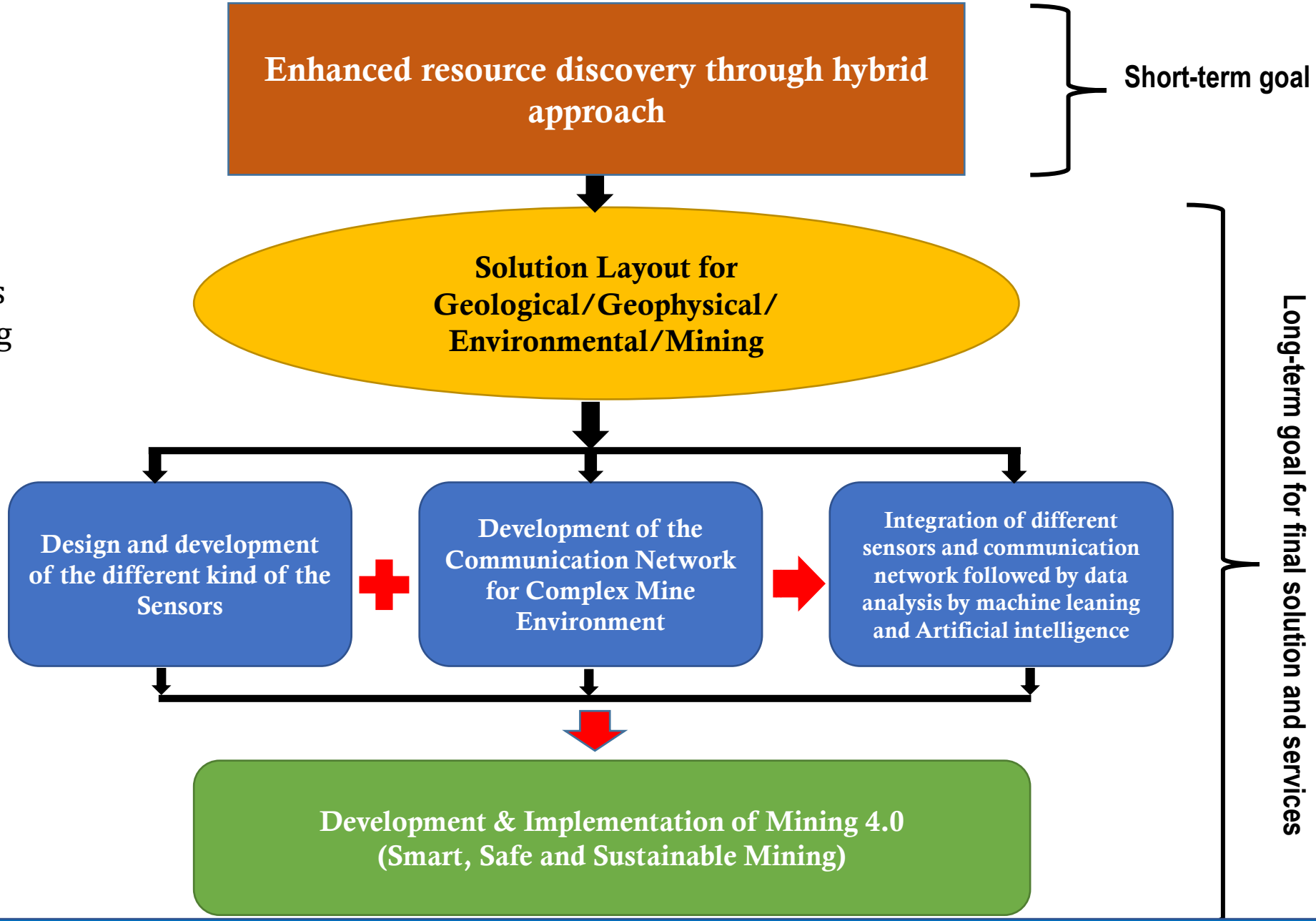
Mining 4.0: Vision, Mission & Goal

Specific Goals

- Enhance Resource Discoveries and Locating Deep Concealed Deposits
- Get Real-Time Data
- Reduce Risk
- Simplify Mining Operations
- Smart & Sustainable Mining

