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The Case for Innovation in the Mining Industry

by Peter Bryant

Highlights

• The current point in the mining 'sawtooth' cycle presents tremendous opportunities for innovation. The time is now for the mining industry to embrace technology and business model innovation.

• Collaboration with world-class leaders, especially those from outside the mining ecosystem, will help companies drive rapid and effective change.

• Mining companies must begin taking the necessary steps towards transformative change that builds competitive advantage, reverses the trends of the past and sets the industry on a new course.

The Case for Innovation paper was first published in 2011 and has been updated in 2015 to reflect the current business conditions and initiatives of the mining industry. The propositions of the original paper remain the same.

This white paper examines the current state of technology and innovation in the mining industry and highlights the internal and external factors that have undermined innovation efforts.

The case for innovation in the mining industry has never been more compelling—whether you believe the industry is in a rather sharp dip in a significant 'sawtooth' cycle or in the midst of a bust—the imperative is the same. Despite record production levels and still above-average prices compared to the lows of 2000, the industry is struggling to make profits and provide the returns on capital that investors are seeking. This represents a large-scale destruction of value over the last 15 years.

The last 10 years has seen a continued sustained rise of operation expenses and capital development costs and a rapid decline in productivity. This trend is unsustainable especially against other key structural challenges such as declining grades and more stranded assets.

Those wanting to reverse these trends and begin to capture the full value of their investments will need to realize important transformations in their business system including: rapid and accurate characterization of ore bodies; faster development of mines and speed of extraction; and improved recovery rates and mine planning. The degree of transformation required can only be realized if we discover a new approach to open pit and underground mining.

The Mining Company of the Future is the transformational paradigm that acts as the focus for this innovation. Several mining companies have developed approaches to the Mining Company of the Future. Rio Tinto, the most notable example, recognized the beginning of this super cycle in 2006 and invested accordingly. The results: Rio Tinto has dramatically increased its output of iron ore, earning the company record profits. However, Rio Tinto has been focusing primarily on the necessary area of optimizing and automating current mining methods, rather than developing truly transformational approaches and new processes.

We are seeing truly transformational initiatives from Anglo American with FutureSmart, from BHP Billiton, and to a lesser extent Vale. AngloGold Ashanti's effort, while deserving merit, is now stalled.

This white paper examines the current state of technology and innovation in the mining industry and highlights the internal and external factors that can invigorate a new approach.

We present a two-part model of (1) knowledge-based analysis and planning and (2) a new operating platform. The former drives value creation while the latter turns value potential into reality. These are complementary activities that require different skills and management approaches. Also, an analysis of energy efficiency and operating costs in a sample mining company shows how opportunity for significant operational efficiencies exists even when room for additional improvements is not apparent.

Given that deficiencies in knowledge acquisition, management, and planning are more visible and commonly accepted, the opportunities for technology-driven improvement are better understood. The reality, however, is that many mining companies do not have the knowledge or resources to implement dramatic technological solutions. Therefore, open innovation through collaboration and alliances with world-leading partners in key areas are proposed to achieve rapid and effective change. Open collaboration and alliances can help companies more rapidly develop and implement a new production, knowledge and planning platform. Furthermore, as more companies successfully adopt Mining Company of the Future initiatives, alliances will be further strengthened as member companies become more competitive. Clearly, the mining industry has lagged behind others in technological advancement but many examples of technologically-driven performance breakthroughs in other industries are a testament to the opportunities for transformation.

While innovations to the business model that result in more effective ways to secure rights to resources, including the social license to operate, are an important part of the Mine of the Future concept, this paper primarily focuses on technologies and innovations related to mining technology and mine operations. For further information on business model innovations that can influence the direction of technology innovation, please refer to the Kellogg Innovation Network's Development Partner Framework by emailing mining@kinglobal.org or visit: www.kinglobal.org/catalyst.php.

Context

The mining industry is in the midst of a severe dip in what arguably remains a sustained-demand growth cycle, often referred to as a super cycle or, as Rio Tinto more accurately refers to it, a sawtooth cycle. Given trends in such areas as urbanization and population growth, the demand trend for most mined commodities will be upwards, albeit with some troughs, as we are now experiencing.

