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The Case for Innovation in the Mining Industry

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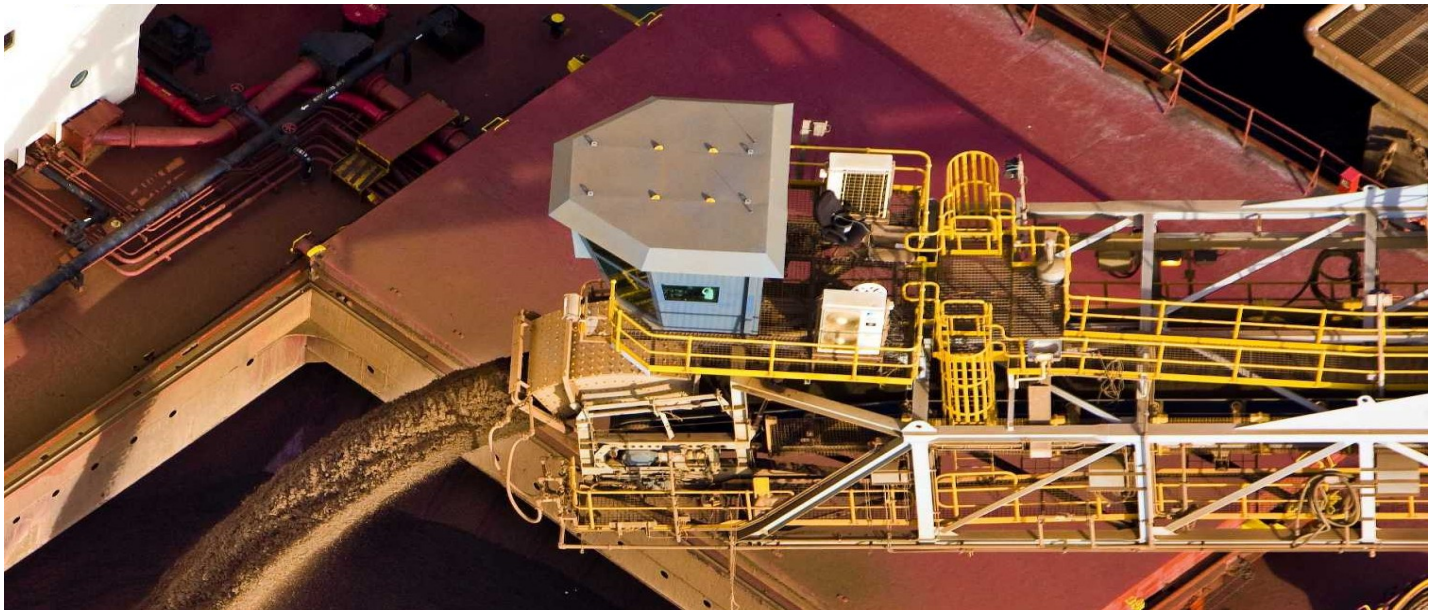

Photo: Rio Tinto

Highlights

- The mining super cycle presents tremendous opportunities for profit growth
- The time is right for the mining industry to embrace technological advancement
- Technology alliances with world-class leaders will help companies drive rapid and effective change
- Mining companies can begin taking the necessary steps towards transformative change that builds competitive advantage

The case for innovation in the mining industry has never been more compelling: we are in the midst of the largest mining super cycle not seen since the Second World War. There is no denying that this super cycle, which began in 2006, may last for many years and have long-lasting impacts on the mining industry.

But those wanting to capture the full value of this super cycle will need to realize important transformations in their business system: rapid and accurate characterization of ore bodies, faster development of mines and speed of extraction, improved recovery rates and mine planning as well as increased use of automation and remote operations. So despite mining companies producing record profits there remains substantial value, from current operations, that is not being captured.

The Mine of the Future is the transformational paradigm that acts as the focus for this innovation. Several mining companies have developed approaches to the Mine 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 in the last four years, earning the company record profits.

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.