Guiding Factor

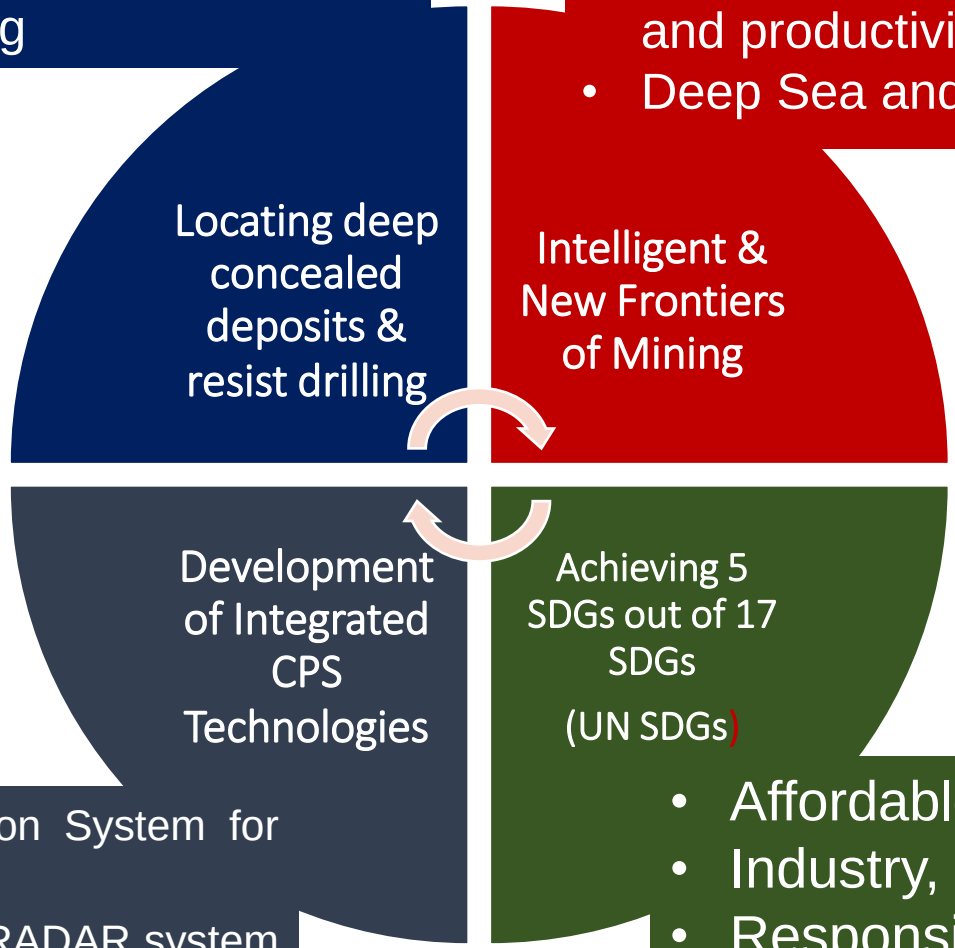
- Mass production technologies
- Indigenous Equipment
- Green Mining initiatives
- Promote transparency



- Lower the cost of exploration through pattern matching, predictive analytics and computer Vision systems (AR & VR)
- Development of technologies for locating deep concealed deposits and resist drilling

- CPS based Asset Management System for maximizing availability and utilization
- Mine simulation and data analytics for mine planning, operational Processes, safety and productivity (CMS)
- Deep Sea and Asteroid Mining

