MINING REIMAGINED

FUTURE BUSINESS ARCHITECTURES

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In our recent reports[1], we explored the large-scale drivers impacting the mining industry and the way its people make decisions on strategy, innovation and organisational architecture. We know the industry must transform under growing pressure to decarbonise and that technological advancements are paving the way for industry disruption. We also know that the way value chains are designed and operated will change, as will the role of people and their structures within an organisation. What we don't know is what those changes will ultimately look like in practice. While the purpose of a business might stay the same, the way it operates will change substantially.

This thought process has fostered a series of ideas, which have evolved into the paper presented here. Our aim is to bring together the insights gathered from survey data, interviews and various workshops to explore how future mining business architectures may emerge. We examine mining businesses through the lens of the different business purposes typically found in the industry: an explorer, an operator and a processor business. Each of these will experience their own unique challenges and will respond to these in different ways. We have identified several key drivers of change for each business type, and we encourage readers to imagine how these different challenges and architectures may apply to their particular business.

EXPLORER	OPERATOR	PROCESSOR
Creates value by finding and defining resources	Creates value by developing and operating mining assets	Creates value by producing refined (energy) mineral inputs

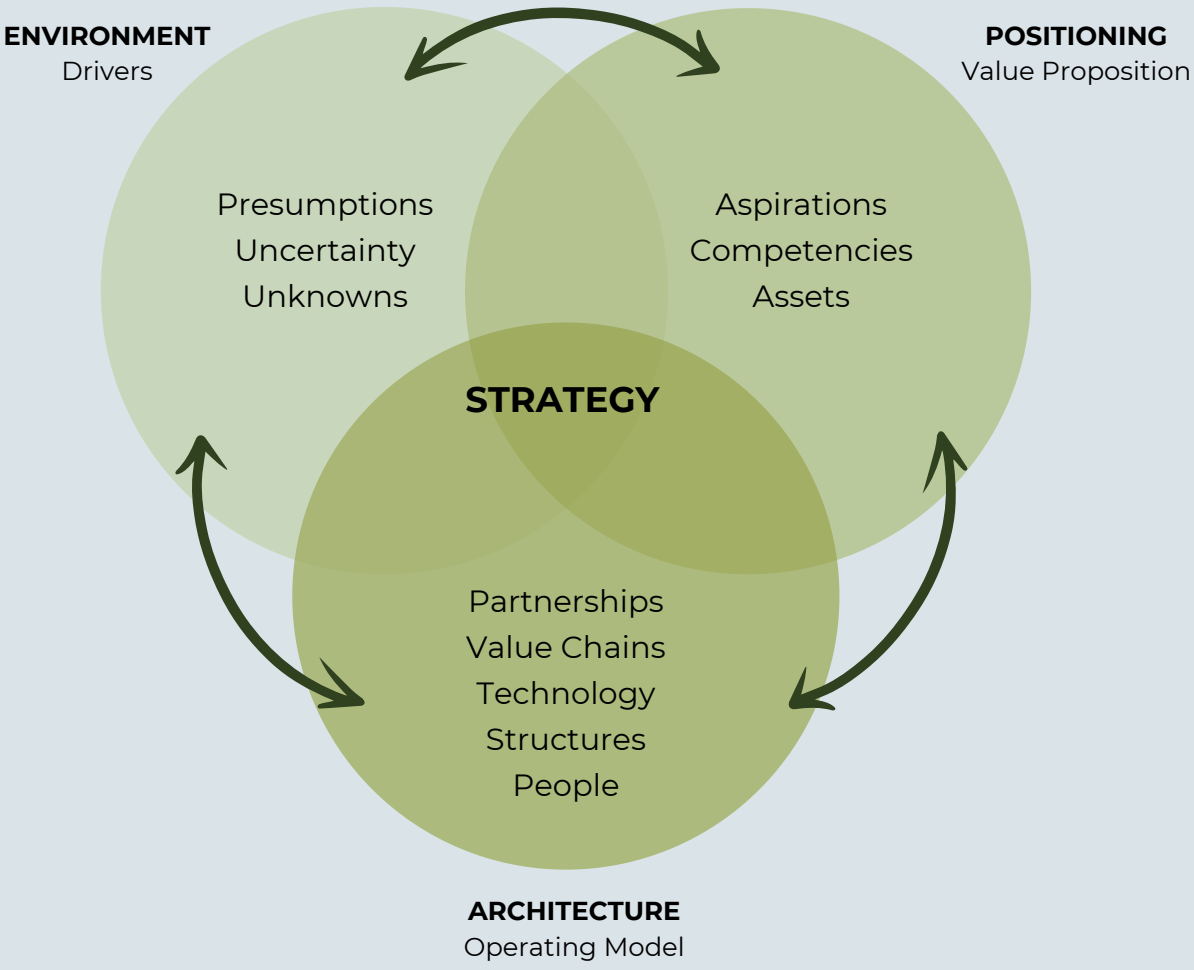
[1] https://stateofplay.org/reports/

CHANGE IS INEVITABLE

If you ask anyone what the future mining business might look like, there is an inevitable pause as they consider the sheer amount of change that might take place over the next 10-15 years.

