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Mining the Magenta Line

Automation, Risk, and the Division of Labour

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This is the formal version of the paper. The presentation version substituted more conversational language and examples and to fit within the presentation time frame did not include text, or some text in paragraphs highlighted with the paragraph marker (as shown thus: .)

1 INTRODUCTION

This paper is deliberately designed to challenge technical and management personnel in the mining industry, particularly in relation to decisions involving implementation of automation, decisions involving risk, and the economics of the mining industry generally.

The paper proceeds in four sections:

1 **Commodity Price Cycle**. Management sentiment in the mining industry is driven largely by commodity price cycles. This first section examines the current state of the cycle and management sentiment associated with the current and two previous phases.

2 **Automation.** Successes of automation have also been accompanied by some failures. This section provides some guidelines and some warnings drawn from nearly 5 decades of experience in the mining industry and from other industries.

3 **Risk.** Recent failures, both physical and in terms of investments, have highlighted shortcomings in how we in the mining industry make choices involving risk. This section draws lessons from these failures and provides guidelines on how these sorts of decisions can be improved.

4 **Division of Labour** – Mining companies are no longer "do everything yourself" companies – they are supported by a large supporting industry of technologists, suppliers and contractors. As technology changes within the industry the appropriate division of labour across the various players in the industry also changes – and this is a key to successfully implementing new efficiency-enhancing systems and tools.

2 THE COMMODITY PRICE CYCLE?

From the perspective of major commodity price cycles, there is arguably no better time than right now to be considering productivity and efficiency in the areas of mine planning, equipment selection, and in management decision-making generally.

Consider first the price of iron ore over the last decade or more, shown in Figure 1.

Figure 1: Iron Ore Price, 2009 through 2019 with Industry Focus

A decade ago commodity prices were high and the sentiment in the industry was that demand would be "stronger for longer." The primary business driver throughout this era wasn't efficiency, it was *production*. The imperative was to bring on production sooner.

This phase of rising prices and mine expansions was characterized by shortages of everything, particularly skilled labour. Optimize the mine plan? Who cared? With selling prices more than double the cost of even-inefficient-production *efficiency* was not the order of the day. Under time pressure good longer-term choices were forsaken for expediency.

With the benefit of hindsight the peak prices for iron ore occurred in 2011, but this information wasn't obvious then. Bullish sentiment prevailed for at least a year later.

In May 2012 I presented a public lecture at the invitation of the University of Queensland School of Economics entitled "Is the Boom already becoming a Bust, and are we prepared?" I was roundly criticized at the time for suggesting that the bust had already commenced, and, by talking about it, I was somehow helping to bring it about. Let the price of iron ore be the judge of the correctness of my assertion. The paper is available on my website at https://ianrunge.com/2016/03/07/is-the-boom-already-becoming-a-bust-and-are-we-prepared/

By mid-2012 with significant declines in commodity prices sentiment had definitely changed. In this next phase the focus was on reducing costs as fast as possible: cutting investment, delaying other investment, reducing working capital, and retrenching any personnel who were not directly associated with production – exploration personnel and long-term planning personnel, for example. For some of the biggest mining companies cost reduction also included taking advantage of suppliers, including not paying legitimate invoices for months and, incredibly, brazenly asking them for explicit price reductions with an implied "or else". As with the previous phase, under time pressure good longer-term choices were forsaken for expediency.

With the retrenchment of mine personnel, and with even-greater redundancies within enterprises servicing the industry, a lot of institutional memory was lost.

During this phase highgrading was the order of the day. "Highgrading" means selectively mining the better parts of the deposit now, even though it leads to higher costs later. Highgrading isn't necessarily bad unless it results in the destruction of viable but less-profitable reserves. Throughout the centuries deposits that facilitate such change have been important for mining companies to operate through cyclical down-turns. Of course, the deposit must allow such flexibility. Some miners, to their regret, discovered that their deposit didn't.

The commodity price cycle for iron ore is more pronounced than for other commodities, but timing for the change in sentiment is still broadly similar. Figures 2 and 3 show the price of copper and nickel respectively, demonstrating a broad correlation with iron ore and similar lags, with nickel more bullish right now compared to the other two commodities.

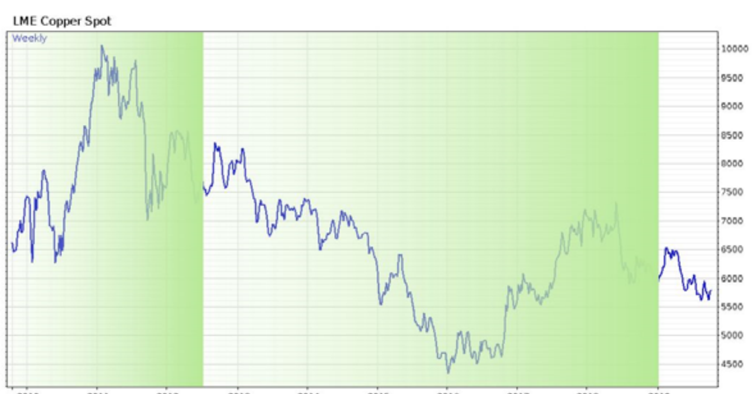

Figure 2. Price of Copper, 2009 to 2019

Figure 3. Price of Nickel, 2009 to 2019

Commodity prices in 2019 have recovered from their lows in 2016, but during cyclical downturns business sentiment lags commodity price trends even more than during booms. This short-term austere business mind-set is only just waning now.

Where are we now? Since 2016 mining company balance sheets have been repaired, and now companies can think about replacing the short-term expedient cost measures adopted in the previous few years with technology or alternative processes whose cost savings are more enduring.

