VIEW POINT

EMBEDDING AI INTO DRILL AND BLAST OPERATIONS IN MINES

Abstract

Drilling and blasting operations are essential yet cost-intensive for the mining industry. Traditional methods are usually manual, complex, and time-consuming, resulting in slow decision making and lower revenue. The use of artificial intelligence (AI) agents can help mining enterprises improve operational efficiency, safety, and compliance, while reducing overall cost.

This paper examines how enterprises can transition drilling and blasting from traditional practices to integrated, AI-enabled operations. It explores the key capabilities of modern architecture and how it supports the implementation of AI across the value chain. It also outlines high-impact use cases of modernized drill and blast operations, along with expected improvements across productivity, cost, safety, and compliance.

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Introduction

Drilling and blasting are essential mining processes that enable access to valuable mineral deposits at depth. These processes break large rock masses into manageable sizes, forming the run-of-mine (ROM) material for downstream processing and revenue generation. Efficient drilling and blasting are important to reduce cost, increase productivity, ensure safety, and improve compliance across the lifecycle. However, smooth drill and blast operations are often hampered by legacy assets, complex workflows, manual processes, and audit-heavy compliance requirements.

The way forward lies in modernizing the existing architecture and adopting innovative operational principles founded on next-generation technologies, such as artificial intelligence (AI) and machine learning (ML). These technologies can drive operational excellence. Moreover, such modernization can close the loop across the drilling and blasting lifecycle, significantly reducing operational costs, improving safety and compliance, as well as enabling informed decision making.

Challenges in Drilling and Blasting

Traditional drill and blast operations are largely driven by rules, formulas, and standard operating procedures (SOPs). There is significant manual effort spent in inspecting the drill and blast site and equipment, validating and processing data, as well as running complex and non-value-adding tasks1. This limits the ability to make timely and proactive decisions.

Figure 1 depicts five phases of drilling and blasting along with the cost, productivity, and safety challenges in each phase. It highlights the need for operational excellence across the lifecycle. Addressing these challenges is critical because drilling and blasting are a significant cost center. They account for nearly 30% of the total operating costs in some mining operations[2]. Moreover, sub-optimal operational performance impacts downstream processes, indirectly increasing crushing and comminution costs, degrading ROM consistency, and creating bottlenecks across the processing plant[3,4].