> ***"...One theme that is actually prevailing all of our discussion is that change is going to happen whether you like it or not."***
> **Professor, US University**

In an effort to understand the potential shifts from the current known to the future unknown, we have defined the typical elements that comprise businesses architecture and examined these through the lens of both the key external drivers and our current survey data. The result is a set of potential changes to business architecture we hope inspires you to think critically about the future of the industry and what your business strategy may look like.



BUSINESS ARCHITECTURE ELEMENTS

While the structure of one business to another may vary considerably, the foundational elements that constitute a business will broadly stay the same. These can be condensed into five key elements.

Element	Objective	Typical design choices
Partnerships	The partnerships required to complement existing business capability to achieve both strategic and tactical business goals.	• Asset ownership models (land ownership, asset joint ventures, cross ownership) • Strategic partnerships (R&D, value chain integration, market entry, risk mitigation) • Tactical partnerships (sourcing, consortiums, innovation, community)
Value Chains	The structure and flow of all the stages of the value chain, including how value will be captured from all sources, stages and core products.	• Design function (efficient, agile, responsive, hedging)[2] • Capital structure (boundaries, processing hubs, logistics, connectivity, inventory) • Operational practices (sales and operations processes, decision analytics, data & ERPs)
Technology	The application of technology to all aspects of the business (products, core operational processes, decision making) to meet business objectives and mitigate risks.	• Energy sources (renewables, nuclear, storage, fossil fuels, grid integration) • Physical technologies (mechanical, chemical, biological, robotics & automation) • Digital technologies (communications, sensing, data, analytics and AI)
Structures	The structure of the business' executives, management, teams and services to effectively execute work and support the value and goals of the business.	• Corporate structure (holding company, strategic oversight, operationally involved) • Primary work delivery mechanisms (systems, projects, hierarchy, networks) • Levels (number, hierarchy and associated incentives)
People	The structure of a workforce which achieves sustainability and high performance, whilst also being appropriately skilled for the work and technology being adopted.	• Skills base (Strategic, operational, technical specialty, research and innovation) • Culture (Leadership style, symbols, decision processes, incentives, openness to change) • Diversity (gender, ethnicity, personality, age, experience)

[2] Adapted from Hau Lee Triple A supply chain

KEY EXTERNAL DRIVERS

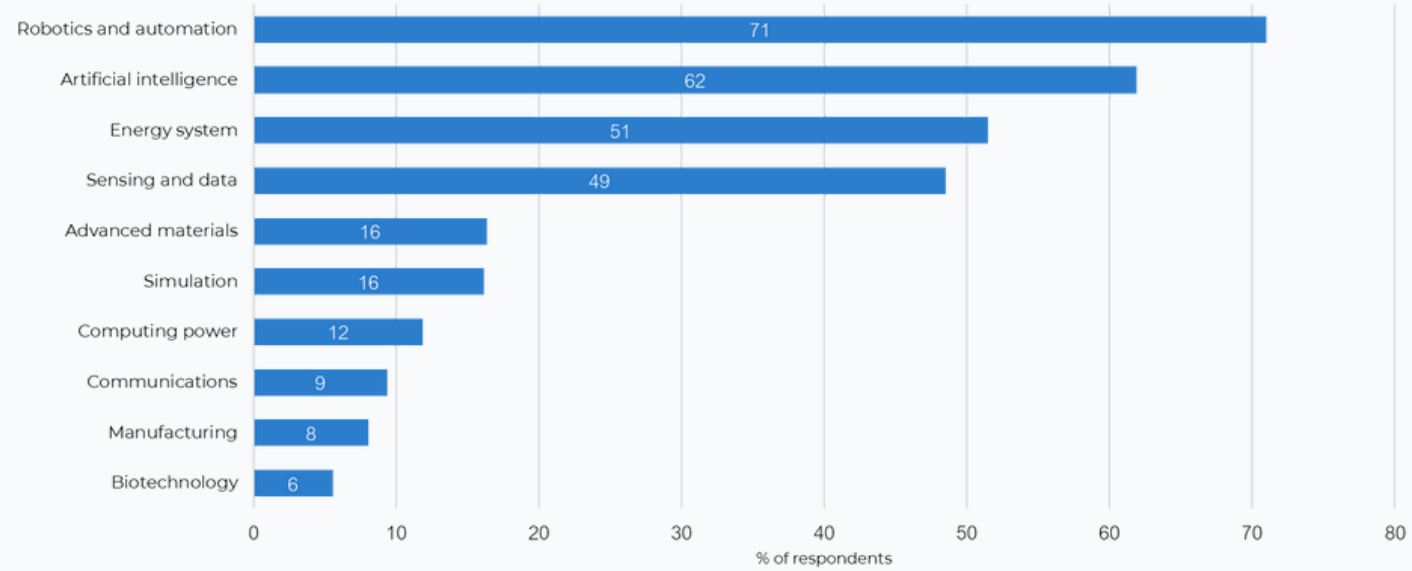
Business models and their supporting architectures are shaped in response to the external environment. Here we outline some of the current most impactful drivers in the mining industry.