We present a two-part model of (1) Knowledge-based analysis and planning and (2) efficient operations. The former drives value creation while the latter turns

value potential into reality. These are complementary activities which require different skills and management approaches. Also, an analysis of energy efficiency and operating costs in a sample mining company shows how opportunity for operational efficiencies exists even when room for any 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, technology alliances with world-leading partners in key areas are proposed to achieve rapid and effective change. Alliances can help companies develop and implement a new production, knowledge and planning platform. Furthermore, as more companies successfully adopt Mine 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 transformational growth.

While innovations to the business model that result in more effective ways to secure rights to resources 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.

Context

Companies have struggled to expand production and meet the surging demand caused by emerging markets such as China, India and others. This has created an opportunity for new entrants (e.g. Fortescue) and sovereign companies that have proven to be nimble and formidable competitors and show no sign of retreating. Existing companies, on the other hand, are hampered by myriad operational, organizational and industry-wide problems:

- Nameplate capacity constrained by maintenance deficit
- Manpower shortages compounded by high turnover and increasing competi-

Technology & The Mine 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**
- **Increasing production and productivity**
- **Reducing the need for people, especially at remote sites and underground**
- **Improving ore body knowledge**
- **Improving the planning process**
- **Aligning the organization around strategic and tactical goals**
- **Increasing the robustness of business, competitor and industry intelligence**

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- Limited planning capabilities
- Lack of deployment-ready drilled reserves
- Lack of information concerning the quantity and quality of lower-grade ores
- Inadequate product strategies that do not address the current business environment
- Inability to maintain economies of scale related to marginal production growth[1]
- Short-term focus on cost-cutting as the primary approach to business improvement

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, 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. We have seen many transformative efforts within the mining industry that focus primarily on supporting backoffice systems. Although building the backoffice of mining companies is an important part of the operation, it is unfortunate that an area that contributes 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 the automotive or mobile phone technology, innovation in the mining industry has been historically much slower.

Aggressive, new entrants like Fortescue are taking advantage of existing mining companies' inability to rapidly expand production.

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 hampering 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[2] and even lower in terms of partnerships with third-parties.

Furthermore, some of the factors that have hampered 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 is generally rare in the mining industry.

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, but not strategic way, as a response to emerging challenges.

Ultimately, the collective lack of R&D 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.

In 2010, CAE, an aeronautics modeling firm, acquired Datamine Group - its first step in an aggressive push into the mining industry services sector.

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 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 advancement. Possible paths include technology adoption from outside the mining industry, a shift towards a strategic focus on R&D and important alliances with suppliers or other institutions such as research laboratories and universities. 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.

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.

Given that Daniel Jackling[3] 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 1 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 the energy consumption, 30 to 40% of actual energy is converted to a productive output. Which means that when accounting for mechanical losses and friction, only 12% of the energy is actually being converted to measureable work (moving the machine and load). But in reality, it is estimated that only 3% is actual useful work 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 which 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[4], but no similar effort has been seriously contemplated for mining.

Inefficiencies are further compounded by the increasing demand for finite non-renewable resources that is driving up prices for oil, coal, and other fuels. 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 but one would think that the incentive to invest in developing cheaper, less labor-intensive alternatives would be enormous. Also, removing people from hazardous operating conditions would also bring significant health and safety improvements.

Table 1— Sample Mine Energy Consumption

The following table illustrates 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 T ANFO	101 TJ	20%	20%
Mining	11,000 MWh	40 TJ	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	878 TJ	20%	2%
Infrastructure	172,000 MWh	619 TJ	n/a	0%
Transportation Losses	50,000 MWh	180 TJ	n/a	0%
Generation Losses	1,485,000 MWh	5,346 TJ	n/a	0%
Total		**15,275 TJ**		**2.9%**

Source: Trantech USA LLC

A New Production Platform

Even though energy losses and non-productive costs cannot be eliminated, mining companies can vastly improve. In fact, in the aerospace, telecommunications as well 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.