During the last decade established mining companies have struggled to expand profitable production and meet the surging demand from emerging markets such as China, India, and others.

Although the strong growth in demand experienced by the sector might be assumed to have created a "golden era" for mining companies, the sector has in fact faced a number of significant challenges in recent years that have made the operating environment increasingly challenging.

Key forces and trends shaping the mining industry:

1. **Despite Short-Term Fluctuations, There is Long-Term Sustained Demand for Commodities**
   - This demand is driven by relentless urbanization, population growth and a rapidly growing middle class.

2. **Environmental Concerns Continue to Mount**
   - Existing mining methods and environmental footprint are becoming increasingly unacceptable to society.

3. **Growing Geo-Political Pressures & Community Activism**
   - Increasing number of projects on hold due to community activism, currently estimated at $25Bn.
   - Increasing nationalism tendencies and government expropriations of close to $30Bn.
   - Social license to operate is being challenged.

4. **Finding, Building, Operating and Closing a Mine Keeps Getting Harder**
   - Costs have been increasing at a rate of 10-15% p.a. for the last ten years.
   - More assets stranded as they become uneconomic to mine under current mining methods, e.g. Olympic Dam.
   - Ore grades continue to decline.
   - Declining productivity at a rate of 10%+ p.a. for the last ten years.

5. **Despite Enormous Challenges, the Industry has Consistently Underinvested in Technology & Innovation**
   - Lower R&D / innovation investment rate than almost any other industry.
   - Mining suppliers remain wary of long-term investments and transformative innovation.

"Our industry is damned by the fact that our spending on innovation is one-tenth of the petroleum industry. If we don't start to bring innovation back…the major diversifieds will be subsidiaries of General Electric or some other conglomerate that still has innovation in their vocabulary."

Mark Cutifani, CEO of Anglo American

Source: Is increasing mining R&D the only hope for saving a stalling industry? Mining-technology.com, 26 May 2014.

These issues feed investor uncertainty and have dramatically increased the risk profiles of projects. These risks in turn increase the cost of capital (particularly problematic in such a capital-intensive industry) and operational costs, leading to negative impacts on balance sheets and income statements.

Therefore, whilst the overall picture of strong demand and relatively high prices (when compared with long-run averages and the lows of 2000) might suggest a very positive operating environment for mining companies, the reality is somewhat tougher for both the industry and its stakeholders.

Looking at the comparison of prices in March 2015 to the lows of 2000 in Table 1, you will see an industry making similar margins and returns on capital with prices still 2-4x above their lows of 15 years ago. This represents a large-scale destruction of value and desperately calls for a new approach.

Table 1: Comparison of key commodities prices between 2000 and Feb 2015.

Commodity	Low 2000	Feb 2015	Highs	Yr. of High
Iron Ore $ per ton	12.45	63	187	2011
Met Coal $ per ton	38	101	156	2008
Thermal Coal $ per ton	25	66	192	2008
Gold $ per ounce	265	1175	1941	2011
Copper $ per ton	1427	5729	9881	2011

Source: Clareo Analysis

One of the challenges for mining companies is that no one "silver bullet" will address the challenges the sector faces. Instead, companies need to recognize that a variety of actions will be required and that these need to be underpinned by a changed mindset that reevaluates the role of mining companies in the societies in which they operate.

Because the industry is in some ways unique, this new mindset needs to reflect the specific characteristics, challenges and opportunities of the sector. Foremost among these is the potential for mining, if properly managed by both companies and governments, to be a significant catalyst for the socioeconomic development of the countries and communities in which mines are developed and operated.

The change needed will require bold leadership from industry, and has the potential to put the sector on a path to a more prosperous future with a much stronger formal and social license to operate. Better outcomes for everyone!

Herein lies the significant opportunity—the rapid advances in such areas as big data; cheap massive computer processing; sensors and robotics; nanotechnology; and much more has helped drive down the unit cost of production of almost every item and raised productivity. The mining industry has an opportunity to

embrace and apply these technologies to help transform not only the current approaches but also develop a whole new operating platform and enable a new business model. Taking advantage of new approaches embodied in open innovation and the principles of the lean start up as applied by other companies, such as GE, combined with a new investment surge, could rapidly accelerate this necessary transformation.