Technology

60% of survey respondents believe technological change will have the biggest impact on innovation in mining over the next 15 years, only second to the energy transition. Robotics and automation (71% of respondents) are expected to have the biggest impact, followed by artificial intelligence, energy systems and sensing and data.

Question: Which underlying technology areas will have the biggest impact on mining over the next 15 years?

Respondents given three answers



> ***"Technological advance accounts for 80% of the productivity growth the U.S. economy has experienced."***
> **Robert Solow, Nobel Prize winner in Economic Sciences**

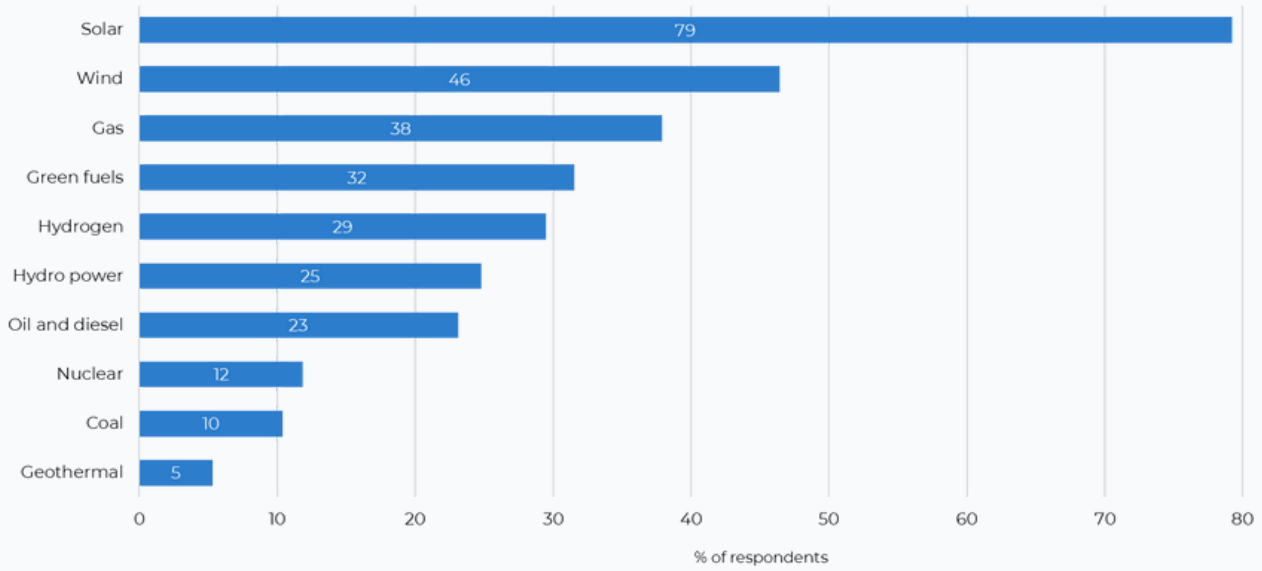
Most of these technologies aren't new, but they are evolving rapidly, particularly artificial intelligence. Going forward, we will likely see the role of technology supercharged as artificial intelligence and big data analysis combines with physical technologies, resulting in a transformation in the way businesses operate. This will have far reaching impacts on the way value chains are set up and are operated, as well as organisational structures. The people and skills required will also shift; with a high level of technological literacy, confidence, and ability to adapt required from the workforce.

Energy

The energy transition is seen as the broad global trend which will have the biggest impact on innovation in mining over the next 15 years. The expectation of solar, wind and green fuels being widely used as energy sources within mining in the future is growing rapidly – 79%, 46% and 38% of survey respondents listed these as the top three sources, respectively. The energy transition will be a major driver for changes across all aspects of business architecture, having a particularly large impact on technology and value chain design, as new forms of processing and logistics are optimised.

Question: What energy sources will become the most widely used in your country's mining companies over the next 15 years?

Respondents given three answer



"What the industry is pivoting to is saying that the metals we produce are essential for the clean energy transition. You can back that up by looking at the current tech stack with solar panels, wind turbines, batteries, and everything else. This energy system is, on average, 400 to 500% more metals intensive than the fossil fuel-based system it largely replaces."

