Microsoft

AI Transformation in Mining

The Next Wave of Digital Innovation

2024 Mining Industry White Paper

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Executive summary

The mining industry operates in a rapidly changing world. Climate change has created growing demand for climate-smart minerals to support the clean energy transition. Solar panels, wind turbines, electric vehicles (EVs), and batteries are built with graphite, copper, lithium, nickel, and cobalt. To meet the unprecedented production rate required, sustainable sourcing of these minerals has never been more important.

The mining industry has been evolving over time with more efficient, resilient processes--enabled by the many organizations embracing digital transformation and technological innovations. But recently, the world has seen one of the greatest technological disruptions in history: generative AI. At Microsoft, we believe that digital technologies, especially AI, can enable mining companies to master a changing world. With so much at stake in a rapidly changing industry, AI transformation is not an option but an imperative.

This paper seeks to help mining leaders think about their own AI transformation journey—from strategic frameworks that illuminate new ways of integrating generative AI across the value chain to AI-enabled mining use cases across the entire mining lifecycle. Specifically, we will cover:

Forces driving change:

The mining industry is working to address three paramount issues: security, affordability, and sustainability. This section will dive deeper into more nuanced challenges given the wide exposure to volatility, risk, and disruption—focusing on the variables miners must master: productivity, cost, mineral recovery, environmental impact, and industrial safety.

AI Transformation:

AI transformation is a journey that many mining organizations have already embraced. And it is exactly that: a journey. At Microsoft we think about AI transformation in the context of the mining industry: empowering your workforce, operating for the future, accelerating to net zero, and unlocking sustainable solutions. This section is about how AI can transform all aspects of the mining lifecycle and support the journey to a digital, sustainable mine of the future.

Empowering new ways of working:

Generative AI is changing the way people work in profound ways. Understanding the value one can extract from generative AI tools is critical to driving meaningful adoption. This section dives deep into a useful framework: Understand, Experience, Enhance, Accelerate, Create, and Innovate. Looking to the future, this section examines four frontiers in AI for mining where mining companies and their partners can realize enhanced value.

Mining leaders have never had more opportunity to make progress against the industry's biggest challenges than they do today. With technology, innovation, and collaboration, there is a real opportunity to accelerate this transformative journey toward the digital, sustainable mine of the future.

Forces driving change

The clean energy transition is shifting the foundation

After a long history of stability, macro-level changes are sweeping across energy and resources. In the next 25 years, the mining industry will look very different than it does today. And everything is happening at once.

The industry at large is grappling with economic uncertainty and rapid digital technology advancement while working to conduct an orderly and managed energy transition with geographical considerations. Meanwhile, energy companies are in a race to proactively build the resilience and agility needed to avoid disruptions and maximize opportunities. The goals are to deliver secure, affordable, and sustainable energy for all—and for energy policymakers to balance these objectives as a guide for policy making. Abundant, affordable, and sustainable energy will enable miners to deliver sustainably sources minerals and metals to the world.

The mining industry operates within a larger global context having shared and competing priorities. The ability to meet energy demand with a secure and resilient supply, abundant and equitable access, and sustainable practices impacts everyone. Digital technologies and AI can help address the energy and mining industry challenges challenges across multiple fronts, as described below.

Access: Increasing energy availability and affordability to meet growing demand and provide new energy to roughly one billion people globally who do not have stable or affordable access to power.

Demand: Global energy demand is expected to increase ~50% in the next 30 years. Digital technology and AI can increase production and efficiency and increase cash flow to drive investments in additional energy capabilities.

Data Sovereignty: Concerns about power production are growing, where power is being weaponized. Digital technology and AI can optimize operations and maintenance, increase reliability and resilience, and help protect assets against cyber threats.

Climate: Energy accounts for >70% of global carbon emissions. Mining accounts for 4 to 7% of greenhouse gas emissions. Digital technology and AI can increase the pace and scale of decarbonization across the energy sector, including electrification, renewables generation, energy, and emissions reduction.

Workforce: One of the biggest challenges in both the energy and mining sectors is the aging workforce and associated skills shortages. Digital technology and AI can upskill and empower the workforce through improved collaboration, training, remote support, automated work processes, and knowledge assistance.

Access	Demand	Data Sovereignty	Climate	Workforce
~1B people	Increase ~50%	"Power as a weapon"	>70% carbon emissions	Skills shortage

Economy	Energy Transition	Technology

The mining industry is at a crossroads

Mining plays a significant role as an energy-intensive industry and a contributor to greenhouse gas emissions. It also plays an important role as a provider of climate-smart minerals and as an investor in renewable energy sources and energy-efficient technologies.

Mining companies are racing to prepare for the future. To better anticipate the many disruptors that could affect operations, they need to identify potential risks and opportunities—then develop strategies to either mitigate these risks or capitalize upon opportunities. To do this, they are incorporating scenario planning within their strategic planning processes and strengthening their supply chain resilience and agility.

Mining companies are under pressure to meet multiple, often conflicting, requirements and expectations. They face significant challenges across the mining value chain to optimize profitability and productivity, ensure sustainability, and manage risk, safety and health—collectively referred to as the mining trilemma: profitable, green, and secure. In addition, there are challenges unique to mining that are critical to address.

Mining industry challenges

Trilemma: Profitable + Green + Secure

Resources and Reserves

Time to Production

Circular Economy

Recovery

License to operate

The mining trilemma: profitable + green + secure

Mining companies must be profitable as they transition to renewable and clean energy sources and advance their ESG objectives and goals. If they can't be profitable, they can't invest in ESG.

To meet regulatory requirements, investor expectations, and community demands, mining companies must operate and invest to become increasingly green. Emissions, water, ecosystems, and biodiversity have always been priorities for miners. Being green includes the ESG objectives and goals in which mining companies invest, not just carbon emissions. And being green is especially important to maintain a license to operate.

In a world with geopolitical strife and bad actors, mining companies and their operations must be secure. This involves more than just physical security and cybersecurity—it also includes supply chain security. The world witnessed the impact COVID-19 had on mining supply chains, and the disruption caused by Russia's invasion of Ukraine. Both events dramatically disrupted energy security.

Resources and reserves

The mining industry is pulled between two opposing forces: urgent demand and dwindling supply.

An enormous quantity of minerals and metals must be supplied in a very brief time, with current estimates totaling three billion tons of minerals and metals needed by 2050. [1] By comparison, the world mined 2.47 billion tons of non-fuel minerals and metals in 2018. [2]

A new World Bank Group report, Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition, estimates that in order to meet the growing demand for clean energy technologies the production of minerals—such as graphite, lithium, and cobalt—could increase by nearly 500% by 2050. [1]

Unfortunately, recent exploration results have been disappointing. The data shows that during the last mining boom, from 2010 to 2015, the cost of exploration exceeded the value of ore discovered. [3] While this example of value destruction in mining may have passed, the exploration value proposition is still unfavorable. Since 2016, exploration results have been largely break-even. [3] Some believe it is getting progressively more difficult and costly to find quality deposits, and to overcome these challenges miners need to be smarter and more efficient in how and where they explore.