MINING 4.0 OBJECTIVES



DELIVERABLES

- Robotic based Surveillance and Evacuation System for Underground Mine Safety
- Development of a low-cost AI/ML portable RADAR system for Monitoring and prediction of Rock and Dump Slopes failure in Open Cast Mines
- Machine learning algorithms for accurate extraction of features in mine areas and characterization of geo-

- Affordable and Clean Energy
- Industry, Innovation
- Responsible Consumption and Production
- Life on Land
- Partnerships to achieve the goal

CPS in Mineral Exploration

Genesis

- The country is endowed with vast resources of a variety of minerals
- GSI has covered 3.11 million sq. km. (99% of mappable area)
- Only 0.57 million sq. km. identified as an Obvious Geological Potential (OGP) area for minerals
- A major part of this OGP area is yet to be fully explored

Challenge

Developing integrated techniques for locating ”near-surface” "deep-seated" and "concealed/ hidden" ore bodies

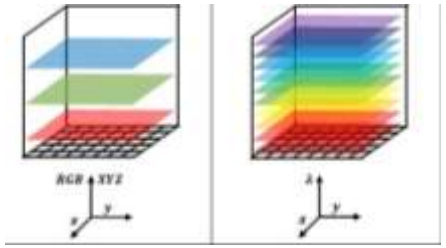
(Geophysical, Geological, Remote Sensing & CPS)

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)

Minerals, metals and their products accounted for **25% of total Indian imports**, second only to petroleum and its products

CPS in Mineral Exploration

Key activities



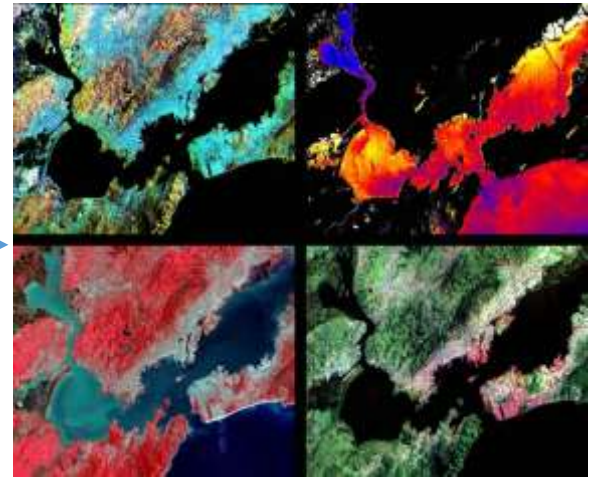
Catalogue of hyperspectral signature of various minerals, IIT ISM Dhanbad has a large bank of mineral samples.

- Gravity survey dataset
- Magnetic survey dataset
- Self-potential datasets

From agencies such as GSI

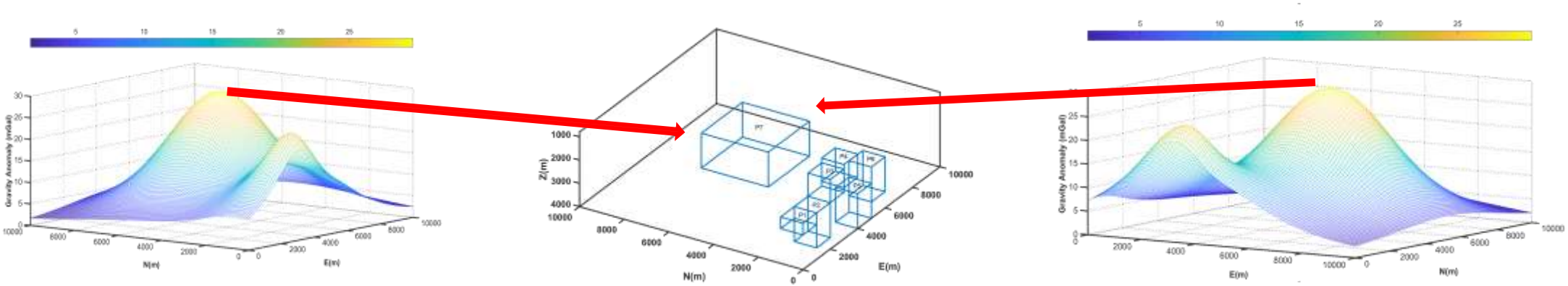
N-Dimensional data cube

Development of AI/ML models using existing datasets



Increase prediction accuracy

- Ore deposits show gravity and magnetic anomalies with respect to whole survey region.