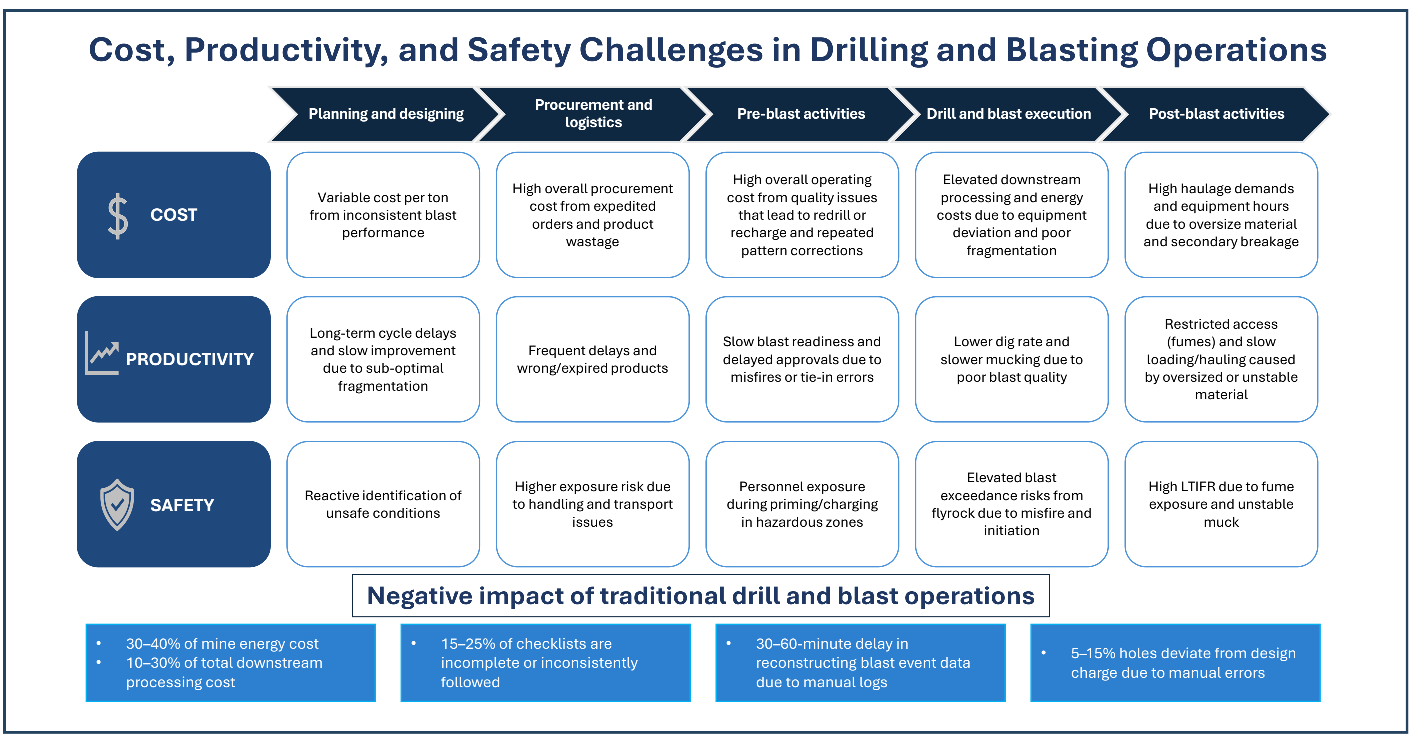

Fig 1: Cost, productivity, and safety challenges in drilling and blasting operations

Key Considerations to Modernize the Drilling and Blasting Lifecycle

1. Choose the right architecture

As with any modernization program, it is important to analyze ways of working, existing systems, and how data flows across the value chain. Using the International Society of Automation's ISA-95 framework as a foundation, Infosys has organized different processes and technologies into layers to enable a modern architecture for drilling and blasting operations[5].

Figure 2 illustrates the ISA-95 framework for drilling and blasting operations. The framework integrates processes, data, personas, and technologies across the drill and blast lifecycle. It also converts field and desktop events into actionable business decisions using structured workflows and diverse data.

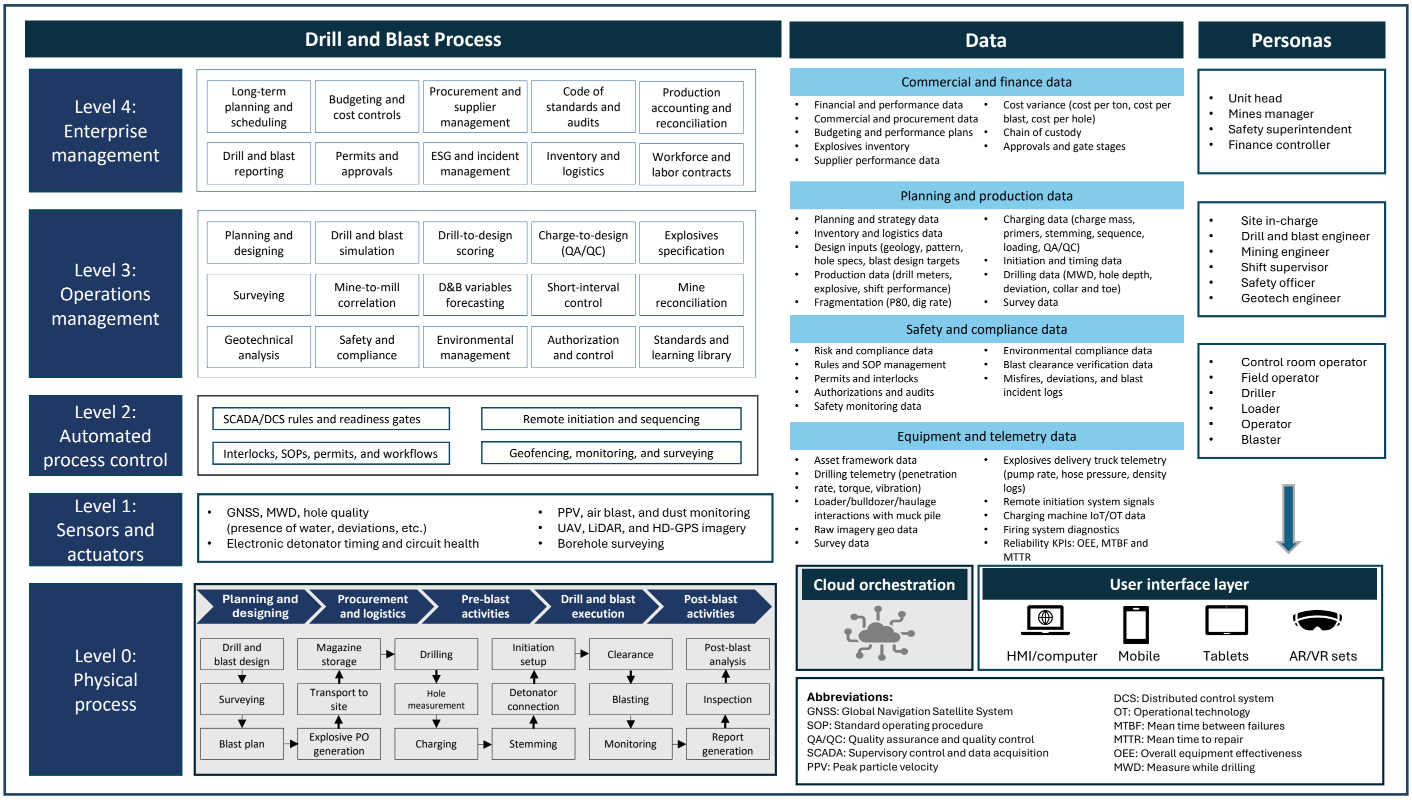

Fig 2: Drill and blast architecture as per the ISA-95 framework

This architecture addresses operational challenges and helps reduce costs, optimize ROM quality from mine to mill, improve safety, and ensure compliance. It streamlines operations across five levels:

- **Level 4** – Enterprise management: Improves planning, governance, and control design, while enabling audit-ready traceability
- **Level 3** – Operations management: Orchestrates execution as well as pre and post drilling and blasting activities
- **Level 2** – Automated process control: Links automated process control with sensors to enable real-time process control
- **Level 1** – Sensors and actuators: Uses sensors to detect physical changes and convert them into signals, while actuators convert signals into physical action
- **Level 0** – Physical process: Focuses on the physical aspects of drilling and blasting

2. Establish a strong foundation with cloud, data, and AI

The architectural capabilities of Level 3 are critical as they generate actionable insights and strengthen decision making. Furthermore, they support the data-driven culture heralded by Industry 4.0, which comprises two layers of capabilities:

- Layer 01: The foundational layer for a data-driven decision-making framework
- Layer 02: Domain agents for embedding AI into the decision-making framework

Cloud orchestration enables data storage and processing. It also runs AI algorithms for high-impact operational and tactical activities. This foundational data layer supports AI implementation across the drilling and blasting lifecycle in several ways. For instance, it can integrate data and documents with the enterprise resource planning (ERP) platform for accurate drill and blast design and planning, explosive inventory, procurement management, as well as environmental, social, and governance (ESG) reports.

During execution as well as pre and post drill and blast activities, AI can automate data retrieval from technologies such as drones, satellites, Light Detection and Ranging (LiDAR), Global Positioning System (GPS), and the Internet of Things (IoT) sensors. This enables faster data processing and improved data clarity. It can also capture real-time data on firing sequence, initiator timing, quality assurance and quality control (QA/QC) management, as well as environmental impact. This increases the ability of mining enterprises to simulate and visualize key data on three-dimensional (3D) simulators for activities such as blast simulations, blast zone geo-fencing, vibration, and air blast analysis[6].

Embedding AI into the Drilling and Blasting Lifecycle

AI transforms traditional drill and blast operations using domain-specific AI agents. It also unlocks new use cases that streamline end-to-end operations, boosting productivity and driving operational excellence.

1.Unlocking new use cases across the drill and blast value chain

AI-driven drill and blast operations can reduce overall costs significantly and improve compliance visibility across the lifecycle. Figure 3 depicts twenty such high-value use cases across the value chain, powered by AI[2,7,8].