To provide the required climate-smart minerals and metals, the mining industry must invest in innovation and improve exploration outcomes significantly. Across the mining value chain, mining companies must cost-

effectively discover more, recover more, and recycle more. Here, the most recent advances in AI could be a game changer for exploration results and its value proposition.

Time to production

Historically across commodities, the delay between ore body discovery and mine start-up is about 12.4 years but may extend beyond 50 years. [4]

In recent years it appears that the delay period has increased. MinEx Consulting estimates that (depending on the commodity) the delay is currently between 15-20 years. [4]

To make matters worse, less than half of discovered ore deposits become producing mines. [4] And for those ore bodies that become producing mines, the capital investment can be enormous. The upfront investment can total several billion dollars, as in one iron ore project in Africa where the potential figure could exceed $15B USD. [5]

We do not have the luxury of such time. Meeting the world's 2050 climate goals requires miners to shorten this time significantly. Here, the most recent advances in AI could help transform the industry by accelerating and improving engineering and design, capital project planning and execution, and contract negotiation and performance.

Circular economy

The term circular economy is sometimes referred to as "mining the waste stream." However, the existential importance of climate-smart minerals demands that we start thinking in terms of the resource stream. This requires abandoning the linear mine-to-product-to-disposal model in favor of a circular lifecycle model.

To help ensure the availability of future resources, current patterns and volumes of production and consumption need to change dramatically and be brought within planetary boundaries. [6] The magnitude of this transformation cannot be overstated. Our greatest challenge is changing humanity's relationship with the earth, in every respect.

Miners, with their metallurgical expertise and scale, are well positioned for the circular economy. However, material alloying during production, and material mixing during assembly—and in the resource stream—present new metallurgical challenges. This is another opportunity for AI to change the game: for mineral and metal recovery from recycled materials and for operationalizing new business models and optimizing new processes.

Mineral and metal recovery

Waste not, want not! Mineral and metal recovery must improve in the mine, in the mill, and from the resource stream of the circular economy.

Opportunities for improvement abound. Underground, we still see miners experiencing excessive overbreak and underbreak in blasting. And, both underground and on the surface, we still see miners misclassify muck piles. Too frequently laboratory information management systems (LIMS) are not integrated with other systems and processes, leaving blending to chance. In the mill, we still see miners missing their targets in comminution, concentration, and refining. AI could address these challenges for mineral and metal recovery from the ground and in the mill, and from the resource stream of the circular economy.

License to operate

Miners must attain and preserve a license to operate while optimizing the business and operations across many requirements and constraints. The license to operate was a featured topic at MineXchange 2022 in Salt Lake City, Utah where former Ambassador Todd Chapman spoke about the importance of trust in mining, and how social license to operate is becoming more complex, challenging, and expensive. [7] He spoke broadly about the need for mining companies to earn a social license to operate, saying simply, "if you do not have the social license to operate, you do not have an operation." [8]

Mining organizations must shape their culture to enable attaining and preserving a license to operate. This requires new disciplines and skills in anthropology, sociology, political science, psychology, marketing, public communications, and more.

AI transformation

AI is an imperative, not an option

AI is changing the nature and pace of business competition in bold ways. Like the adage "the smart fish eats the other fish," the same is true in how AI is being used across industries. AI-savvy organizations are utilizing AI to:

- Increase the speed and efficiency in decision making

- Enhance the quality and innovation of products and services

- Optimize plans and schedules

- Improve engineering and design

- Solve complex problems and challenges

- Reduce operating costs and risks

- Automate and streamline processes

- Create new and disruptive business models, and

- Transform value propositions and competitive advantages [9] [10] [11]

AI transformation opens a new wave of innovation in which the winners create value and differentiation and accelerate outcomes for customers and stakeholders. To thrive in this world, miners must innovate at scale and at speed.

Digital technology enables AI transformation across the organization

Digital technologies and AI can empower miners to overcome their challenges, accelerate business outcomes, lower costs, and achieve more. But miners require reliable outcomes from their investments, including where they choose to invest in technology.

Mining companies are under pressure to meet multiple, often conflicting, requirements and expectations. They face significant challenges optimizing across the mining value chain for profitability and productivity, safety and health, and sustainability and risk.

Their world is tough enough. Miners require reliable outcomes from their investments including their digital investments. Digital technologies and AI can empower miners to overcome these challenges and achieve more.

Using these industry pillars below, which contain the most common and impactful digital solutions to mining challenges, help mining clients and partners accelerate business outcomes, lower costs, and reduce risk. By quickly solving common challenges, these industry pillars free up professionals enabling them to work on more valuable activities and innovate at scale and at speed.

Collectively, this framework encompasses more than 60 proven mining uses cases. Here, 'proven' means that each use case was successfully delivered multiple times—thereby the reference model, technologies, and associated partners are available.

Industry Pillars

Empower your workforce

Build an inclusive and collaborative culture that attracts, engages, and retains employees who are empowered to do their best work

- Digital field worker
- Talent management and skills enhancement
- Knowledge management and collaboration
- Productivity and process improvement

Operate for the future

Increase operational profitability and productivity by securely connecting and maximizing existing assets

- Health and safety
- Intelligent supply chain
- Connected assets and operations
- Physics-based models

Accelerate to net zero

Achieve net-zero commitments through emissions reductions, grid decarbonization, and renewable energy optimization

- Manage emissions and environmental performance
- Manage and reduce carbon
- Enhance renewables and decarbonize the grid
- Power the intelligent grid

Unlock sustainable business

Create new business models with innovations that serve customers and stakeholders, expand your market position, and increase growth opportunities

- Accelerate energy efficiency
- Scale EVs
- Business innovation
- Enhance sustainable industries

This is a powerful way for miners to do more with less.

By quickly addressing common challenges, these solutions can enable mining professionals the time they need to work on more valuable activities and innovate at scale and speed.

As the global demand for energy—and minerals—continues to rise, the mining industry must continue evolving and innovating at a rapid pace to remain competitive and sustainable. For mining companies to remain competitive they need to become more insight-driven and collaborative so they can achieve better business outcomes. AI is key to achieving this.

The AI journey leads toward the digital, sustainable mine of the future

Microsoft's vision for the Digital Sustainable Mine of the Future (DSMotF) combines the physical mine with new ESG-aligned business models and capabilities enabled by an intelligent enterprise digital backbone. With such a powerful backbone, miners can innovate at scale and at speed.