Technology & the Mining Company of the Future

Technology is a key foundation and enabler of the Mine of the Future initiative. We suggest that technology must play a role in the following:

- Restoring agility and flexibility in the value chain
- Shifting from a cost reduction mindset to one of value creation
- Increasing production and productivity
- Reducing and eliminating waste
- Reducing the need for people, especially at remote sites and underground
- Improving ore body knowledge and the planning process
- Improving recovery rates
- Aligning the organization around strategic and tactical goals
- Increasing the robustness of business, competitor and industry intelligence

Technology & Innovation in the Mining Industry

When talking about technology in the mining industry we are referring to: physical hardware, operational procedures, organizational structures, information systems, and management practices. Mining and processing technology includes both fixed and mobile machinery and equipment (e.g. drilling, blasting, loading and hauling equipment, crushers, conveyors and mills) as well as supporting technologies such as monitoring, control, and communications systems, planning and design tools and other support services.

Software applications such as accounting and human resources systems are also covered under support services. Many transformative efforts within the mining industry focus primarily on supporting back office systems. Although building the back office of mining companies is an important part of the operation, it is unfortunate that an area contributing little to actual value creation garners such attention.

There is no doubt that substantial innovation has taken place during the history of the mining industry. Open pit mining, block caving, long wall mining, draglines, sulfide flotation, and metal leaching are some notable examples of breakthroughs that have dramatically changed productivity and reduced operating costs. Additionally, most productivity or cost efficiencies in recent decades have also been driven by the incremental improvement of existing technology such as larger, longer-lived, and more efficient shovels, haul trucks, the LHD, larger crushers, grinding mills, flotation cells and better chemistry to improve processing recoveries.

On the one hand, the trend toward increasing size and longevity of production equipment offers incremental benefits in the short term. On the other hand, it inherently limits innovation in the longer term because the longer equipment lifespan limits the volume supplied by manufacturers. When compared to the pace of innovation at other industries, such as automotive, aerospace or mobile phone technology, innovation in the mining industry has been historically much slower.

Innovation in the mining industry has been hampered by a historical collective focus on cost reductions as the primary mechanism for business improvement. Also, industry consolidation and cooperative purchasing agreements have enabled the commoditization of key products and supplies, further hindering innovation efforts. Indeed, mining operations have almost exclusively acted as price-takers rather than price-makers where risk taking has

been discouraged. As a result, R&D spending within the industry is low[1] when compared to any other industry and even lower in terms of partnerships with third-parties.

Furthermore, some of the factors that have mired product innovation have also had a detrimental effect on other critical technology areas including design and planning systems and business applications in mining operations. Unfortunately, the increasing complexity of modern mine planning operations demands increased business applications capabilities to remain competitive.

Effective application of information technology to drive transformation is generally rare in the mining industry.

In 2010, CAE, an aeronautics modeling firm, acquired Datamine Group, and in 2012 Dassault Systems acquired Gemcom Software, representing their respective first steps in an aggressive push into the mining industry services sector.

ERP offerings are typically based on templates from other industries and do not provide particularly useful platforms for production, maintenance and management functions. Generally, most of their utility is limited to accounting functionality. As a consequence, most software solutions have been developed in an ad-hoc, nonstrategic way as a response to emerging challenges.

Ultimately, the collective lack of R&D/ Innovation investment and inflexible focus on short-term cost reductions instead of longer-term value creation have largely destroyed any internal or supplier incentive that might drive new breakthroughs. It is important to point out that many of the challenges inherent to the mining industry such as remote operations sites, difficult operating environments, and (usually) tight economic conditions have produced a generation of inward-looking, self-reliant managers and executives who have failed to fully grasp the benefits of modern technology and innovations. Understandably, for many of these executives, the concept of innovation produces a sense of panic, not opportunity.