Non-executive director, Mining Company

Perceptions

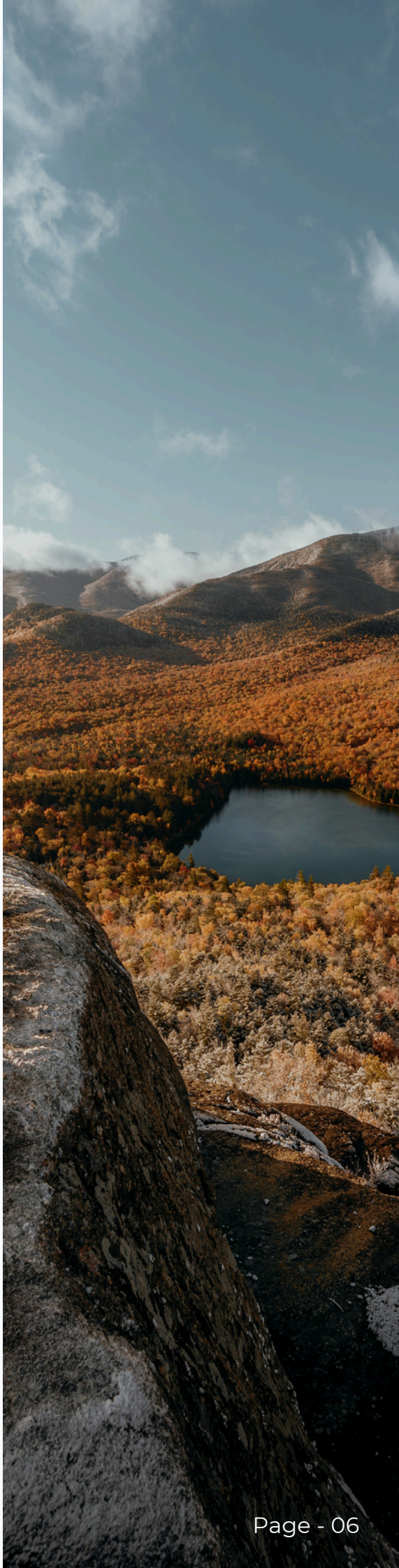
"And yet you look around the place… everything was either grown, mined or pumped. Everything society needs… you can't have any of that without mining. I think there's a massive disconnect between the public's perception of mining and the reality."

Partner, Investment Firm

The industry understands that there is work to be done when it comes to society's perceptions of mining – 73% of respondents believe the industry is viewed negatively. Negative perceptions have significant potential to disrupt the progression and development of the mining industry, impacting the way the industry operates, accesses capital, and attracts talent. They can also influence government policy. The industry is already seeing the impacts perceptions can play, with situations like First Quantum's mine delays and suspended production in Panama resulting from protestors becoming more common.[3]

Geopolitics

The world has experienced a sustained period of globalisation throughout the latter half of the 20th century. In more recent years there has been collective demand from countries around the world to democratise the production, transmission, and consumption of energy, altering international alliances as individual nations focus on their domestic priorities. Emerging policies such as Australia's Future Made in Australia Act, the US' Inflation Reduction Act and the EU's Green Deal demonstrate the shifting global commitments towards the shoring up of critical minerals supply, local manufacturing, and green energy production. This shift will impact partnerships, ownership structures, and value chain design and operations of future businesses.



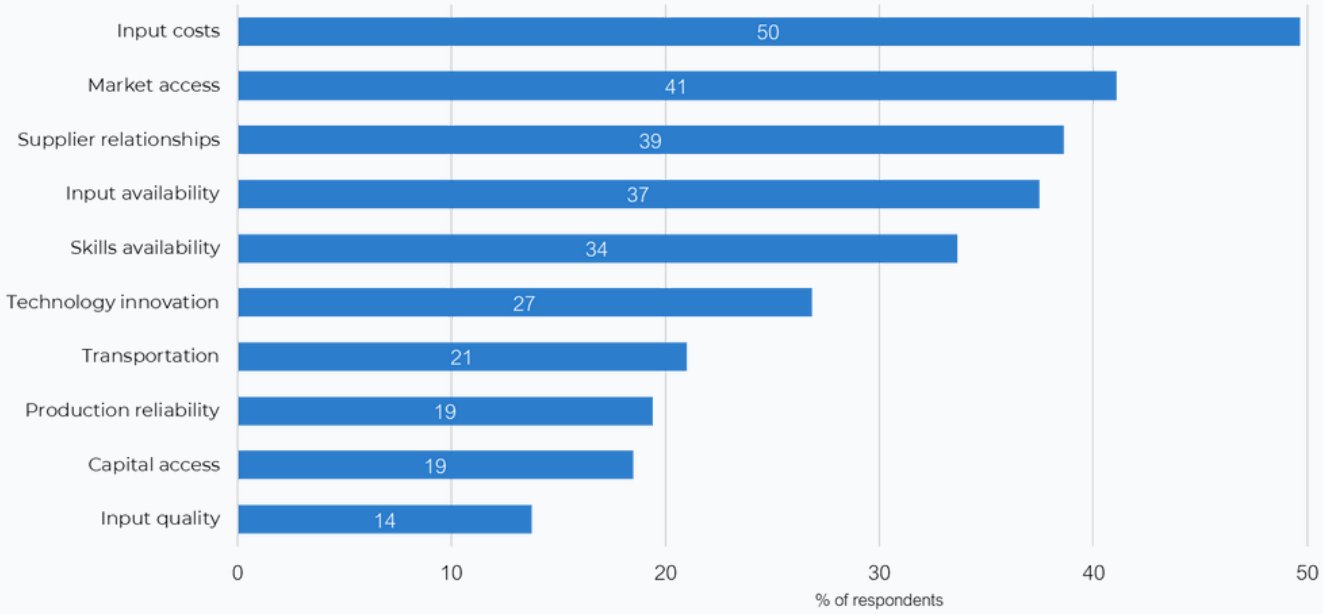
[3] https://www.mining-technology.com/news/first-quantum-have-been-forced-into-suspending-operations-at-panama-copper-mine/?cf-view