Our vision for the Digital Sustainable Mine of the Future provides a framework with six categories of attributes we'll examine in the following sub-sections.

Timely: The digital, sustainable mine of the future would provide timely insights into changing conditions. It would leverage the Industrial Internet of Things (IIoT) and utilize pervasive sensors and networks. Essential information would flow to decision makers and automated processes.

Insight-Driven: Analytics would draw data from a data foundation, implemented as a systems of intelligence layer, to provide actionable insights to decision makers and automated processes. This would enable operations to rapidly sense and respond to conditions and quickly optimize across various goals and constraints.

Human Enabling: Mobility, hybrid work, and augmented reality would enable a digital workforce of frontline workers, information workers, and other professionals to work more safely and more effectively most anywhere.

Flexible: To create new capabilities quickly, miners would leverage citizen developers and citizen data scientists using low-code, no-code tools, copilots, and generative AI. Various accelerators would shorten the time to a solution while reducing cost and risk.

Extensible: Energy transition, climate change, and increasing regulation are creating pressure for stronger interdependency among miners and their partners, vendors, and customers. Miners would build interconnections with technologies like the industrial metaverse, open platforms, and open standards.

Interoperable: Finally, a digital, sustainable mine of the future would be interoperable at an entirely new scale. Through open mining ecosystems, miners and their partners, suppliers, vendors, and customers would share data and information securely and solve complex problems. Together they would unlock additional value.
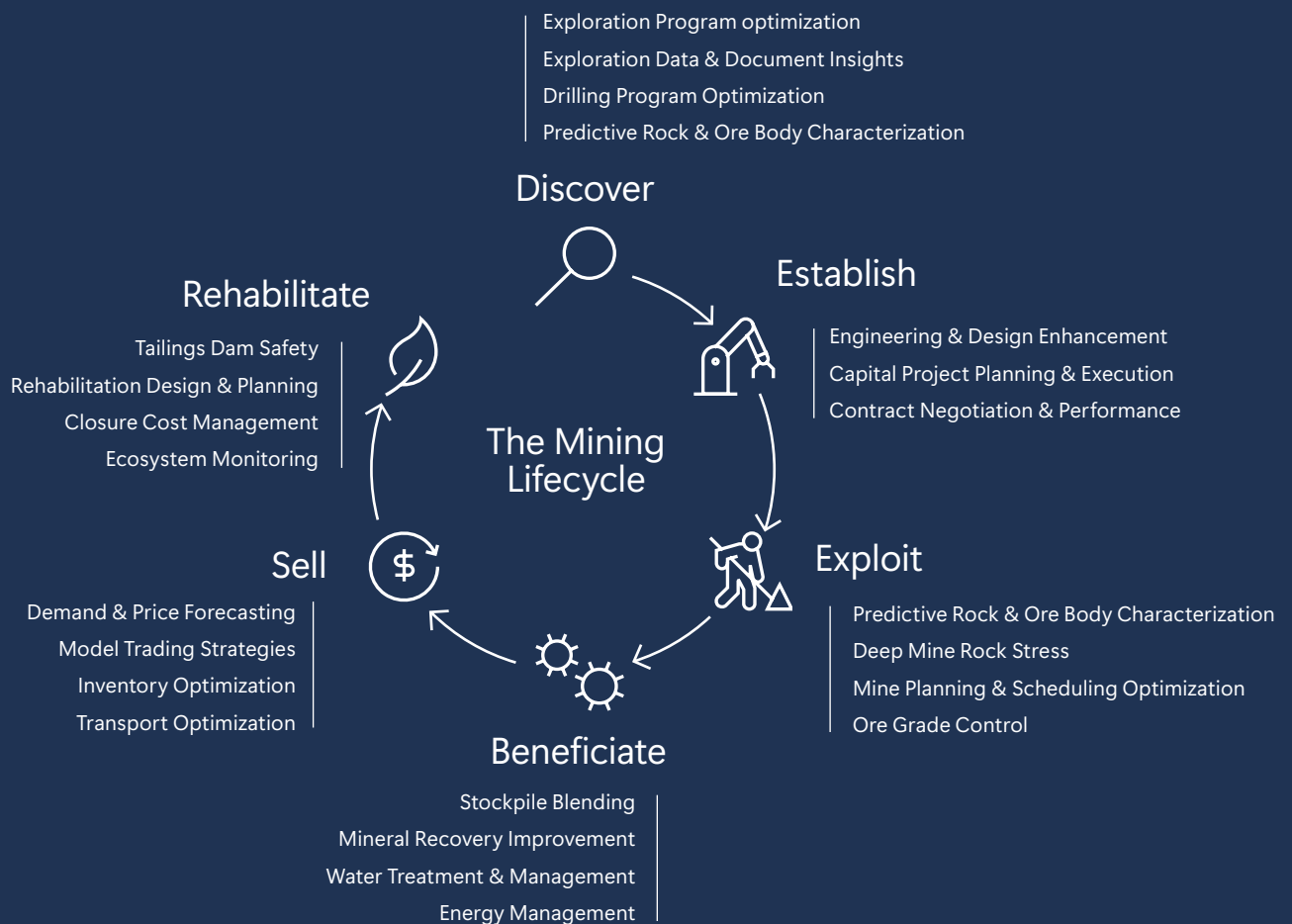
Innovating at scale and speed across the mining lifecycle

Contrary to popular belief, mining companies and their partners are innovators. The mining industry was one of the early adopters of AI with other industries like manufacturing, technology, retail, financial services, and transportation. These industries have used AI to process large amounts of data, generate insights, and provide solutions.

Early mining solutions were often focused on autonomous vehicles and predictive maintenance, process improvement, and dashboards for specific processes and equipment types. As one example, the mining group Rio Tinto has operated fully autonomous haul trucks since 2008. [12] And since June 14 2019, Rio Tinto has operated its 1500 km-long fully autonomous AutoHaul™ railway. [13]

Recent solutions, enabled by advances in AI, are tackling significantly more complex challenges. In the sections to follow, we'll examine ways in which miners are exploring AI's potential across these six phases of the mining lifecycle.

Discover
- Exploration Program optimization
- Exploration Data & Document Insights
- Drilling Program Optimization
- Predictive Rock & Ore Body Characterization

Establish
- Engineering & Design Enhancement
- Capital Project Planning & Execution
- Contract Negotiation & Performance

Exploit
- Predictive Rock & Ore Body Characterization
- Deep Mine Rock Stress
- Mine Planning & Scheduling Optimization
- Ore Grade Control

Beneficiate
- Stockpile Blending
- Mineral Recovery Improvement
- Water Treatment & Management
- Energy Management

Sell
- Demand & Price Forecasting
- Model Trading Strategies
- Inventory Optimization
- Transport Optimization

Rehabilitate
- Tailings Dam Safety
- Rehabilitation Design & Planning
- Closure Cost Management
- Ecosystem Monitoring

The Mining Lifecycle

Discover: Miners are exploring AI's potential to find more minerals while decreasing exploration costs. This is essential to restoring value creation in exploration. Miners are looking to optimize their exploration programs, derive insights from structured and unstructured data contained in documents, optimize exploration drilling programs, and predict rock and ore body characteristics.