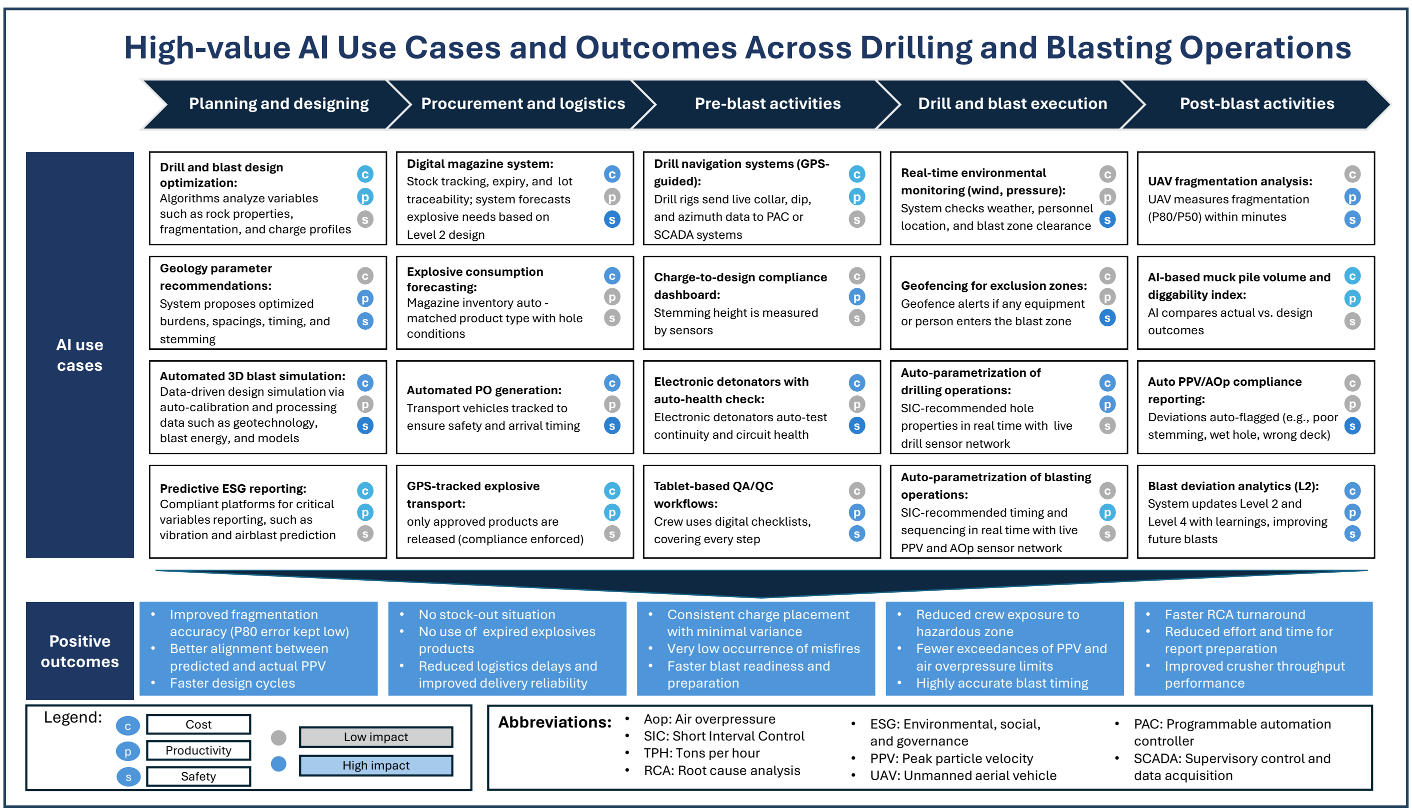

Fig 3: High-value AI use cases and outcomes across drilling and blasting operations

2. Integrating domain AI agents for different personas

Integrating domain agents into ISA-95 architecture brings the power of AI to all critical operational and decision-making activities across the drilling and blasting lifecycle.

Figure 4 lists two categories of domain agents: managers and operators. Managers include those responsible for drilling and blasting processes, mine planning, geotechnical engineering, overall mine management, and safety supervision.

Operators or blasters refer to drill and blast technicians, blasters, safety engineers, and others. These agents elevate drill and blast operations by addressing common challenges and uplifting the user experience.

Domain Agents for Drilling and Blasting Operations

Manager, Planner, and Mining Engineer

Department: Operations and production
Reports to: Superintendent of drill and blast operations or mine planning manager
Reportees: Drill and blast planner, mine planning engineer, technical service teams, and operations manager
Lifecycle phases involved: Pre drill and blast activities, blast execution, and post-blast activities
Focus: Safe execution, compliance, inspection, and operational performance

Key activities:

- Blast design generation and optimization
- Scenario comparison: Cost vs. safety vs. productivity
- Risk prediction: PPV, flyrock, and fragmentation
- Post-blast learning and calibration

Data/information required:

- Geological and geotechnical data: UCS, RQD, and structures
- Drill data: Layout, depth, deviation, and MWD
- Historical blast outcomes
- Environmental and regulatory limits
- Downstream KPIs: Crusher and mill performance

Traditional methods:

- Rule-of-thumb designs
- SOP-based burden, spacing, and PF
- Manual spreadsheets and static assumptions

Pain points:

- High blast outcome variability
- Limited rock variability modeling
- Slow design iterations
- Weak feedback from execution and post-blast analytics

AI-embedded capabilities:

- Generates multiple outcome-driven drill and blast options with confidence scores
- Predictive models estimate P80, PPV, flyrock, and cost before execution
- Continuous model learning from post-blast results
- Faster design cycles with data-backed, defensible decisions
- Reduced downstream variability and rework

Benefits:

- Outcome-based, adaptive drill and blast designs
- Predictive risk and performance modeling
- Faster and confidence-scored decisions
- Closed-loop learning from post-blast results

Operator or Blaster

Department: Mine planning and technical services
Reporting to: Shift supervisor or blasting superintendent
Reportees: Blaster in-charge, shotfires/charging crew, safety officer, control room, and operations supervisor
Lifecycle phases involved: Planning and designing, procurement and logistics
Focus: Drill and Blast design accuracy, supply readiness, and cost optimization

Key activities:

- Hole validation and charging execution
- Detonator programming and health checks
- Safety clearance and blast authorization
- Compliance confirmation during execution

Data/information required:

- Final blast design and charge plan
- Real-time drill deviation and hole condition
- Explosive inventory and type
- Sensor data: PPV, AOP, gas, and personnel tracking

Traditional methods:

- Paper-based drill and blast plans
- Manual checks and radio confirmations
- Experience-driven adjustments

Pain points:

- High reliance on individual vigilance
- Limited real-time visibility
- Safety depends on procedures, not systems
- Post-event blame, instead of prevention

AI-embedded capabilities:

- Step-by-step, AI-guided charging and execution
- Real-time charge-to-design compliance monitoring
- Automated geofencing, lockouts, and blast authorization
- Live PPV/AOp monitoring with auto-abort capability
- Tamper-proof, audit-ready execution logs
- Reduced misfires, delays, and safety incidents

Benefits:

- Step-by-step execution guidance
- Automated safety enforcement: Geofencing and lockouts
- Real-time compliance and deviation alerts
- Tamper-proof, audit-ready execution records