Supply Chains

Given the rollercoaster experienced by the business community more broadly over the last few years, it is unsurprising to see supply chains rank in the top three sources of potential disruption in the mining industry. Supply chains are a major capital and operating cost factor for companies; they define access to the market and cause price volatility. As a shift to de-globalisation takes places, the impact of supply chain factors will flow on to the partnerships, ownership structures, and value chain design and operations of future businesses.

Question: Where would de-globalisation of supply chains impact your business most?

Respondents given three answer



FUTURE BUSINESS ARCHITECTURES

If we look at the business architecture elements through the lens of the above key drivers, we can start to develop ideas around the pivotal changes that might take place within different mining businesses.

EXPLORER >>> OPERATOR >>> PROCESSOR

Creates value by finding and defining resources

Creates value by developing and operating mining assets

Creates value by producing refined (energy) mineral inputs

Expanded data sources
- Technology led
- Policy incentives
- Data quality

Broadened asset horizons
- Ocean mining
- Urban mining
- Specialisation

Clustering downstream
- Infrastructure capital
- Project approvals
- Recycling

New commercial models
- Capital increase
- Technology + asset
- Portfolio balance

Automations arrival
- AI enabled
- Data rich
- Systems work

Optimising supply-chains
- Integrated optimisation
- Consolidated assets
- Customer driven

Adaptable people
- AI adoption
- Community facing
- Adaptable to change

Shifting services boundaries
- Technical complexity
- Skills aggregation
- Services integration

Strong partnerships
- Technical capability
- Co-investment
- Shared intent

EXPLORER

An explorer creates value by finding and defining resources. Their DNA is embedded in taking risks for large rewards - to identify economically viable mineral resources in the hopes of either selling the deposit to an investor or mining company, or to develop a mine themselves. Their success (in addition to some luck), will largely be contingent on their geological expertise, data, and ability to deploy advanced exploration techniques.

What's likely to change?

Expanded data sources

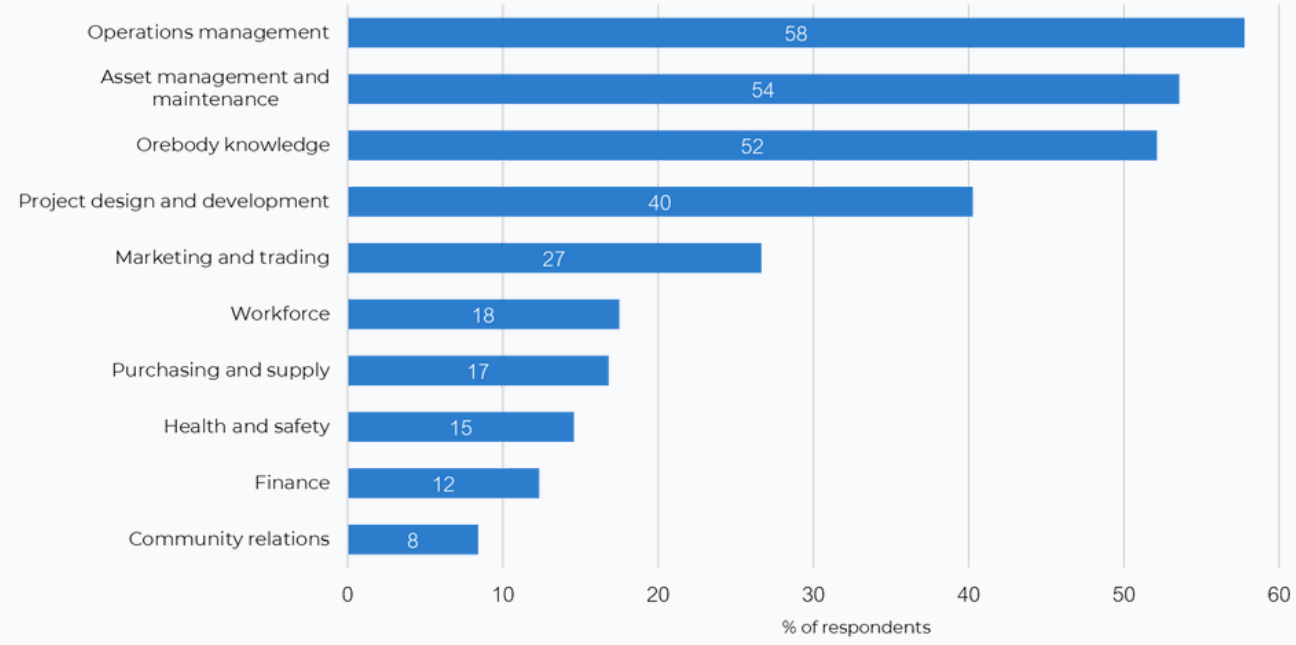
The sourcing of data and its integrated deployment is critical to decision making and therefore the success of all exploration business. The sources of data available to explorers is set to expand substantially, driven by technology (both digital and physical) and government policy.