Establish: Miners are exploring AI's potential to reduce the cost, time, and risk in large scale capital projects. This enables and accelerates building new mines and mine extensions to deliver climate-smart minerals on time. Enhancements can be made throughout this phase, from engineering and design, to improving capital project planning and execution, streamlining contract negotiation, and improving contract performance.

Exploit: AI can help miners recover more ore from the ground, reduce dilution, lower costs, and improve safety. This is essential to maximizing the value of the mineral asset while operating more profitably and safely. Miners are looking to predict rock and ore body characteristics, model rock stress in deep mines, optimize mine plans and schedules, and better control ore grade.

Beneficiate: Miners are exploring AI's potential to recover more minerals and metals in the mill, reduce costs, and protect the environment so they can operate more profitably, productively, and safely. Miners are looking to improve ore blending, optimize crushing and grinding circuits, lower comminution energy consumption and costs, enhance process water treatment, and better manage energy.

> "A new collaboration between BHP and Microsoft has used artificial intelligence and machine learning with the aim of improving copper recovery at the world's largest copper mine. The use of new digital technology to optimize concentrator performance at BHP's Escondida operation in Chile is expected to improve copper recovery." [14]
>
> - BHP press release, 30 May 2023

Sell: AI can increase revenue, reduce costs, assure delivery, and reduce risks. This is essential for profitability, productivity, and value creation. Miners are looking to optimize trading strategies and forecast commodity demand and price—and to optimize inventories, transport routes, and costs.

Rehabilitate: Miners are exploring AI's potential to reduce costs and risks while improving environmental outcomes to help protect the environment and their communities and maintain a license to operate. They are investigating how to improve tailings dam safety and to prevent tailings dam failures, how to improve rehabilitation designs and plans while minimizing mine closure costs, and how to better monitor the ecosystem before, during, and after a mine closure.

Empowering new ways of working

Harness next-generation AI technology to go farther on your journey

In the fall of 2022, generative AI began to enable new creative and innovative capabilities with the potential to transform mining. With these advancements, miners can derive greater value from data, improve the way they work, and transform their business. Recent advancements in AI provide new capabilities on top of existing ones, like geostatistical methods. With AI, miners can leverage the latest techniques to solve complex problems including Reactive Machines (RM), Machine Learning (ML), and Deep Learning (DL).

These advancements are changing how miners understand, experience, enhance, accelerate, create, and innovate. We'll now look at why these categories of value are important for miners in the following sub-sections.

| Understand	Experience	Enhance
Accelerate	Create	Innovate

How we UNDERSTAND our world, especially the business of mining

AI enables deeper understanding across four vectors as described below.

Insights are especially important in the complex business of mining. In 2018, one mining executive explained its importance this way, "We don't need 'data-driven.' We have too much data. What we need is insight-driven." [15] Here, AI has the potential to improve insights by evaluating large quantities of data from multiples sources, which leads to better actionable insights. Miners use insights derived from data to improve and accelerate decision making, and to automate equipment and processes, for better business outcomes.

Modeling enables miners to identify the best conditions, parameters, and configurations for a given mining problem. These problems may involve scientific, engineering, or business questions. Here, AI can improve the accuracy and efficiency of modeling by analyzing large volumes of data to identify patterns that humans may not detect. More efficient modeling yields more precise predictions and better designs with fewer resources expended.

Analysis is a mainstay in mining. It is used to grade, classify, categorize, assess, rate, evaluate, and appraise. Here, AI can improve analyses by reasoning over vast data sets with multiple formats including structured, time-series, video, and more. Miners can use the results from this analysis to improve profitability, productivity, mineral recovery, efficiency, effectiveness, availability, utilization, workforce safety and health, and environmental outcomes.

Simulation is used to model and test the behavior of complex mining systems. These systems may involve scientific, engineering, or business questions such as the mineral deposition for an ore body, the stress field for an underground mine design, or the resilience for a critical supply chain. Here, AI can help improve the accuracy and efficiency of simulations by automating parameter selection, identifying, and correcting errors in the underlying model, and applying non-traditional simulation techniques. Miners can thereby gain a deeper understanding of complex challenges and options for better decisions and business outcomes.

How we EXPERIENCE the workplace and the experiences we create there

AI produces insights that, when surfaced to users through their devices, enable them to understand information more clearly, make wiser decisions, and achieve better results. Workers feel a greater sense of accomplishment and satisfaction. AI also enables mining leaders to refine existing processes and to define new processes that can modernize and transform the work experience. Combined, these positive effects from AI can strengthen employee recruitment and retention strategies, boost employee engagement, and help organizations be perceived as an employer of choice.

AI transforms workplace experiences across the human-system interface through several dimensions as detailed below.

Visualization provides mining and other professionals with a more intuitive way to understand insights and explore underlying data. The visualized insights may involve conditions and/or trends for any mining subject of interest such as workers, processes, equipment, financials, contracts, inventories, and more. Here, AI can help identify patterns in predictive rock and ore body characterization, improve predictions in predictive maintenance, and optimize plans or schedules in adaptive planning and scheduling.

Collaboration enables miners to work better together and improve communication, productivity, and innovation in an environment where everyone can share their knowledge and expertise toward a common goal. Here, AI can automate routine tasks so participants are able to focus on what matters most, to identify and correct errors and inconsistencies that will yield higher quality artifacts, and to identify insights that will improve individual and group decision making.

Assistance from chatbots and digital agents enables workers to be more productive, work safer, and feel more satisfaction. Digital assistance helps mining companies improve productivity, lower costs, and enhance the employee experience. It can also improve recruitment and retention efforts by promoting employer of choice rankings that in turn improve worker perceptions. Here, AI has the potential to make chatbots and digital assistants be more responsive and capable of handling diverse and demanding user requirements in mining.

Augmentation from robots and collaborative robots (co-bots) also enables workers to be more productive, work safer, and feel more satisfaction. These technologies reduce physical strain by automating repetitive and strenuous tasks and free up time for more valuable activities. Robots and co-bots enhance quality by automating tasks that require the most precision and consistency. These technologies, unlike humans, can operate continuously and produce results without interruption. Robots and co-bots can operate in hazardous environments, such as 'smoke time' after a blast, where worker safety is most at risk. Here, AI can transform mining operations by enhancing the capabilities of both robots and co-bots.