Fig 4: Categories of domain agents and their characteristics

Application of Domain Agents

There are four scenarios in which domain agents can be used across drilling and blasting operations. The scenarios are explained below:

Scenario 1: Planning and designing
Scenario 2: Pre-blast activities
Scenario 3: Blast execution
Scenario 4: Post-blast analysis and learning

Scenario 1: Planning and designing

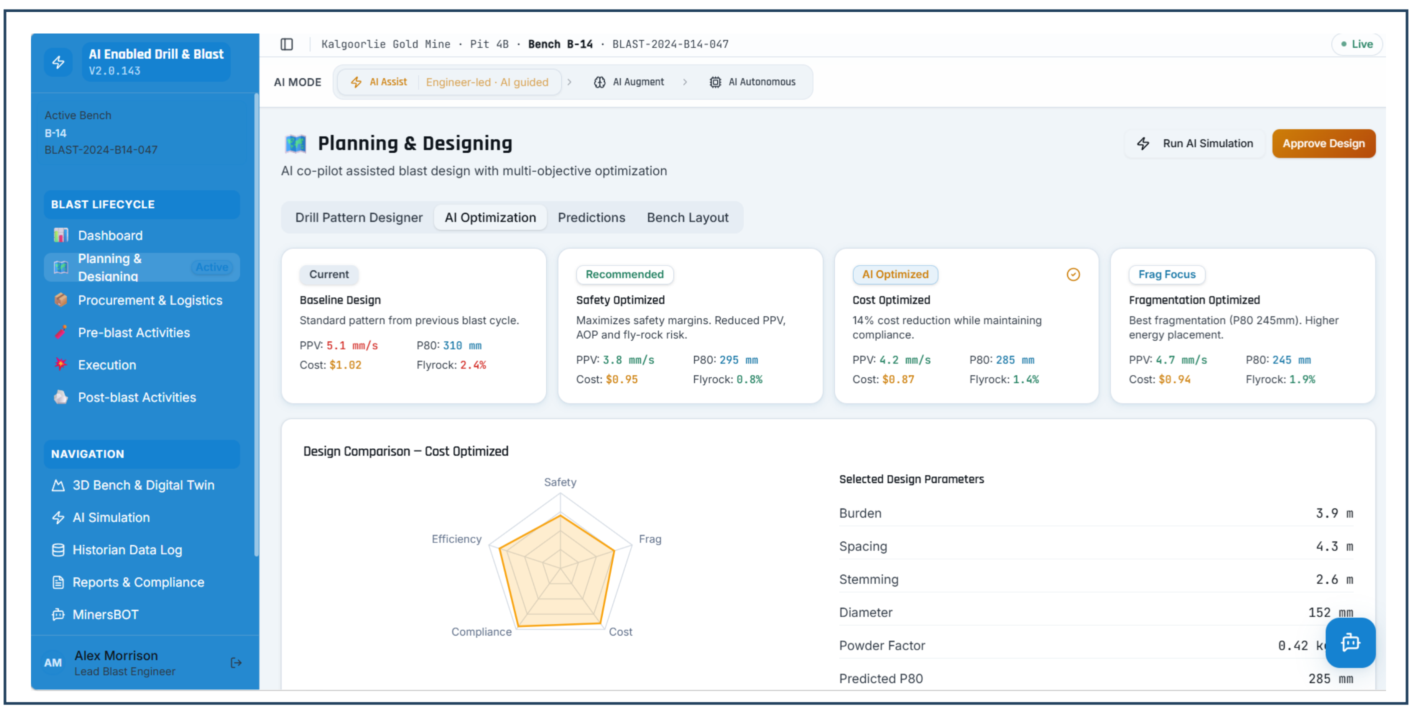

Fig 5: AI agent interface for planning and designing

In the planning and designing stage, blaster and operations supervisor AI agents function as co-pilots within an AI-assisted design environment. They replace static, rule-based approaches with dynamic, multi-objective optimization. As shown in Figure 5, geological data and historical blast patterns are automatically ingested, enabling planners to interactively adjust key parameters such as burden, spacing, and stemming. The system then generates multiple 'optimized' design scenarios, such as safety-optimized, cost-optimized, and fragmentation-optimized scenarios.

Each scenario option has predicted outcomes for parameters like peak particle velocity (PPV), P80 (the particle size at which 80% of an ore sample's mass passes through a specified screen), flyrock, and cost. These alternative design scenarios are presented through a comparative visualization dashboard, allowing planners to evaluate outcomes across dimensions of safety, efficiency, compliance, cost, and fragmentation. For high-risk scenarios, the planner can review and approve the most suitable design using AI simulation insights. For low to medium-risk cases, the system can autonomously recommend and implement the optimal configuration. This AI-enabled approach significantly improves key performance indicators (KPIs), such as fragmentation quality, oversize reduction, powder factor efficiency, flyrock mitigation, blast design compliance, and vibration control.