- Empirical methods of parameter estimation have various assumptions and limitations.
- During survey we encounter with complex datasets.
- Using Machine Learning/AI on training sets, it is possible to extract relationships in parameters and corresponding geophysical anomaly values.
- Using the training sets, it may be possible to detect the depth/geometry from the surface to the top of the body which may help to reduce the drilling cost in exploration.

CPS in Mining: 3S Mining (Safe, Smart and Sustainable)

Genesis

- An average of 0.21 individuals have lost their lives per thousand persons employed during 2011-2018 [DGMS].
- An Import of 235 million tonnes of coal at a total spending of Rs.1,71,000 crore (World's 4th largest coal reserve).
- Need to bridge the demand-supply gap by innovation and adoption of frontier technologies

Challenge

Operation & process optimization across mining value chain through

- Design / development / integration of sensors /communication network
- Data Standardization, and,
- AI/ML/Deep learning with IoT and Block Chain

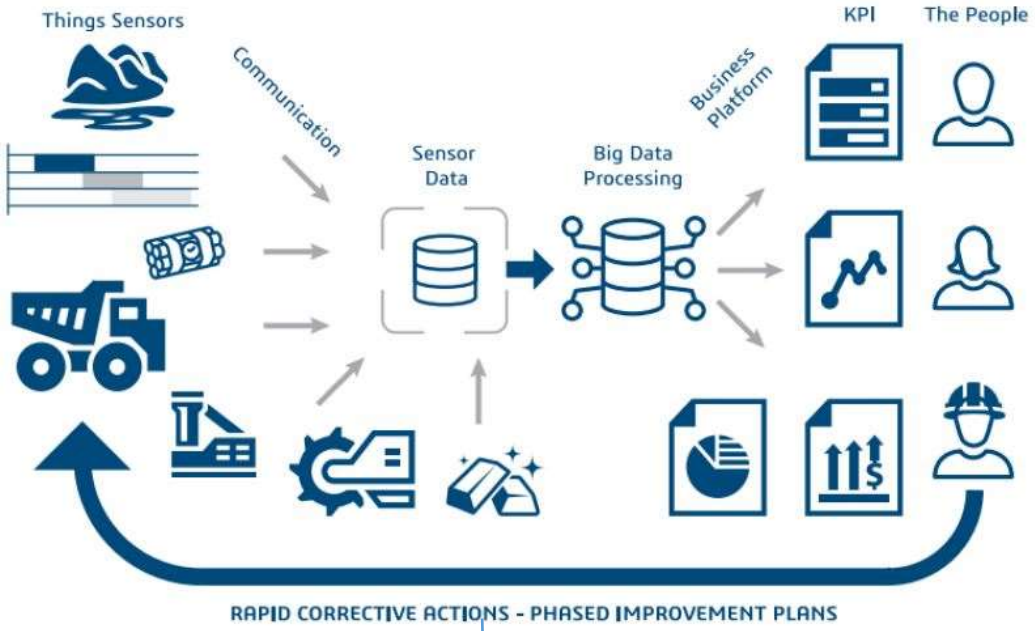
- **Digitalization of Mining Process in a harsh and dynamic environment | Big Data integration | Operation & Process Optimization**