In early 2023, Roy Hill launched RoyBot, a chatbot powered by Azure OpenAI Service and Azure Cognitive Services. Employees interact with RoyBot on an internal web application and use natural language to ask RoyBot questions ranging from production data to company policies and procedures, and even general HR information. [16]

> "AI has incredible potential in all industries, including mining, and we are fortunate that through the leadership and encouragement of our Executive Chairman, Mrs. Gina Rinehart, we are consistently pushing the boundaries of what is possible in this space."
>
> - Kate Flanigan, Executive General Manager of Technology, Roy Hill

Automation transforms operational productivity, financial dynamics, and safety conditions of mining operations. Automation can improve workforce safety and health, increase productivity, reduce unscheduled downtime and cost, enhance quality and predictability, and provide many more benefits. AI can uplevel mining operations by automating equipment and processes, improving productivity and efficiency, and promoting safer and more profitable mining operations. It can also boost accuracy and reliability in robotic process automation (RPA), data analytics, decision making and more.

How we ENHANCE processes and activities to attain operational excellence

AI is redefining how the industry achieves operational excellence. It already enables autonomous vehicles, predictive maintenance, adaptive planning and scheduling, predictive rock and ore body characterization, mineral recovery, and energy optimization. With AI we can enhance operational excellence in new ways, across four key vectors as detailed below.

Optimization helps drive enhanced productivity, profitability, and safety. It enables mining operators to plan, schedule, execute, measure, and manage with greater accuracy and precision. Here, AI can produce insights for more cost-effective operations, provide analysis across data sets to yield more resiliency, and be used to predict outcomes in various scenarios such as blasting.

Stability helps ensure predictability and reliability in mining operations. It improves productivity, planning accuracy, supply chain efficiency, safety outcomes, risk management, and more. Here, AI can help teams improve exploration outcomes and cost efficiency, predict failures before they disrupt production, enhance blast designs for better fragmentation and over-/under-break control, and more.

Productivity includes attributes such as profitability, efficiency, effectiveness, and safety. Unfortunately, productivity is trending downward in mining. A McKinsey study found that miners were 28% less effective digging and hauling one ton of material compared to a decade earlier. [17] Miners must reverse this downward trend in productivity through better operational practices, workforce enablement, cost controls, and innovation. Here, AI can help improve productivity across equipment, processes, and the workforce. AI-generated insights are helping miners reduce downtime through predictive maintenance, improved mine designs, tune plans and schedules, automated tasks, enhanced decision making, and more. Miners can use AI to improve exploration outcomes, detect costly mistakes in designs and plans, improve resource utilization, reduce waste, increase predictability and reliability, and more.

Quality is one of the most critical priorities in mining operations. Miners strive to maintain quality in every stage of the process, from exploration and economic viability assessment of discoveries to ore extraction and processing. Miners also work to maintain quality in the data, interpretations, and decisions upon which their business operates. To use AI in mining, a solid data foundation and quality data are essential. AI has the potential to improve quality by detecting errors in designs and plans, optimizing blasting, and enhancing mineral recovery. With respect to data, AI can improve quality by automating data entry, detecting duplications and errors, and by converting unstructured data into machine-readable formats.

How we ACCELERATE outcomes

AI opens new avenues for accelerating outcomes which yield several benefits for miners. For one, it increases the value of investments which, in mining, are often quite large. It also decreases cost, risk, and resource commitments. Accelerating outcomes builds competitive advantage and fuels business growth. It improves problem resolution and decision making. And it hastens greenhouse gas emissions reduction and realization of corporate ESG commitments.

We can think about AI-enabled outcome acceleration across four categories as detailed below.

Value realization is paramount to mining operations. Mining value chains extend from ore identification through extraction and processing to final customer delivery. As such, mining value chains are complex and often dependent upon other parties such as railroads and ports and the customs offices that oversee imports and exports. These complexities are growing as the need for climate-smart minerals is changing the commodity demand mix and redefining suppliers and buyers. New strategic mineral legislation, such as the Inflation Reduction Act [18] in the US and the Critical Minerals Strategy [19] in Canada is creating both barriers and opportunities.

AI can be a powerful ally across this intricate landscape of mining value chains. It has the potential to help miners effectively manage their value chains, drive profitability, and gain a competitive edge. AI-enabled trading systems can help miners analyze market trends and forecast mineral and metal prices. AI-enabled logistics systems can help miners optimize routes and avoid disruptions from geopolitical conflicts and piracy.

Time-to-discovery holds increasing importance in the mining industry. The world requires significant quantities of climate-smart minerals and metals to meet 2050 goals. However, ore deposit discoveries are now fewer, smaller, and more expensive.

Miners must discover more new ore deposits faster while significantly improving the value-to-cost proposition.

In mineral exploration, AI can improve time-to-discovery and cost effectiveness for finding new ore deposits. AI-enabled systems can predict and target potential deposit locations from vast geological, geophysical, and historical exploration datasets. AI-enabled processing of remote sensing and surveying data can extend the reach of exploration into remote areas. AI-enabled modeling, leveraging subsurface digital twins, can produce insights into subsurface structures and potential deposits.

> "Currently ~50 deposits (>="Moderate" in-size) are found each year in the world. This is half the rate prevailing prior to 2005… It now costs ~$200M USD to make a discovery, up from $65M USD (in constant June 2023 dollars) prior to 2005."
>
> - Richard Schodde, Managing Director, Minex Consulting, International Mining and Resource Conference 2023

In this way, AI can transform exploration from a labor intensive, time-consuming activity to a more agile, data-driven endeavor.

Time-to-production holds similarly increasing importance in the industry. The timeline for supplying climate-smart minerals and metals to the world is quite short—however, not all discoveries become the minerals and metals the world needs. Worldwide, less than half—about 45%—of all discoveries since 1950 have become producing mines. [4] For those discoveries that do become mines, the time from discovery to production (time-to-production) can average 12.4 years and even exceed 50 years. [4] The initial investment can reach several billion dollars, as with the Simandou iron ore project where the potential investment could exceed $15B USD. [21] Miners must shorten the time-to-production while converting more discoveries into mines and decreasing costs.

AI has the potential to accelerate the construction and commissioning of new mines and their extensions. During project initiation, AI-enabled systems can help miners draft project proposals and evaluate financial and resource alternatives. During engineering and design, AI-enabled systems can assist professionals with collecting and validating criteria, preparing concepts, detecting technical errors, and evaluating options to yield the

definitive version. During construction, AI-enabled systems can assist miners with shaping contract terms, improving contract performance, optimizing plans and schedules, adapting plans and schedules, and improving equipment maintenance to minimize downtime. During commissioning, these systems can assist technicians with tuning equipment settings, diagnosing faults, troubleshooting problems, and drafting turnover documentation. Across the entire project lifecycle, AI can empower miners to make insight-driven decisions that enhance productivity, reduce downtime, and accelerate the journey from discovery to production.