Technology driven data expansion could occur through:

- Advances in earth observation, i.e., satellites
- Application of geophysics, as we have seen take place with the oil and gas industry
- Drill sensors capturing data from more parameters
- Advancements in drilling technology, allowing deeper and faster drilling
- Inferential analysis, via AI
- Machine co-operation, via swarming technologies

Question: Where would the application of AI provide the most impact in your business?

Respondents given three answer



Government policy could also expand publicly available data sources through both direct funding of exploration and policy pertaining to the public release of data. Direct funding may be in the best interest of government, allowing them to shore up supply chains and develop sovereign capabilities. Policies designed to make exploration data a public good may be a catalyst for greater advancements in exploration, as new people have access to the data to analyse it in different ways.

One of the biggest hurdles that will need to be overcome for data use to reach its full potential is the quality of the data. For AI models to be effective, the data must be complete and with an understanding of where the data comes from, neither of which currently exists in many instances. We envision that in the next few years the importance of good data management will increase, and we will see an emphasis on capturing and storing data with more rigour, in order to effectively run advanced analysis.

New commercial models

The commercial models for exploration will likely shift, driven by the need for more capital, the increasing role of sophisticated technologies (and access to data), the shortage of energy minerals (e.g. copper), and the continued need for risk taking.

Currently, exploration is mostly carried out by small exploration “juniors” who have ample risk appetite. However, the juniors are under capitalised, have limited ability to invest long term in technology innovation, and are incentivised by markets towards short term strategies. Historically, major mining companies have played a more active role in greenfields exploration than they do now; a trend that is likely to reoccur given their capital resources and the lack of new discoveries.

Interestingly, new venture structures could emerge to aggregate exploration assets and technologies. As exploration becomes more technology focussed, technology companies should see greater opportunities to be actively involved in exploration, and early-stage exploration asset investors will in turn see technology as a means of valorising currently marginal assets. Typical venture funds have a higher risk appetite commensurate with exploration, but to date their involvement in exploration has been limited. Venture funds could provide exploration companies with new access to capital, but also help to balance risk across a broader portfolio.

Adaptable people

With technology advancements and increasing community expectations around the mining industry's behaviour at a local community level, there will be a shift in the skills that are considered key to success in exploration companies. As technology and AI begin to play a larger role in exploration decision making and operations, people who can see the potential of this technology, and who can innovatively deploy it to interpret complex datasets, will become even more valuable than they currently are.

As community rights and expectations increase, roles in community engagement will be more important. Explorers are typically the first contact that communities have with mining businesses and are critical in setting the tone for the relationship to follow (positively or negatively). Consequently, people with a local understanding, those who speak local languages and those with Indigenous backgrounds will become more valued.

OPERATOR

An operator creates value through the extraction and initial processing (i.e., crushing or grinding) of minerals. Their DNA is one of developing and managing physical assets in challenging environments. Core to their strategy is the optimisation of mining operations through leveraging their capabilities. In particular, the focus is on cost effective extraction, maintaining consistent production volumes and ensuring output quality meets market requirements. They invest heavily in both their equipment, advanced technology and in skilled labour to maximise productivity.

What's likely to change?