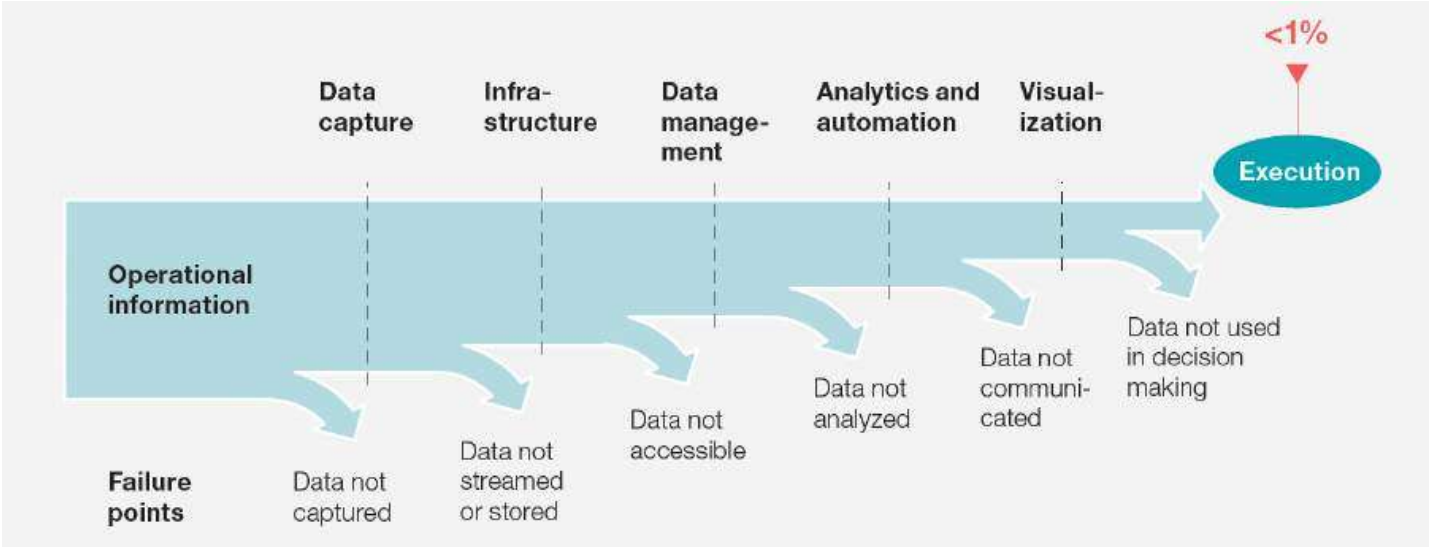
- National Mineral Policy, GoI (2019) emphasizes on the development of robotics, and automated equipment for mining, especially for deep mining

CPS in Mining: 3S Mining (Safe, Smart and Sustainable)

- **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/UPS navigation, LIDAR and drones).
- **Big Data integration**: Enhancing the performance of mining processes and solving complex problems using Internet of Things (IoT) & block chain.
- **Operation & Process Optimization**: Use of big data and robotics (e.g., machine learning, data analytics, automation, remote operation, digital twins).