Scenario 2: Pre-blast activities

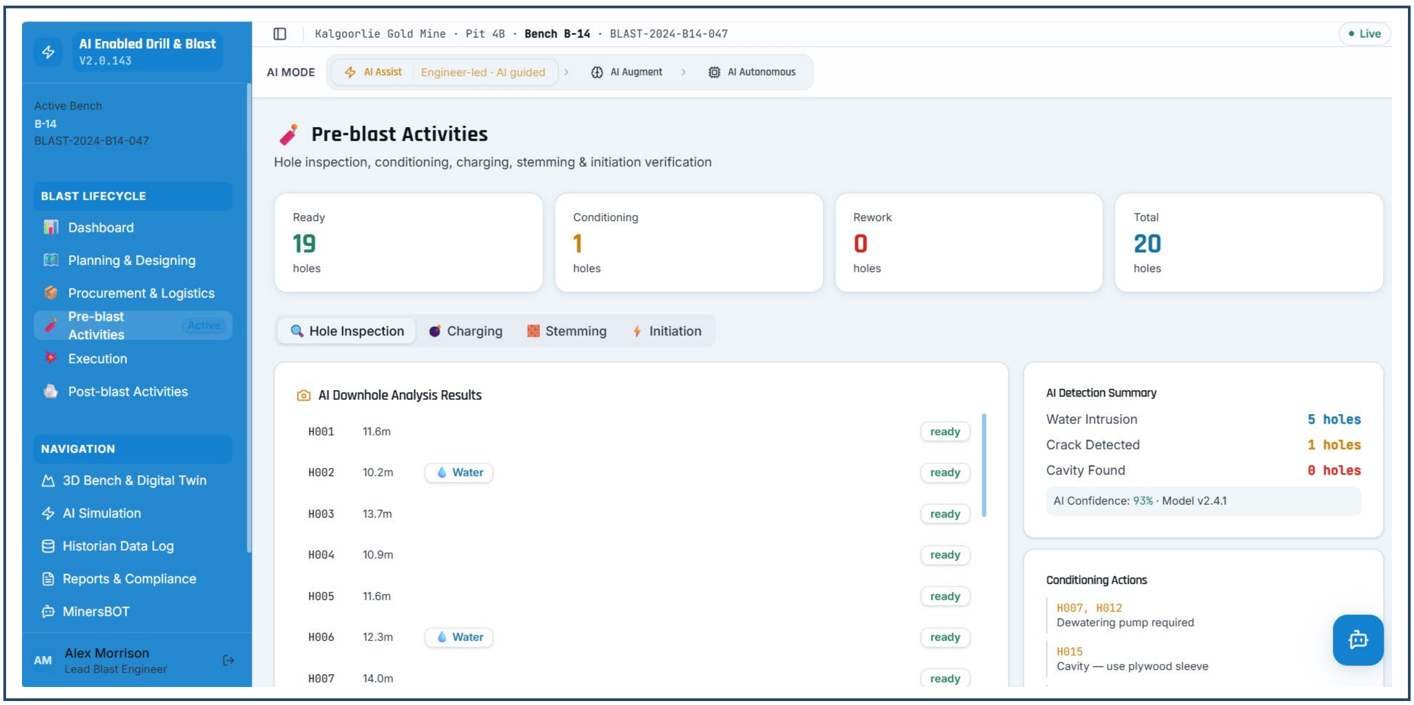

Fig 6: AI agent interface for pre-blast activities

In the pre-blast stage, blaster and planner AI agents act as real-time coordinators within a digitally-assisted verification environment, replacing manual inspections and radio-based communication. As shown in Figure 6, the system continuously monitors the status of each hole and classifies them as 'ready', 'under conditioning', or 'requiring rework', while aggregating overall readiness. AI-driven downhole analysis automatically evaluates conditions such as water intrusion, cracks detected, and cavities found. It also provides confidence-scored detection results.

Based on these insights, the system recommends and triggers appropriate conditioning actions, while ensuring that all prerequisites for blasting inspection, charging, stemming, and initiation are verified in real time.
A consolidated detection and action panel enables human planners to quickly identify critical issues and resolve them before execution.

This integrated, AI-enabled approach strengthens operational readiness and significantly improves KPIs such as completed inspection rates, drill plan adherence, charge accuracy, predicted misfire reduction, blast clearance compliance, and overall blast readiness time.