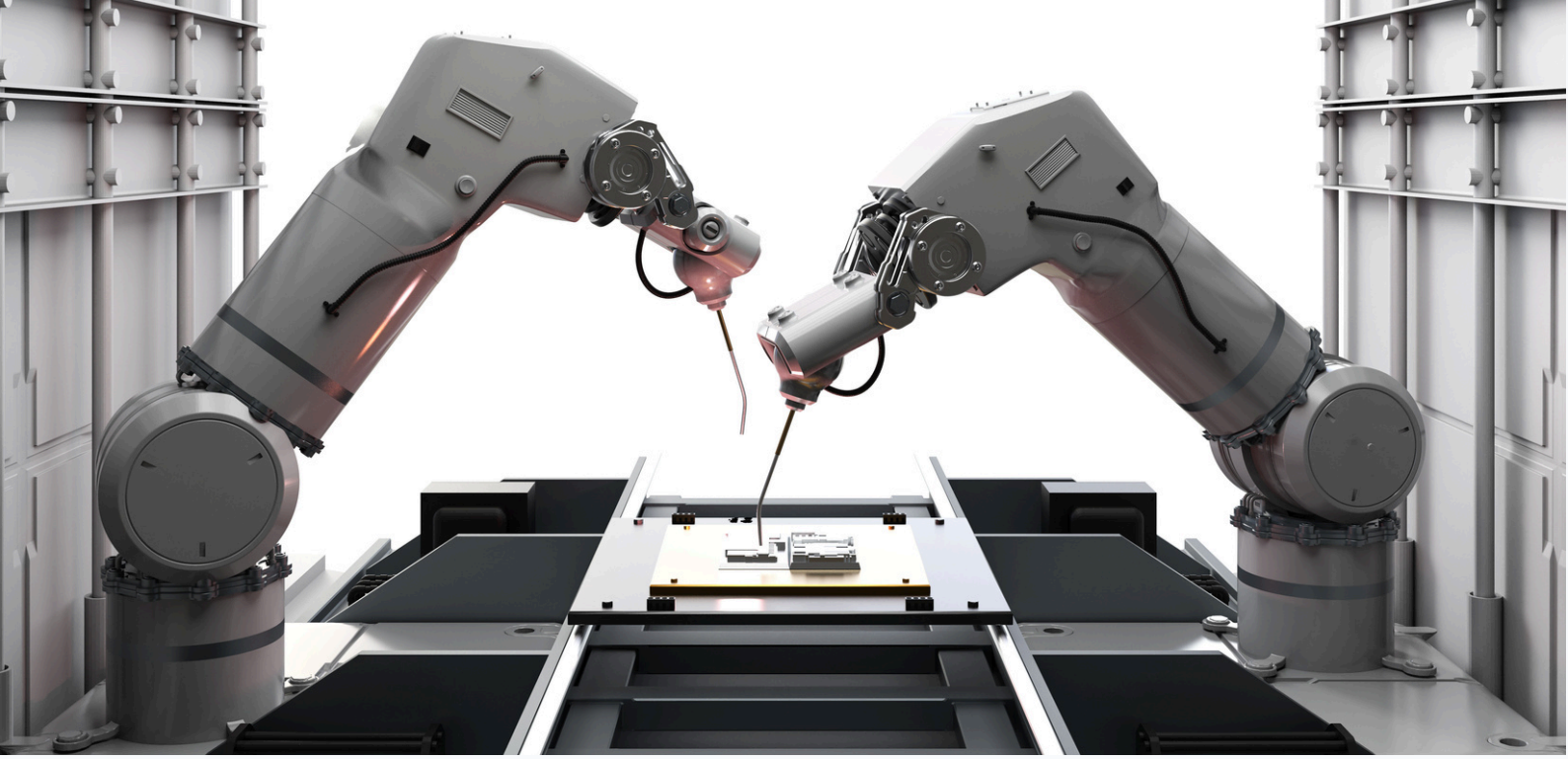
Broadened asset horizons

The current shortage of new mineral discoveries will force businesses to reevaluate what they think of as a mining asset - both where they mine (the source of material) and how they mine (the extraction of materials). We envision a world where industry will increasingly source minerals from the ocean and through 'urban mining'.

Ocean extraction is a contentious topic, but high demand for energy minerals combined with access to an underexplored asset such as the ocean floor will see companies capitalising on mining the seabed. This will likely be in the form of both mining of solid resources (for example, extracting nodules from the ocean floor to mine the minerals contained within them) and through sea-water extraction (which can be rich in minerals such as lithium and manganese).

'Urban mining' (or recycling) will increase in prominence, particularly given the pressure for reduced carbon emissions. Minerals such as lithium, nickel and cobalt can be extracted from old batteries, however it is not economically or commercially viable at this stage given the small volumes of batteries able to be recycled. With advancements in technology, this will begin to be more cost effective and ultimately profitable for companies.

A shift in extraction methodologies will be driven by community demand for lower footprint mines, and the opportunity that low-cost intermittent renewable energy presents. Forms of chemical & biological mining (in-situ and on surface) will increase in prominence. These broadening horizons could lead to more specialised mining businesses emerging given the technological complexities.



Automation’s final arrival

A common theme across the future of all mining business models is the increasing role of technology. The most visible manifestation will be the full automation of physical operations for mining businesses, driven by the combined advances in AI, sensor technology, computational power, high definition mapping, and swarm technology.

Physical automation will be the keystone allowing mining to be fully automated end-to-end from planning to operations and through the tiers of decision-making time frames. Not only will this improve efficiency throughout the organisation, but there will also be significant data produced, enabling customer benefits including more customisation, supply chain optimisation and provenance verification.

The greater use of automation will change the roles of employees, shifting them away from the completion of simple tasks that can now be automated, to a greater focus on building, sustaining and monitoring systems, creative problem solving, and human engagement. The automation of tasks will also see roles being displaced by robots powered by generative AI, potentially reducing the workforce size.

As employees turn their attention to their role in systems across the organisation, organisational structures will also evolve. There will be a shift from strict vertical hierarchies to more of a systems orientated approach. Routine task assignment will become more embedded in the systems, rather being issued through vertical hierarchies, and teams will be freer to focus on taskforce objectives and problem solving.