Sustainability Impact is critical to securing and maintaining the mining license to operate. ESG performance, actual or perceived, spurs stakeholders, community, and regulatory actions. Miners are working to reduce, and even eliminate, greenhouse gas (GHG) emissions from their operations; the conversion to electric vehicle fleets and to renewable and clean electricity sources are clear examples. Miners are also working to protect water resources, ecosystems, and biodiversity.

AI can help miners meet their corporate ESG commitments as AI-enabled systems use data to identify risks that help miners make more informed decisions in line with ESG goals. AI-enabled systems can evaluate and predict risks to worker safety and health, to the environment, and to community well-being. For example, an AI-enabled system can monitor tailings dam conditions along with groundwater, weather, and other conditions to help miners prevent disasters. In another example, AI-enabled systems can analyze mine design, geology, weather, groundwater, tidal force, seismic, and other data to help coal miners prevent longwall cavitation.

How a mine operates determines its business performance and its ESG performance. AI helps miners make insightful decisions and operate to achieve both business goals and to meet ESG commitments.

How we CREATE in every phase of mining

AI is a powerful ally for amplifying human creativity and opening new possibilities. It is enhancing creativity for many businesses by automating repetitive tasks which frees professionals to focus on higher-value thinking. Generative AI can augment human creativity by promoting divergent thinking, challenging expertise bias, assisting in idea evaluation, supporting idea refinement, and facilitating collaboration. [22]

AI can help enable creativity across five key areas in mining as detailed below.

Exploration programs must improve to meet climate-smart mineral demand. As noted previously, exploration must lead to more discoveries, faster, and at a favorable value-to-cost ratio. AI is playing a key role in this effort to help teams process vast datasets, promote divergent thinking, challenge expertise bias, and bolster collaboration. Several mining companies including BHP, Vale, Teck Resources, and Debswana Diamond Company are already using AI-enabled prospecting. [23] [24] [25] [26]

Engineering and design play increasingly important roles in constructing new mines and their extensions as resource depletion drives miners to go deeper underground. As miners go deeper, engineers and designers face new challenges ranging from increased in-situ rock stresses and ambient temperatures, to longer workforce transits and ore haulage, and greater seismicity. Here, AI has the potential to improve engineering and design creativity and productivity. AI-enabled algorithms can help engineers and designers generate multiple design alternatives based on specific requirements and optimize for cost, time, sustainability, and other priorities. AI-enabled algorithms can analyze vast quantities of data to assist engineers and designers with key decisions for mine/mill performance, material choices, equipment, worker behavior, safety, energy consumption, and more. These algorithms can also help engineers and designers apply digital-first principles to create their digital sustainable mine of the future. [27]

Program and project management Management helps teams optimize the cost, time, and resources in large mining capital investments. More than just delivering on time and on budget, it's about creating value for stakeholders and customers while reducing risk and improving safety. Program and project managers are using AI to create schedules, work breakdown structures, and resource allocations. They are also using it in the creation of risk logs, risk descriptions, mitigation actions, and contingency plans. [28]

Contract modeling and management are important tools to ensure alignment across parties, meet legal and regulatory compliance requirements, manage risks, optimize performance, and minimize disputes. AI is being used to improve the ease, efficiency, and effectiveness of contracting processes. In one example, Daimler AG digitally transformed its business including its companywide procurement system. The new solution is based on the SAP S/4HANA database, SAP Supplier Relationship Management on HANA, and the Icertis Contract Management platform. Daimler AG is using Microsoft Cognitive Services, Azure Machine Learning services, and Azure Bot Service to further reduce costs and risks in the contracting process. [29]

Reports and summaries are ubiquitous in the mining industry and play a necessary part of everything, from daily operations to annual financial reporting. Applying AI to reporting and summarization improves efficiency and productivity. In one example, Sandvik Coromant digitally transformed into a data-driven company to maintain their market position and grow future business. To enable more advanced analytics, the company needed to connect more than 20 production sites and replace legacy reports with a new solution that leveraged Power BI and Azure Machine Learning. [30]

How we INNOVATE

AI has been applied to innovation in the mining industry for more than a decade. Applications range from simple to enormously complex and include solutions from smart dashboards to predictive maintenance and autonomous vehicle fleets. Today, AI enables mining organizations to operate more profitably and productively with greater efficiency and effectiveness while improving workforce safety and health.

In this section we'll investigate new frontiers in mining, including the sizable role generative AI is already playing.

Content Creation enabled by AI helps people be more productive, efficient, and cost effective. It helps workers spend more time on high-value activities that benefit the business. New forms of generative AI can help individuals produce text, images, and videos. One especially fruitful area for both mining companies and their partners (OEMS, SIs, and ISVs) is using generative AI to create software. Drafting code with generative AI saves significant developer time and frees them up to focus on other outputs.

New products and services is an exciting area of collaboration for miners and their partners. Collaborating over shared data and AI-generated insights, OEMs can improve equipment design and production. In turn, mining companies get equipment that performs better and lasts longer. Intelligence at the edge enables OEMs to create smart equipment and products. When OEMs apply AI to gather data from across the deployed fleets, they can offer new insights and services to their mining customers.

New business models, enabled by AI, is a promising space for mining companies and mining partners (OEMs, SIs, and ISVs) that are exploring new platform-based service offerings. AI-enabled SaaS applications can help organizations address safety, health, and sustainability requirements. Platform and application providers benefit in turn from new revenue streams—while consuming organizations benefit from proven solutions at a lower cost. Mining companies and mining partners are also exploring Open Mining Ecosystems to monetize data and algorithms securely, privately, and contractually. Applying AI to larger cross-organizational data sets would generate powerful new insights.

Generative AI is creating new frontiers in mining

The mining industry is abuzz over generative AI and many mining companies are exploring new use cases. There is good reason for such excitement because generative AI can significantly improve worker productivity with the potential to add $2.6 to 4.4T USD in annual value to the global economy. [31] Since the mining industry comprises about 7% of the global economy, the potential impact on mining productivity could be $182 to 308B USD in annual value.

However, before chasing new technology, miners should focus on business potential within their unique context. This requires rethinking accepted methods, practices, and especially assumptions. And it involves reimagining mining across operational, financial, workforce, partnership, regulatory, and sustainability dimensions. For some miners, it may even involve reimagining their vision, strategy, and market.

Recent advancements in AI open four new frontiers for innovation in mining, which we'll explore in the following sections.