The mining industry has yet to fully accept and embrace the strategic role of technology and innovation in successful business planning and execution. While we are beginning to see some shifts with the work undertaken by Rio Tinto in automation and remote operations as well as Caterpillar's and Komatsu's work on automation and electric drive vehicles, some less obvious competitors are creating commodity-killing substitutes and alternatives. As of today, only limited inroads have been made into iron, copper and aluminum applications, but it is only a matter of time before fibers, ceramics, composites, or nanotech deliver a significant economic blow to one of the core mining products.

The good news is that after such a lengthy period of relative stagnation in technological advancement, the mining industry is ready for technological transformation and advancement. Paths of high opportunity include technology adoption from outside the mining industry, a shift towards a strategic focus on R&D and important collaborative efforts with suppliers, both existing and newer entrants to mining. Indeed, early movers in the mining industry are likely to build a significant competitive advantage over their competitors. It is worth mentioning that Rio Tinto has become an industry leader through implementation of some of these progressive Mine of the Future initiatives, and the likes of AngloGold Ashanti has had some successes, notably the use of reef boring technology to dramatically extend the life of many mines.

1 A study in 2007 found that mining industry expenditure on R&D has decreased from 1.1% of revenue in 1997 to 0.6% in 2002 and an updated study found in 2013 it was around 0.25 to 0.5%, and that R&D investments are in increasing competition for funding with exploration, also a risky venture, as well as with traditional business activities with less uncertain returns.

Cost & Efficiency in the Production Chain

It may appear that applying new technologies to mining operations will not lead to a significant increase in bottom-line profits. As it is, many existing operations represent the pinnacle of efficiency and cost-effectiveness, most mobile and fixed plants are generally well-managed and reasonably modern; plant capacity expansion efforts have followed best practices; and shovels, trucks, rail and port infrastructures have increased in size. As of today, most economies of scale have been realized and the latest efforts in 2014/15 will realize those final 20% of savings.

Given that Daniel Jackling[2] would have no problem recognizing the latest P&H electric shovel, it would be beneficial to examine the fundamental efficiency of the unit processes we take for granted in the industry. Table 2 gives a summary of the energy consumption for size reduction and transportation (both lateral and vertical) compared to the actual productive output actually carried out at each stage of mining and processing.

The energy inefficiencies are both staggering and pervasive. In the case of diesel power, which accounts for close to half of energy consumption, 30 to 40% of actual energy is converted to a productive output. This means that when accounting for mechanical losses and friction, only 12% of the energy is actually being converted to measurable work (moving the machine and load). In reality, it is estimated that only 3% is actually used for haulage. This is based on simple calculation of the weights of payload and vehicle and the time spent hauling rock. Likewise, the 5% estimate for rail is based on similar factors. The other half of the total energy consumption is derived from the use of natural gas in generation facilities. The loss in electric power generation itself is enormous. Only about 40% of the heat value of natural gas is turned into power, even after heat recovery. Electric power is further reduced by transmission losses associated with end use. As this table suggests, the stages of production that involve size reduction are somewhat more efficient than the ones that involve material movement, though the numbers are still not impressive. It should be noted that a fledgling industry effort is underway to adopt more efficient crushing methods to replace grossly wasteful milling[3] but no similar effort has been seriously contemplated for mining.

Inefficiencies are further compounded by the increasing demand for finite nonrenewable resources that is driving up prices for oil, coal, and other fuels, although recently through the 'fracking revolution' these prices have declined by 30%-50%. Additionally, the associated costs of maintenance (including sustaining and replacement capital) and labor, which usually accounts for 60% of the total operating cost, must also be considered. Indeed, the low energy efficiency of current processes is incongruent with many companies' stated focus on sustainable development and carbon reduction in particular.

The current life-of-enterprise project plan, with its accompanying cost structure that is employed by many companies, will continue to be used for at least the next 20 years. However, one would think that the incentive to invest in developing cheaper, less labor-intensive alternatives would be enormous, and by this we do not just mean automating current approaches like trucks. Also, removing people from hazardous operating conditions would bring significant health and safety improvements.

2 The father of open pit mining, responsible for initial development of the Bingham Canyon Mine in 1904.

3 High Pressure Rolls Crushing is estimated to be about 10 times more efficient than SAG milling, which uses 1-2% of energy consumed to reduce particle size.