Shifting services boundaries

Technologies used in the management and operations of mining businesses will increasingly be offered through services (servitisation), driven by the complexity of new technologies, skills shortages and competition in the services and technology sectors. Mining companies will consequently become more focused on the core of mine development and total operations, with an emphasis on effectively integrating services offerings across the supply chain.

The servitisation process will create multiple opportunities for new business models in both mining companies (e.g., services integration) and contractors (e.g., full operating platforms). This trend could well result in the blurring of boundaries between contractors and mining companies.

In more remote locations, miners may well step into the energy asset ownership space to reduce costs and shore up continued supply, particularly as intermittent renewable sources become more integrated with operational optimisation. This could lead to new business model opportunities for mining businesses more broadly.

PROCESSOR

A downstream processing company creates value by producing refined energy mineral inputs for end use applications. Their DNA is one of complex process optimisation - they invest in specialised equipment, technology and expertise to efficiently process and transform minerals to create a higher value product. These companies often create strong relationships with end-users to strengthen their supply chains.

What's likely to change?

Clustering downstream

Downstream processing assets will increasingly be clustered in precincts, driven by the efficiency of shared infrastructure, sourcing inputs, recycling, and government planning and incentives. Clustering reduces capital requirements for water & energy. It also enables common energy storage to manage renewables and facilitates sharing of thermal energy (via steam). Processors are heavy users of chemical inputs (e.g. acid) which can also be produced on site given aggregated demand and infrastructure.

Precincts can compress development time frames (thus increasing project value) through government pre-approvals and incentives as part of broader economic development plans. Ideally, processing clusters would be located near aggregations of major orebodies to reduce logistics costs and minimise energy losses. Clustering also opens up the possibility of recycling of batteries and minerals in the same precinct, with the co-location of necessary 'hot processes'.

Optimising supply chains

Processors will be industry leaders in the application of technologies and structures to optimise supply chains. Simulation, advanced analytics and AI will play key roles in optimisation and 'orchestrating' the integrated supply chain, with optimisation focussed on all stages, from mining through to delivery of refined products. The integration driven by technology and data will enable a shift from a supply push to demand-driven supply chains, enabling customers to influence products and production schedules in real-time.

Organisational structures will be strongly systems oriented, fully breaking down siloed hierarchies, focussing on the delivery of certain outcomes at each stage of the supply chain. Capacity for R&D and innovation partnerships will be further enabled as technology is the only means to continually increase productivity and maintain competitiveness.

Beyond optimisation, there may also be supply chain consolidation for critical minerals. Manufacturers will be attracted to Australia for its lower carbon footprint (despite deterrents such as higher labour costs), driven by the market pressures for companies to reduce carbon emissions.

Strong partnerships

Processers will be adept at using strategic partners, driven by the need to share capital risk, access technology, and the importance of their product in customer supply chains. These partnerships will transcend industries and cross public/private sector boundaries.

Partnerships are essential to managing technology risk. Downstream processing technology is highly specialised and does not typically reside in current mining companies. Collaborations across other companies, including technology firms, will ensure that risk is distributed.

Co-investment between the public and private sector will assist with achieving the value benefits of downstream processing. The capital requirements for traditional mining companies moving into downstream processing are prohibitive for medium sized companies, and typically do not fit investment criteria for majors. Co-investment will assist in reducing the capital investment and risk for private companies, whilst ensuring the benefits for government in shoring up supply chains are realised.

Long term strategic partnerships with end users, such as offtake agreements, will become even more critical. This will enable refined mineral inputs to be reliably tailored to suit customers' manufacturing processes, enhancing the total supply chain.

CONCLUSION

When we started the process of considering what a future mining business might look like, we had well intentioned plans of re-designing business architectures 10 – 15 years into the future. But it quickly become evident to us that there were too many unknown variables, and the rate of technological change too rapid, to do this full justice in a simple paper.

What the process did do was to force us to think about what the fundamental shifts in industry would look like, and what would be driving these. The shifts in business architectures are universally technology and capital driven - from the expanded data sources and new commercial models in exploration, to the arrival of automation and the investment in new horizons in operations, to need for partnerships and the sharing of infrastructure in processing businesses.

> ***"I think finding a couple of companies that are building next generation infrastructure, and getting them engaged in the question of the broad set of how to build a functional mine. That would be the place I would be really interested in exploring because I can imagine doing a couple of invited workshops where you just reach out to all your colleagues in the infrastructure industry, like 'who's building the weird stuff'?"***
> **Director, Innovation Centre**

While technology is the one constant change driver (and it is accelerating thanks to AI) it will bring with it profound changes in organisational structures with people in the industry being more focussed on building, managing and operating systems, remote from assets in many cases, and with far less emphasis on traditional hierarchies.

It's hard to see a future where there isn't profound change to value chains, technology, partnerships, organisational structures and people. What the final architecture looks like? Well, that remains to be seen.

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