CPS in Mining: 3S Mining



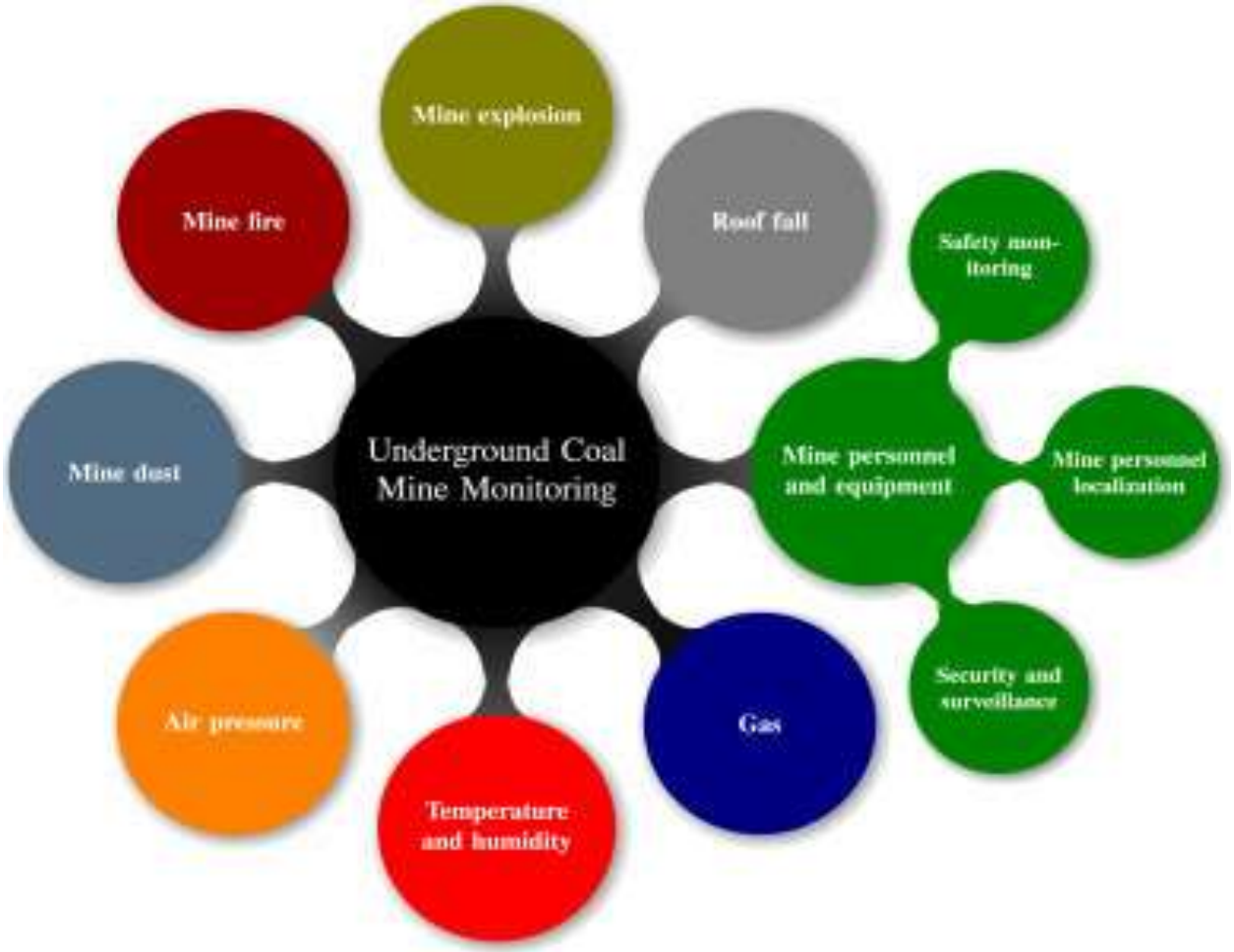


CPS for enhanced safety and productivity

Major and repetitive causes of disasters :

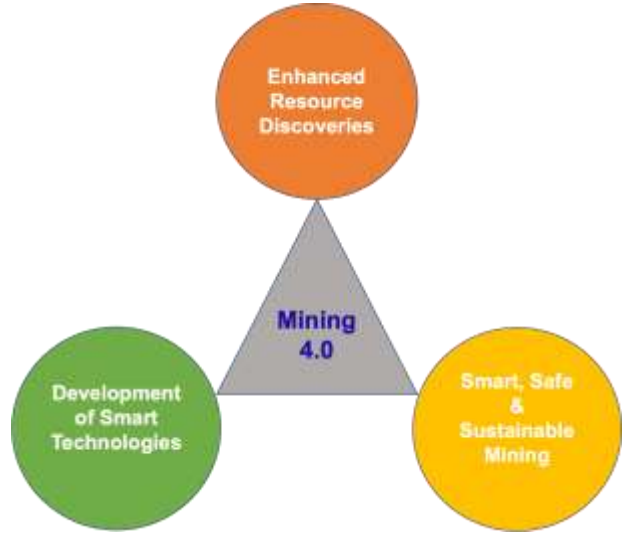
- Spontaneous heating of coal and mine fire
- Methane Explosion
- Inrush of water or unconsolidated mass
- Strata failure
- Roof & Side Fall in Underground mines
- Bench and Waste Dump failure