A healthier approach to the knowledge-based side of the mining business would be to recognize its complementary role to operations.

Table 2–Sample Mine Energy Consumption

The following table compares the typical energy consumption at a mine company to the actual productive output.

Activity	Energy Source	Energy	Work Done	Valuable Work Done
Drilling and blasting	63,000 TANFO	101TJ	20%	20%
Mining	11,000 MWh	40TJ	40%	5%
Haulage	79 Mi Diesel	2,844 TJ	12%	3%
Processing and handling	313,000 MWh	1,127 TJ	15%	10%
Rail	115 Mi Diesel	4,140 TJ	12%	5%
Ports	244,000 MWh	878TJ	20%	2%
Infrastructure	172,000 MWh	619TJ	n/a	0%
Transportation losses	50,000 MWh	180TJ	n/a	0%
Generation losses	1,485,000 MWh	5,346 TJ	n/a	0%
Total		15,275 TJ		2.9%

Source: Clareo and Chris Carter - Chief Consultant, Rio Tinto.

A New Production Platform

Even though energy losses and non-productive costs cannot be eliminated, mining companies can vastly improve. In fact, the aerospace, telecommunications, oil and gas exploration and production sectors have driven meaningful productivity advances by increasing their R&D spending and product cycles times in response to intense competition. This has been especially apparent in the intensity and rate of innovation that has unleashed fracking in the USA—the nature of the innovations, the timing and rate catching most, if not all industry leaders and pundits by surprise! In 5 years the USA has been transformed from a laggard in oil production to becoming the number one producer in the world surpassing Saudi Arabia, and in the process, dislocating many well-held norms of the industry.

Although technology can certainly improve operations in the mining field, its true benefits can be realized when it is applied to a "platform" approach or our proposed "New Production Platform" that encompasses all major phases of the operation such as mine development, drilling and extracting, processing, transportation, as well as the provision of utilities.

In some cases, elements of the production platform may already exist (for example, both Nordberg and Krupp have developed large, fully mobile crushing plants) but it is certain that others will require R&D resources.

The general characteristics of our proposed approach are the following:

- Increased energy efficiency–less waste
- Continuous rather than batch operations
- Less movement of equipment
- Increased preventative maintenance and self healing
- Increased reliability and availability
- Faster operation
- Automation and remote operations to reduce labor costs
- Flexible vs. fixed
- Less waiting and queuing
- Increased instrumentation and monitoring
- Rapid mobilization
- Scalability
- Removal of less to zero waste
- Able to mine lower grade resources at low cost

Generally, mining companies may not have all the resources necessary to design, construct and implement a new production platform, but they can either leverage outside industry expertise or third parties with relevant knowledge and capabilities. In fact, we suggest that a commercial mining technology alliance or consortia, formalized through appropriately constructive arrangements, is the quickest, most effective way to drive results. The main components of this platform might include:

- Major global industrial engineering company (e.g. Krupp, MAN)
- Major global logistics company (e.g. Kuehne + Nagel)
- Major global O&G Services provider (e.g. Baker Hughes)
- Specialist technology solution providers (e.g. Schneider Electric)

We have seen glimpses of the success this can have with Rio Tinto, albeit a more proprietary approach, and the AngloGold Ashanti tunnel bore drill that was a more open collaboration.

Commercial incentives for such an open collaboration can be significant. An effective alliance can profit from sales and implementation (including contract operations and maintenance) of the new production platform at a global and inevitably industry-wide scale. And mining companies within the alliance may not only experience increased efficiencies and productivity from the new production platform but would also have the opportunity to develop future business within the consortia. When compared to industry standards, this innovative approach certainly has a greater degree of risk, but companies can mitigate some of these risks with an initial, low-cost discovery phase leveraging Minimum Viable Product and other Lean Start Up principals.

It is time to modernize mining and reinvigorate the entire industry by overturning existing production paradigms and perceived constraints. This will be achieved one company at a time. Rio Tinto's commitment and success is certainly driving other companies to action and now the current state the industry finds itself in leaves companies with no real choice!