Scenario 3: Blast execution

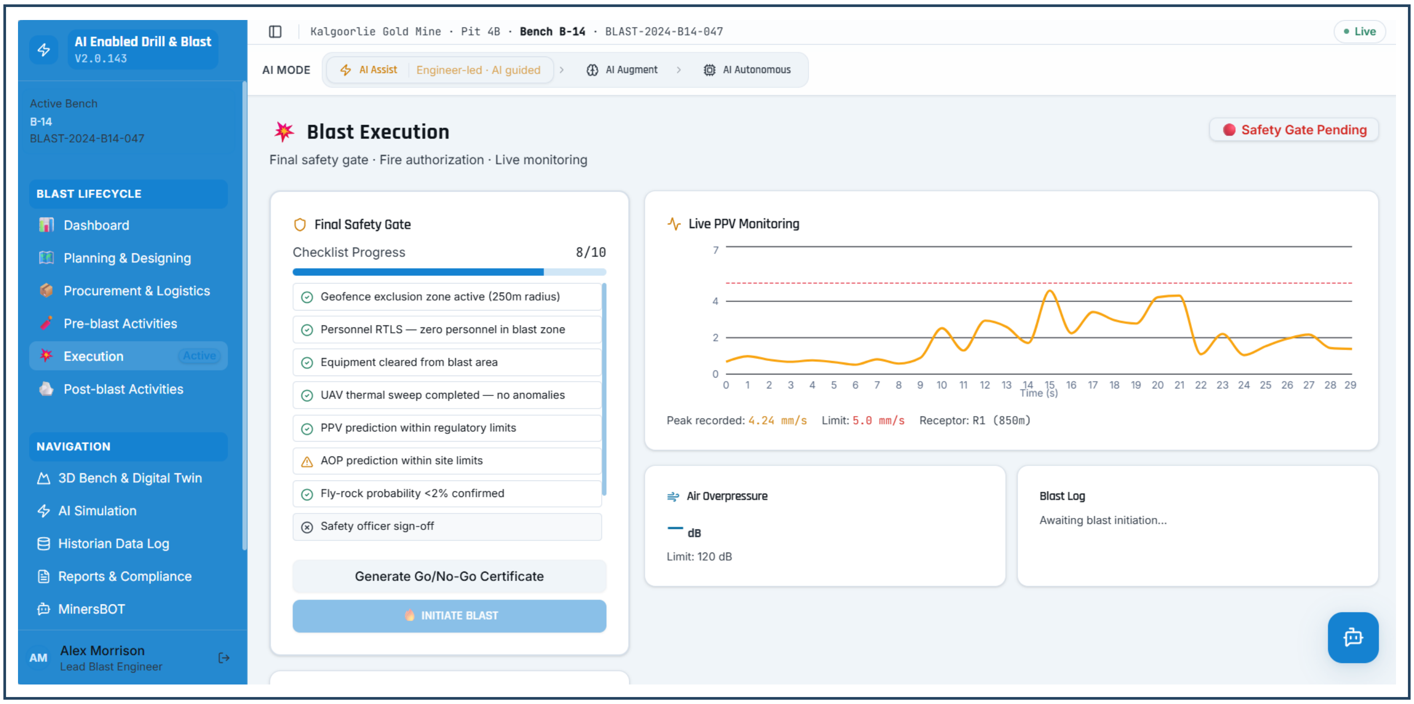

Fig 7: AI agent interface for blast execution

During the blast execution phase, blasters, safety officers, and operations manager AI agents operate within an integrated command and control interface, replacing manual verification and radio-based coordination. As illustrated in Figure 7, the system enforces a structured, final safety gate where all critical pre-initiation checks are digitally validated before proceeding with blast authorization. These checks include geofence activation, personnel clearance, equipment evacuation, unmanned aerial vehicle (UAV) inspection, and regulatory compliance. Alongside, real-time monitoring modules track key parameters such as PPV and air overpressure (AOp) against defined thresholds. Live graphs provide continuous visibility. Any deviation beyond permissible limits automatically triggers a system lock, preventing unsafe blast initiation. The interface also supports automated generation of go/no-go decisions and maintains a digital blast log for audit readiness.

This AI-enabled execution framework strengthens control and compliance, delivering several improvements. It accelerates blast authorization cycles and reduces misfire probability, execution delays, as well as personnel exposure risks. Further, it optimizes explosive usage and improves auditability as well as charge-to-design, PPV, AOp, and regulatory compliance.