Optimizing the value chain and lifecycle

Revolutionizing the nature of work

Capturing value in near-real time

Creating value across corporate boundaries

Optimizing the value chain and lifecycle

Optimization is not new to the mining industry. Seeking better operational and business outcomes, mining companies and their partners (OEMs, SIs, and ISVs) have long employed various digital and non-digital methods to optimize processes, activities, and tasks.

Recent efforts with AI have often focused on individual processes, activities, circuits, and equipment types. There are AI-enabled solutions for optimizing the crusher bin level [32], process water treatment [33], blast furnace energy consumption [34], and more. With respect to mining partners, there are AI-enabled solutions for improving product engineering and design [35], material quality [36], equipment operating efficiency, equipment sustainability [37], and more.

New advancements in AI unlock opportunities across the value chain and production lifecycle to achieve even greater operational and business outcomes. This optimization spans multiple processes, activities, circuits, and equipment types. With modeling and simulation, such optimization may span long periods of time sometimes referred to as the 'life of a mine.'

Optimizing across the value chain and lifecycle can yield dramatic results. In one example, A global moveable equipment OEM automated its end-to-end supplier invoice processing, saving over 300 labor-intensive manual entry hours for a single supplier alone. [38]

Revolutionizing the nature of work

The mining industry faces Herculean challenges with respect to its workforce. In general, mining is not perceived as an employer of choice. Mine sites are most often located where the talent base is quite small to non-existent, and where educational attainment, literacy, and digital fluency may be lacking. Work at mine sites is usually difficult, dirty, and dangerous compared to other industries. And, as the baby boom generation retires, the talent pool is shrinking. "Fewer people will be working by the end of the decade—and employers need to brace for a 'forever' labor shortage." [39]

To remain profitable and productive, mining companies and their partners (OEMs, SIs, and ISVs) must revolutionize the very nature of work and the workplace. They must accomplish more with fewer people while constantly developing and reskilling their employees. AI, especially generative AI, can propel this revolution in three key areas, which we will examine in the follow sub-section.

Knowledge Work: At one time, most digitally enabled automation solutions aimed at knowledge work focused on data collection, movement, processing, and management. More recently, this automation has expanded to include data analysis, dashboards, and reports with the advent of new tools like Power Platform Power BI. These tools have brought additional benefits including business process streamlining, productivity improvement, and lower development costs through low-code and no-code platforms. [40]

For mining companies and their partners, generative AI creates an enormous opportunity to reimagine and reinvent knowledge work.

> "Generative AI is likely to have the biggest impact on knowledge work, particularly activities involving decision making and collaboration, which previously had the lowest potential for automation."
>
> - M. Chui, E. Hazan, R. Roberts, A. Singla, K. Smaje, A. Sukharevsky, L. Yee and R. Zemmel, 2023

The knowledge work revolution in mining will transform business processes and disciplines across the mining lifecycle. Miners will employ AI, especially generative AI, to:

- Explore and find new mineral deposits
- Predict rock and ore body characteristics
- Enhance engineering and design of mines, mills, and other infrastructure
- Manage large capital projects
- Improve planning and scheduling
- Manage rock stress and movement
- Enhance mineral recovery
- Forecast demand and price
- Model trading strategies
- Manage mine closure costs
- And more

Productivity: AI, including generative AI, can help organizations and nations grow their productivity, an important capability considering persistent labor shortages. The benefit can be significant. Economic growth, which contributed 2.5% CAGR to global GDP from 1972 to 1982, fell to 0.8% between 2012 – 2022, a three-fold decrease. [31] During these same periods, productivity rose from 0.7% to 2.1%, a three-fold increase. [31]

Generative AI and other digital technologies accelerate productivity growth to offset impacts from an aging workforce, declining birth rates, and shrinking talent pool. AI-enabled productivity growth will remain an important lever for the mining industry as it addresses workforce challenges.

In one example, a Swedish mining company developed a solution using Azure AI Vision, Azure Machine Learning, and Azure Time Series Insights to bring greater productivity, sustainability, and safety to its other mine sites. [41] An Australian mining company pushed AI workloads to the edge to accelerate operational innovation at its mines which led to significant productivity gains and cost savings. [32] A Japanese mining OEM developed a solution using Azure Synapse Analytics and Power BI to double productivity. [42]

Automation: Again, recent advances in generative AI and natural language processing (NLP) play important roles in revolutionizing the nature of work. Applied on its own, or in combination with other technologies, AI could help mining companies and their partners automate between 60-70% of worker hours. [31] This will not come as a surprise to those working on zero-entry, "eliminate live work," and fully autonomous mine initiatives.

AI-enabled automation enables mining companies and their partners to address several current and future workforce challenges. It could help organizations become an employer of choice and provide reskilling and career development opportunities. It increases productivity while moving workers to high-value activities that are also more engaging, satisfying, and safer. And it fills the talent gap arising from mine site location and from generational talent pool shrinkage.

In a way, the COVID-19 pandemic provided a sneak-peek at this new world of work. One innovative Australian-based mining company used digital technologies to deliver support and training to field workers from around the globe. [43] Another European-based mining and metals company used digital technologies to make faster and more informed decisions when COVID-19 disrupted many on-site activities. [44] And one South America-based mining company used digital technologies to communicate its COVID-19-related plans and processes to large groups. [45]

Capturing value in near real-time

Time is the most restrictive resource in mining. One cannot create or buy more time—and once time has passed, its value is lost forever.

Time is perhaps the most under-utilized resource in the mining industry. At Microsoft, our teams who work on-site with mining clients and their partners still encounter manual data recording and data entry, paper-based calculations and workflows, printed paper reports, and physical status boards. They also find disconnected equipment sensors, connected sensors lacking integration with core systems, isolated proprietary applications and data stores, and legacy software lacking APIs. Each is a source of delays, errors, and rework.

These conditions lead to significant lost time. Too often the time to act has passed before key personnel receive the data. And too often such data is incomplete or rife with errors.

During a recent onsite project with a South Asian mining client, our team found that progress and status were reported verbally during an end-of-day meeting. By that point, the opportunity to act had already passed. What's more, the opportunity to incorporate learnings into the next day's plan had also passed. Worse still, the client's onsite general manager reported that half of the information received during these meetings was incorrect!

To remain profitable and competitive in an increasingly difficult market, mining companies and their partners must treat time as a valuable enterprise resource. They must convert data into insights, and insights into actions, in near real-time.

That means detecting and acting on signals to either realize value from an opportunity or avoid negative impact from a problem or failure. These signals can originate from many sources including, but not limited to: operations workforce, supply chain, market, customer, regulatory, and the community.