Deposit Knowledge & Planning

Operations are the most visible aspects of the mining industry and they are the means by which most of the value is realized—ideally at minimum cost and with minimum permanent impact. But many other, less tangible functions, such as knowledge-based strategy and planning are very important and essential parts of value creation. However, as we have seen, investment in systems and technology to support deposit knowledge acquisition and planning has been minimal.

Indeed, the greater proportion of resources allocated to the operations side of the business has led to a greater perceived notion of importance of operations over other business areas. Also, in contrast to the operating side, poor performance in knowledge and planning functions are difficult to estimate and rarely

"The mining industry urgently needs to get a grip on its challenges… and innovation is the key."

Tony O'Neill, Group Director Technical and Sustainability, Anglo American

contemplated. Therefore, it is no surprise that in most mining operations the planning function has been placed under the operations organization resulting in an unbalanced focus on cost reductions and less productive incentive schemes. Indeed, in our experience in the mining industry, we have seen the following:

- Late blast hole assays that result in improper ore and waste separation
- Incomplete metallurgical test work resulting in performance shortcomings
- Insufficient evaluation drilling results that lead to poor mine design and unexpected ore shortages at start up
- Relatively unsophisticated planning software that cannot handle the necessary complexity, producing suboptimal approximations and simplifications
- Insufficient district-wide information efforts, resulting in suboptimal that limits development strategy efforts resulting in sub optimal decision making
- Optimistic or pessimistic assessments of market demand that creates redundant investment or missed opportunities
- Unforeseen competitor actions that negate or pre-empt a mining company's strategies

In addition to limited dedicated resources, knowledge and planning-related functions also suffer from a lack of continuity. For example, staff turnover is typically high because of limited recognition, reward and advancement opportunities. Also, there are no effective knowledge management systems in place to capture and retain essential capabilities and technical know-how. However, pockets of effectiveness have emerged in specialist areas with the advent of database add-ons for mining software applications, affordable GIS tools for geographic information, and advanced visualization. We recognize the advancements made in the last few years but they still lag significantly what is possible even within the realms of today's technology. Unfortunately, these are the exception rather than the rule as critical knowledge is frequently lost because of staff attrition.

Big operating and capital costs and thin margins have characterized the mining industry. But in this current cycle, poor performance related to lack of investment in knowledge management and substandard planning has negatively affected the record of the last 10 years peaking in 2008-2011. The result is that the industry in 2015 is experiencing poor margins when prices are still 2-4x the lows experienced just 15 years ago, in 2000! Even though intellectual capital and planning costs are small in comparison to operating costs, their leverage on business results and profits is enormous. Just think what a 2% improvement in recovery rates, due to superior solutions, would mean to the bottom line—it dwarfs any upside from efficiency!

Finally, the lack of investment has not only been limited to the mining companies themselves. Innovation investment by suppliers has also suffered. For example, the total pool of third-party mining software providers generates less than $500M in annual software revenue (as distinct from consulting revenue) and ERP vendors offer cut price mining solutions based on thinly disguised oil and gas templates. It is apparent that both software and ERP vendors have commoditized software solutions, a particularly unfortunate approach to developing intellectual products for the mining industry.

A healthier approach to the knowledge-based side of the mining business would be to recognize its complementary role to operations and that different human resource capabilities and systems are required to achieve greater levels of effectiveness. Management and incentives clearly require different approaches given the focus on value creation rather than the value realization emphasis of operations.

The role of technology in improving knowledge and providing a foundation for sound strategy and planning efforts is much clearer than the

At the opening keynote at the 2015 SME Conference in Denver a participant challenged the Mine of the Future panelists, "If the industry is made up of fast followers, who will be the leader?"

equivalent case for operations. The deficiencies of the current system are visible and accepted. A better approach would include the following elements:

- Timely, near real time, acquisition of deposit knowledge
- Safe, efficient and effective collection of complete deposit data
- Holistic deposit modeling
- Value-maximizing mine and process design
- Maximum economic resource extraction
- Value-maximizing development strategy
- Comprehensive industry monitoring and analysis
- Accurate competitor information
- Rapid scenario evaluation
- Governance and compliance functionality

As with the case for a new production platform, we suggest that most companies do not currently possess the necessary in-house skills, and we propose a second series of open collaboration through alliances or the consortia model that would address these shortcomings. Some of the major players would include:

- Deposit knowledge acquirers and modelers (e.g. Schlumberger, Baker Hughes)
- Industry planning software vendors (e.g. Mintec, Vulcan)
- Knowledge management providers (e.g. IBM, HP)
- New age companies (e.g. Planetary Resources)

Given the increasingly competitive landscape and opportunities for large-scale productivity gains, the development and implementation of an advanced "Knowledge and Planning Platform" across the industry should provide substantial commercial incentive to all parties.