Scenario 4: Post-blast analysis and learning

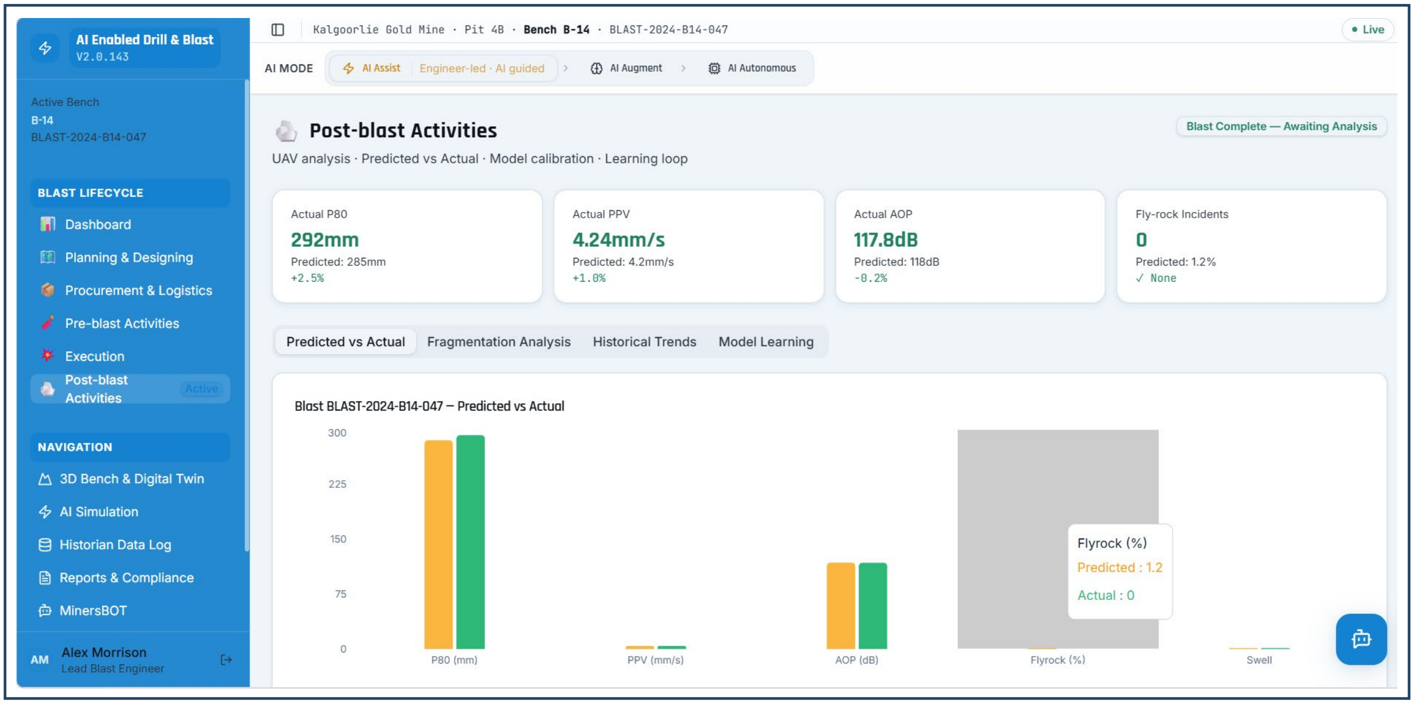

Fig 8: AI agent interface for post-blast activities

In the post-blast stage, blaster and operations manager AI agents operate within a data-driven analysis and learning environment, replacing traditional manual reviews and documentation-intensive workflows. As illustrated in Figure 8, the system automatically consolidates field measurements and compares actual versus predicted outcomes across key parameters including P80 fragmentation, PPV, AOp, and flyrock incidence. These insights are presented on interactive dashboards. They display KPI summary tiles, predicted versus actual parameters, and dedicated tabs for fragmentation analysis, historical trends, and model learning. AI models continuously calibrate themselves using this feedback loop, generating outputs such as fragmentation distributions and root cause insights. They also report on model accuracy to validate prediction reliability. Additionally, the system produces standardized, ready-to-download reports for operational review and compliance tracking.

This AI-enabled closed loop learning enhances decision quality and drives continuous improvement across KPIs. These include fragmentation prediction accuracy, oversize reduction, alignment between predicted and actual vibration levels, air blast control, drill to blast compliance, crusher performance stability, and the overall learning effectiveness of blast optimization models.

Conclusion

Drilling and blasting are critical business processes for the mining industry to generate value. They directly influence ROM quality, plant stability, and overall control of mine economics. Traditional drilling and blasting practices are characterized by siloed workflows and manual controls, resulting in variability, revenue leakage, and increased risk.

Modernized architecture, founded on the ISA-95 framework, optimizes drill and blast operations, improving performance, safety, and productivity. It also embeds AI domain agents across end-to-end drilling and blasting processes, transforming the value chain and bolstering operational excellence. This approach shifts drill and blast operations from reactive firefighting to proactive, AI-driven decision making. The result is predictable performance, reduced variability in fragmentation and vibration, auditable safety, and sustained improvements in cost efficiency, productivity, and mine-to-mill throughput[9,4].

About the Authors

Venkateshprasad H. S.

Consultant

Venkatesh is a Consultant in Mining and Metals, Manufacturing and Resources Domain Consulting Group at Infosys. He has over 10 years of experience in the mining sector, with specialized expertise in underground and open-cast mining.

Harish Yendamuri

Senior Consultant

Harish is Senior Consultant in Mining and Metals, Manufacturing and Resources Domain Consulting Group at Infosys. He has more than 10 years of experience in mining plant operations, digital transformation, and process automation as well as optimization.

Joseph Michael

Lead Consultant

Joseph is Lead Consultant in Mining and Metals, Manufacturing and Resources Domain Consulting Group at Infosys. He has over 17 years of experience driving digital transformation projects in this industry.

Reviewer Section

Dr. Indresh Rathore

Principal Consultant

Dr. Indresh is Principal Consultant in Mining and Metals, Manufacturing and Resources Domain Consulting Group at Infosys. He has more than 23 years of experience advancing operational and business excellence in the mining and metals sector.

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