CPS in Mining: 3S Mining



Parameters requiring real-time detection and monitoring through robust sensors in a hazardous and dynamic environment

CPS in Semi Automated Self Advancing Goaf Edge Support Systems (SAGES)

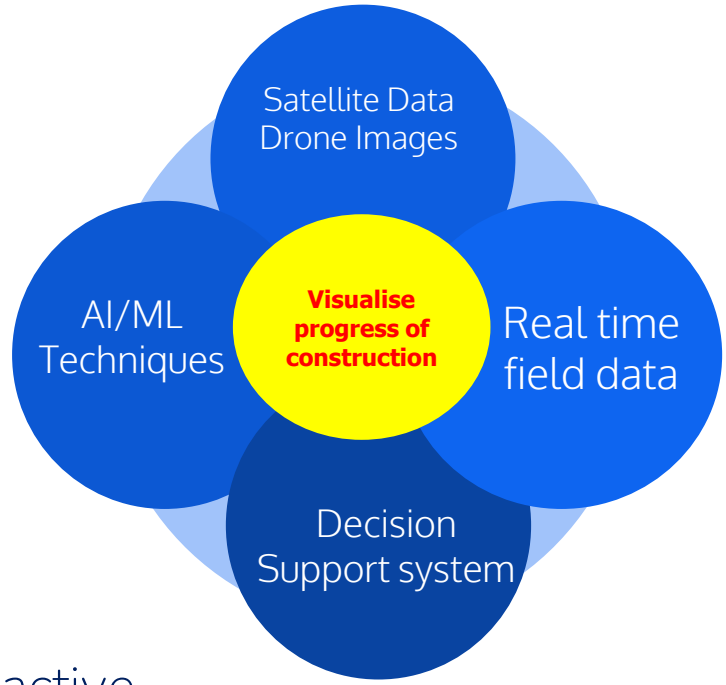


The golden triangle of mining 4.0

Possible Applications of CPS in Mine Monitoring

Smart Sensing Technologies

- Monitoring the mine prgress remotely in real-time.
- Fusion of Satellite & Drone data with Artificial intelligence and machine learning algorithms – DSS
- Machine learning algorithms for accurate extraction of features in mine areas.
- With constant monitoring, understanding the changes that is taking place



Development of Integrated monitoring systems

- Providing a safe and cost-effective way to monitor regional stability over active mines.
- Identifying unstable areas over open cuts and capture the extent of subsidence