A Better Approach to Innovation

Even though some of the approaches that we have described in this document cannot be easily replicated, continuous innovation is the key to long-term advantage! But as we have seen, innovation in the mining industry has been characterized by low R&D spending, antagonistic supplier relationships, inward industry focus and a continuing trend towards fewer, larger, longer-lived components. Even though the industry may have been able to continue experiencing efficiency and productivity gains in the past, we seem to have reached the pinnacle of current technologies. Indeed, bigger trucks and shovels represent an improvement over smaller versions and deliver marginal cost and production benefits, but they still depend on grossly wasteful energy conversion and human supervision at every stage.

It is these kinds of underlying fundamental paradigms that must be challenged if we are to develop innovations that bring sustainable competitive advantage. In his 1985 book, *Innovation and Entrepreneurship: Practices and Principles*, Peter Drucker suggests that one of the seven fundamental sources of innovation opportunities is the inadequacy in an underlying process that is taken for granted. If we look at the current state of the mining industry, how many of these could we find? There are enormous opportunities for innovation in the mining industry!

In general, industry innovations are developed by internal R&D groups focusing on new and existing product development, academic research institutions, VC-backed inventors and entrepreneurs, or even by customers, as well as through extended ecosystems and networks enabled by open innovation. But today, even the most innovative companies like Apple are turning to a broad external ecosystem for design and production. The reason is that maintaining an entrepreneurial environment becomes much more challenging as companies grow. As smaller entrepreneurial firms become large corporations, the focus tends to shift from innovation to risk management and preservation of the core business. Although

One particularly exciting aspect of innovation in the mining industry is the opportunity to directly adopt existing innovations from other industries.

focusing on the core business is a necessary and expected way to preserve shareholder value, companies often succumb to smaller, more nimble startups. Furthermore the transformative and disruptive innovation we largely associate with CPG industries is now upon capital intensive and long cycle time industries. Witness SpaceX in the space arena. By challenging conventional thinking, they are doing what a Boeing would do, but with a fraction of the time and resources!

As large companies try to balance these dynamics, they are increasingly developing close ties with innovators and supporting research that may produce direct benefits to the company.

BP is a good example of a company that has been developing external ecosystems to boost its innovation efforts. For example, BP created an independent group to develop, build, and manage coalitions, or ecosystems, made up of outside organizations that systematically innovate around BP's needs. One such coalition brought together Rockwell, ARA (military integrator), OTI, Emerson, Intel, and Crossbow to help BP develop its next-generation remote monitoring and management system.

The trend towards partnerships or ecosystem development has resulted in a geographic concentration of technology start-up companies, and forward-thinking industry players have deliberately relocated close to these innovation centers. Silicon Valley is the first and best-known example, but others have rapidly developed across the globe, usually centered around leading research and academic institutions such Stanford and MIT, combined with readily available venture capital (VCs or Corporate Venture Capital) and willing entrepreneurs.

What is missing in the mining industry is the spark that will jump-start a new cycle of innovation. We believe that the alliance/consortia approach suggested for the New Production Platform and the Knowledge and Planning Platform will meet this need. However, companies must also focus on their own long-term goals and preserve their competitive advantage.

Based on benchmarking of R&D/Innovation investments in other industries, mining companies should contemplate increasing their R&D investments to 1-2% of revenues from the current anemic 0.25-0.6%. It would also be very beneficial for such investment by key suppliers in joint projects to increase spending from the current 1% to 3-4%. These levels of investment are consistent with approaches in the oil and gas industry. Also by taking the consortia approach of open collaboration, we can see shared investment, shared risk and shared upside. Furthermore we encourage the majors to open these consortia to innovative junior miners.