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.

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

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
- Continuous rather than batch operations
- Less movement of equipment
- Increased preventative maintenance
- Increased reliability and availability
- Faster operation
- Automation or remote operations to reduce labor costs
- Less waiting and queuing
- Increased instrumentation and monitoring
- Rapid mobilization
- Scalability

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 Services provider (e.g. Halliburton)
- Specialist technology solution providers (e.g. Siemens)

The commercial incentives for an alliance 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.

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!

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. But 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 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 inappropriate 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
- Unsophisticated planning software that cannot handle the necessary complexity producing suboptimal approximations and simplifications
- Insufficient district-wide information that limits development strategy efforts resulting in poor 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 and affordable GIS tools for geographic information. 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 had negatively affected even today's record bottom lines. Even though intellectual capital and planning costs are small in comparison to operating costs, their leverage on business results and profits is enormous.

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 $300M in annual 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 the 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 equivalent case for operations. The deficiencies of the current system are visible and accepted. A better approach would include the following elements:

- Timely 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

What is missing in the mining industry is the spark that will jump-start a new cycle of innovation.

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

- Deposit knowledge acquirers and modelers (e.g. Schlumberger)
- Industry planning software vendors (e.g. Mintec, Vulcan, Datamine)
- Knowledge management provider (e.g. Hummingbird)

Given the increasing 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 have seemed 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!

Industry innovations, in general, are usually developed by internal R&D groups focusing on new and existing product development, academic research institutions, VC-backed inventors and entrepreneurs, extended ecosystem and networks enabled by open innovation as well as by customers. 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 en-

trepreneurial firms become large corporations, the focus tends shifts from innovation to risk management and preservation of the core business. Although focusing on the core business is a necessary and expected way to preserve shareholder value, companies often succumb to smaller, more nimble upstarts.

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 Cross-bow to help BP develop its next generation remote monitoring and management system.

The trend towards partnerships or ecosystem development has resulted in a geographic consolidation 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.

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 required to preserve their competitive advantage.

Based on benchmarking of R&D expenditures in other industries, mining companies should contemplate increasing their R&D investments to 2-4% of revenues. It would also be very beneficial for R&D investment by key suppliers in joint projects to increase spending from the current 1% to 3-4%. These levels of spending are consistent with approaches in the oil and gas industry.

The company that establishes and early leadership position in building an industry alliance will be in a strong position to drive a strategic agenda that will be closely lined 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 other 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 from the current super cycle being driven by heavy Chinese and Indian demand.

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 in since 2006. If companies truly embrace this super 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 has been 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 an approach to innovation
- Look outside the mining industry to gain a fresh perspective and insights from other industries
- 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
- Building the necessary partnerships and alliances
- Pilot implementations of technological advances, including selective automation, remote management and communications as well as other initiatives

It is worth mentioning that Rio Tinto has become an industry leader through implementation of some of these progressive Mine of the Future initiatives.

Applying these suggestions is sure to bring many benefits to your organization, but in order to create a lasting, sustainable advantage; a holistic approach to innovation is required. We are certain that the "New Production Platform", "New Knowledge and Planning Platform" and the "Innovation Approach" presented in this paper is one of the most effective ways to do so.

Acknowledgements

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End Notes

[1]Rand Corporation, 2001

[2]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 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.

[3]The Father of open pit mining, responsible for initial development of the Bingham Canyon Mine in 1904

[4]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

[5]Drucker, Peter, Innovative and Entrepreneurship Practice and Principles, 1985

About Clareo Partners

Clareo Partners is a premier strategic consulting firm that empowers companies to grow through business innovation. Clareo's association with the Kellogg Innovation Network at Northwestern University, provides a tremendous network of thought leaders and experts available to clients. Clients range from blue-chip firms to start-ups and include Kraft, Rio Tinto, Hewlett Packard, Alticor, Fulton Innovation, Zaharoff and BP Castrol. For more information, visit www.clareopartners.com

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