Such near real-time capabilities are in use in mining today. In one example, a European-based mining and metals company recently developed a solution that analyzes data in real time to enable predictive maintenance and reduce costs. [44] A multi-national technology conglomerate with clients in the mining industry developed a solution using Azure AI services, Azure AI Vision, Azure Machine Learning, and Machine Learning Studio to accelerate AI model development at real-time speed. [46]

Creating value across corporate boundaries

Access to data limits what organizations can reason over to derive actionable insights. This, in turn, limits the value they can realize. There is a direct relationship between the quality and quantity of data inputs and subsequent outputs: less volume of data (and lower quality) leads to fewer, and poorer insights. Whereas a higher volume of data (at a higher quality level) delivers more insights, and more quality insights.

In mining there are multiple forces that restrict available data, often determined by either process maturity forces or digital maturity forces. Process maturity forces include manual data recording and data entry, paper-based calculations and workflows, printed paper reports, and physical status boards. Digital maturity forces include disconnected equipment sensors, connected sensors lacking integration with core systems, isolated proprietary applications and data stores, and legacy software lacking APIs. In addition, mining organizations may not share data across geographic boundaries, business unit boundaries, and/or site boundaries. The result is fewer actionable insights and reduced value realization.

Despite these restrictive forces, some mining clients and their mining partners are finding ways to increase their available data for mutual benefit. They are developing platforms to share data securely and privately and to share algorithms across corporate boundaries. This involves participation in open mining ecosystems.

These open ecosystems are built on a secure platform with a specialized trust framework. Participation in such ecosystems goes beyond typical supplier, vendor, or partner relationships. It may involve sharing and/or monetization of data and/or algorithms. It may also include sharing of operations and expertise. [47]

How Microsoft can support AI transformation

Turn technology into a business advantage

Microsoft has a strong track record of helping mining companies and their partners accelerate business outcomes with world-leading digital technologies and expertise. That's because of Microsoft's holistic platform and advanced technologies, open and flexible approach, enterprise-grade solutions, deep industry and technology expertise, and partner ecosystem. Working with Microsoft brings a distinct set of business advantages. In this next section we'll explore each set of advantages.

A trusted, flexible, and open-cloud platform

Today, the Microsoft Cloud infrastructure supports over two billion customers in more than 190 countries. With this unique experience and scale, the Microsoft Cloud can help organizations achieve higher levels of security, privacy, and compliance. Azure has received more compliance certifications than any other cloud provider, including major global, national, regional, and industry standards and regulations.

Microsoft's extensive global datacenter footprint covers more regions than any other provider, to better meet data sovereignty requirements. Azure fully supports hybrid architecture, offering complete flexibility and control of organizational data and applications delivered between public and private clouds and edge computing. The Microsoft Cloud works with any operating system, database, middleware, and application framework, enabling a wide range of choice over tools and platforms.

A powerful, adaptable, and open AI platform

At Microsoft, AI is the defining technology of our time.

> "The age of AI is upon us, and Microsoft is powering it. We are witnessing nonlinear improvements in the capability of foundation models, which we are making available as platforms."
>
> – Satya Nadella, Chairman and CEO, Microsoft

Microsoft's advancements in AI are grounded in its mission to empower every person and organization on the planet to achieve more—from helping people be more productive to solving society's most pressing challenges. Microsoft is committed to making the promise of AI real and responsibly. That means developing and democratizing the technology as a platform so people and organizations can use, build upon, and benefit from AI innovation.

Microsoft offers a range of AI products and services to help organizations infuse AI throughout every service experience. Microsoft's AI tools and technologies are designed to benefit everyone at every level in every organization. The Microsoft AI platform provides a suite of powerful tools, such as the Bot Framework, Cognitive Services, Azure Machine Learning and many more, that allow developers to incorporate AI easily and quickly into their applications and scenarios, enabling new, intelligent experiences for users.

Enabling AI transformation

With the Microsoft Cloud, we can help organizations power their AI transformation in three ways.

First, we've built AI capabilities into the Microsoft Cloud solutions that customers are already using today—helping everyone be more productive, more creative, more efficient, and more innovative with Microsoft Copilot.

We've offered simple things like autocomplete or PowerPoint Designer built into the products that people know and love. We think this is the type of innovation that really matters, giving customers pragmatic value every day. This is the same pragmatic innovation we're now applying to our Microsoft Copilots, which can change the way people and organizations operate.

Second, we're making it easy for any organization to build and extend AI capabilities into new and existing apps and Copilot solutions using the same open ecosystem stack and AI services Microsoft uses to build our own Copilots.

From a usability standpoint, we have a surface area comprised of billions of users. Our AI platform is put to use every day with the capabilities we bring to life at scale, across the Microsoft Cloud.

We're proud of our strategic, unique, and differentiated partnerships, such as our partnership with OpenAI, and the array of choice we provide customers through our wide range of partnerships.

And third, our commitment is built on a foundation of trust. Every organization needs to safeguard their business, their customers, and their data—particularly in this new era of AI.

We're helping organizations through co-innovation and by empowering everyone to build safety and responsibility into their AI journey from the start. We help organizations become more competitive, drive top-line revenue, and become more profitable.

Comprehensive, enterprise-ready solutions

Microsoft solutions span the full spectrum of business needs, from data access, high performance computing, advanced analytics, visualization, and business process automation. Windows 11 offers universal application capability across devices, with innovations like Surface, Surface Hub, and HoloLens. Individual and enterprise productivity is increased through a suite of collaboration, knowledge management, work process, mobility, business insights, and advanced analytics capabilities.

Advanced technologies designed for ease of use

Microsoft helps organizations apply advanced technologies to business challenges once deemed too costly or complex to solve. For example, Microsoft's Industrial IoT capabilities enable organizations to ingest data from any source, in any format, apply machine learning models, visualize data, and integrate results into collaboration and work process solutions. Data-driven insights enable individuals to make better business decisions and deliver better business outcomes.

Largest ecosystem of industry-leading partners

Microsoft has an extensive ecosystem of prominent systems integrators and independent software vendors which leverage existing technology investments and offer the flexibility to select the best solutions for each business.

Our partners design and deploy innovative, industry-focused solutions built on a Microsoft foundation, giving customers best-in-class technology coupled with deep industry expertise. Microsoft offers a leading end-to-end portfolio as well as an open and flexible approach which helps customers drive digital transformation across their organization to change the way it optimizes operations, empowers employees, transforms products and services, and engages with customers.

Transform your business with Microsoft

Work with Microsoft and its global partner ecosystem to extend and develop solutions that will transform your business. Tap into our knowledge and expertise with a business outcome workshop, deeper solution session, private preview, or customer focus group—or develop a proof-of-value or minimum-viable product to drive the right implementations and solutions for your business.

For more information on business solutions and case studies, please visit the Microsoft for Energy and Resources website.

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