The company that establishes an early leadership position in building an industry alliance will be in a strong position to drive a strategic agenda that will be closely aligned with its strategic needs, even in the presence of competitors inside the alliance. There is a big first-mover opportunity to capture a significant share of the value created by the partnership.

One particularly exciting aspect of innovation in the mining industry is the opportunity to directly adopt existing innovations from other industries. Traditionally, the mining industry has had an unfortunate tendency to believe that its business has little in common with others. But if other industries have applied technologies from seemingly unrelated disciplines (e.g. NASA technology for sports apparel), why can't the mining industry do the same? Mining companies that are able to do so will be in a much stronger position to extract the most value being driven by the macro demand trends.

This of course requires a belief that the industry is in a super cycle and not a typical "boom and bust" cycle, something that this author has

believed since 2006. If companies truly embrace this cycle and accept that a bold, new approach is required, they will be more likely to provide the sustained investment required to make the "New Production Platform" and "Knowledge and Planning Platform" realities and to take their rightful place as industry leaders.

The Next Steps

The purpose of this paper is to provide fundamental facts and arguments endorsing transformation, not to present the blueprint for achieving the necessary transformation. We realize that deliberately undertaking a transformative change initiative in the mining industry will not be easy or straightforward, but here are suggested first steps necessary to prepare lay the groundwork for this transformative change:

- Design and implement a strategic approach to innovation.
- Look outside the mining industry to gain fresh perspectives and insights.
- Encourage a value creation culture to replace the cost-cutting focus so that enlightened decisions are made concerning production and longer term spending.
- Make organizational changes at the highest levels that reflect the strategic importance of the new platforms and technology and innovation in general.
- Build the necessary partnerships and alliances based upon open collaboration and shared investment and risk.
- Pilot implementations of technological advances, using the principals of Minimum Viable Product and Lean Startup.

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Peter Bryant is an executive business strategist with more than 30 years of experience developing and driving high-growth strategies for companies in the US, Asia Pacific and Europe. He has advised executive teams at a range of enterprises, from emerging businesses to Global Fortune 500 companies. He has held senior leadership roles, at global companies, including General Electric and Computer Associates.

In addition to his corporate experience, Peter is a serial entrepreneur, has been CEO/President for two emerging technology companies, Co-Founder of an enterprise software services company, and he continues to be an active advisor to startups and a mentor for accelerators Clean Launch, Founders, and Innovation Pavilions. He also co-authored *The Growth Champions–The Battle for Sustained Innovation Leadership*, published in 2012.

Peter is a leading authority on business innovation especially around social license and technology, in the resource and energy sector. He is a frequent speaker on this topic and has advised many leading resource and energy companies including BP, Castrol, Rio Tinto, Iron Ore Co., BHP Billiton, Peabody Energy, AngloGold Ashanti, Anglo American and Barrick Gold. Also he is the Co-Chair, along with the CEO of Anglo American, of a transformative initiative for the resources sector to redefine the business and technology approaches of the resource companies. Peter has been involved with the mining industry since 1982 when he visited his first mine, the MIM Holdings mine at Mt. Isa, to implement a new financial management system on behalf of GE.

Mr. Bryant holds a Bachelor of Commerce and Administration from Victoria University in Wellington, New Zealand. He holds a CA from the NZ Institute of Chartered Accountants and is a Fellow of the Australian Institute of Company Directors. Peter also serves on the Board of Advisors of the resources venture fund Chrsyalix and the World Economic Forum's Mining 2050 initiative.

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About Clareo

Clareo is a strategy-consulting firm designed to inspire and achieve transformational change for enterprising businesses. Our clients benefit from our extensive network of thought leaders and experts, including Clareo's association with the Kellogg Innovation Network at Northwestern University. Clients range from blue-chip firms to start-ups and include Kraft, Rio Tinto, Barrick Gold, Exelon, Johnson Controls, Baker Hughes, Anglo American, AngloGold Ashanti, Dingo Software, Alticor, and Fulton Innovation. For more information, visit www.mineofthefuture.net.

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