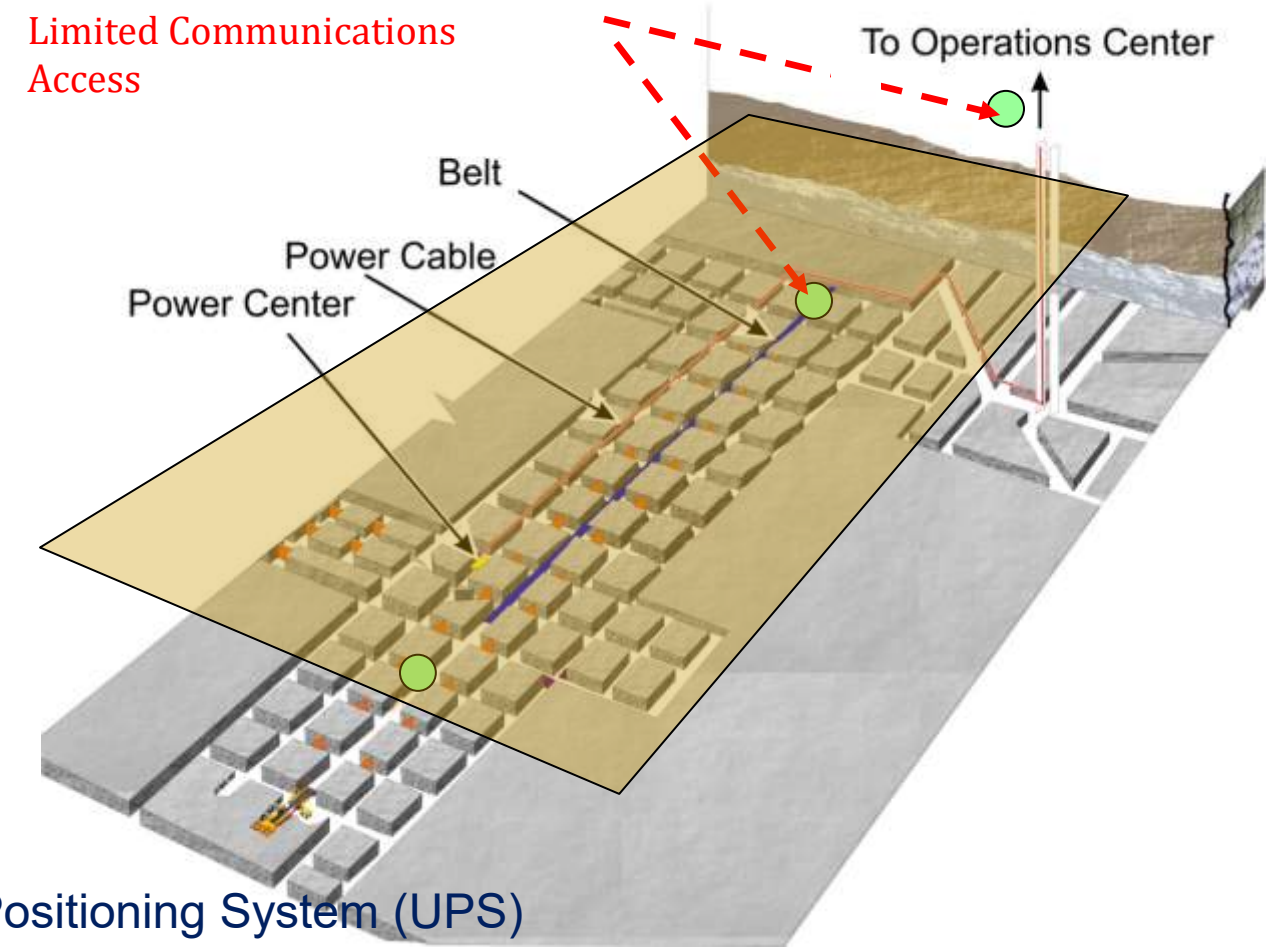
Possible Applications

Change detection

- Mining Footprint
- Green Mining

CPS in Mining: Communication issues

- Investigate the shortest and safest route for a miner in the aftermath of fire or explosion.
- locate the personnel when centralized system is disrupted.
- Investigate whether rescuers can be guided with, inside the mine details without jeopardizing their lives in the lethal atmosphere after the explosion.
- Collection of all possible information from the data extraction strategies followed within the mine to help the rescuers
- Development of a system to display all the above information in real-time.



"GPS denied" navigation and tracking: Underground Positioning System (UPS)

Key goal - Miner would be able to communicate smartly for day to day operations

EXMiN

Technology Innovation Hub of IIT (ISM) Dhanbad

A Govt. of India mandated Mining Innovation Hub for implementing Mining 4.0

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THANK YOU