Longer-term measures usually involve incremental capital investment to replace inefficient ways of doing things that prevailed in the previous two eras. In this current phase there is more *time* to implement change – expediency is no longer such an overriding influence on business sentiment. If there is some better, more efficient, alternative way to get something done, now is the time to push for it.

This is the foundation for the assertion that "there is probably no better time than right now within major commodity price cycles to be considering productivity and efficiency."

Nevertheless, the industry is not starting from square one … it is starting from *before* square one.

Hundreds of experienced people have left the industry – each taking with them knowledge that will now have to be re-learned along the path to building a solid foundation for the future.

3 AUTOMATION

I start with the issue of automation, and the issue of automation dependency. By "automation" I mean the term to cover the full cross-section of applications and modern technologies from computerised planning systems, analysis tools, through to automated trucks, drills, and the like.

In the consumer world this over-dependence on technology is hardly a surprise, as illustrated in Figure 4.

Figure 4 – Dependence on Technology displacing Common Sense

In the <u>consumer</u> world, where the technology is designed for millions of users, we can expect that some of them will rely on it *ahead of common sense*.

This shouldn't happen in the professional world – in *our* world. Yet it is happening. Professionals are hardly professional when technology overrides common sense. This is the key issue illustrated in this section.

Automation and AI mean that less people are needed, but the skill set of the remaining people has to be elevated. In many ways automation and AI have resulted in not just less people, but *degraded* skill-sets.

Underpinning automation is the microprocessor. At the same time as microprocessors started to make inroads into the mining industry they made inroads in other industries, with some of the earliest uptake being in aviation. We can learn from their mistakes.

Automation has surely made aviation more efficient and safer. But it has also given rise to a whole slew of accidents involving "automation dependency" – where pilots are distracted by the technology, or where the reliance on automation had so degraded their fundamental piloting skills that an accident happened. In 1997 American Airlines captain Warren Van Der Burgh coined the phrase "Children of the Magenta" to refer to pilots who essentially knew only how to follow the magenta line on their display. Hence the rather enigmatic title of my presentation of "Mining the Magenta Line."

In aviation when significant errors occur people get killed. Fortunately in mining this is seldom the case. But this same degradation of skills applies. It applies for technical personnel in mine operations, and it applies for management and board-level decision-making skills, particularly in decisions involving risk.

3.1 Aviation and Automation Dependency

Navigation computers and displays in aircraft are not greatly different to the ones in motor vehicles. Figure 5 shows a typical navigation screen for a flight off the coast of Brazil, showing the magenta line being faithfully followed by the autopilot. It was off the coast of Brazil that one of the worst examples of automation dependency occurred: the crash of Air France Flight 447, an Airbus A330, in June 2009.

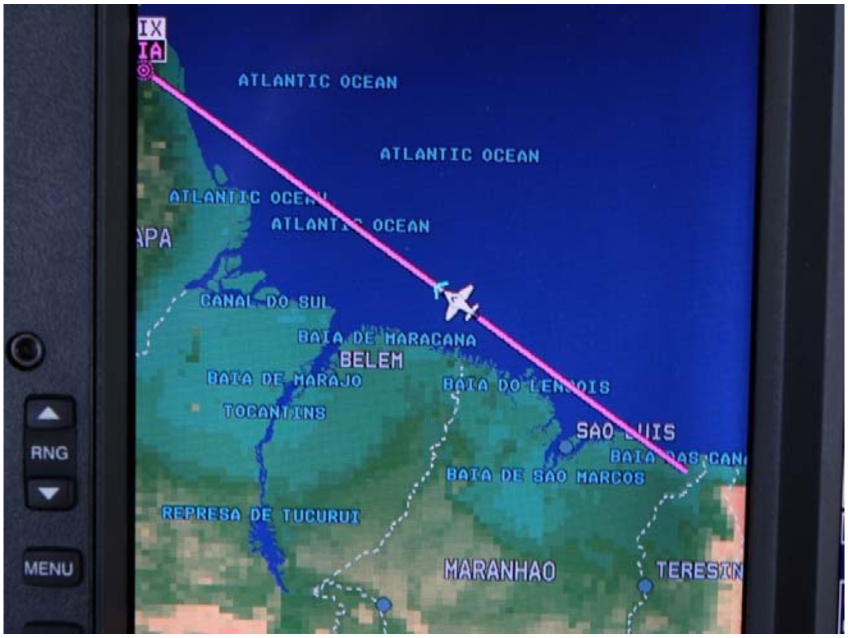

Figure 5 – The Discomfiting Magenta Line

What was the cause of this failure? The autopilot dropped out due to weather, and the crew, called upon to fly the plane manually simply couldn't do it. They didn't recognize until it was too late that they had stalled the plane, and the otherwise perfectly good plane with perfectly good engines, and its 228 persons on board crashed into the Atlantic Ocean with no survivors.

The accident is well documented on many internet sites. Figure 6 shows initial debris recovered. The flight data recorders and cockpit voice recorders were not recovered until May 2011, nearly 2 years later.

Figure 6 – Wreckage from Air France Flight 447, June 2009

Anyone who has trained as a pilot will know that one of the first lessons of flying a plane is recognizing a stall and, if you inadvertently find yourself in one, how to recover from it. The fundamental flying skills of these Air France pilots had seemingly deteriorated to the point where this was no longer in their skill set – something that a 25-hour student pilot knows how to do.

This isn't the whole story however. The A330 is equipped with technology that makes it impossible to stall the plane. Furthermore, this anti-stall technology cannot be disabled or turned off in flight. What the pilots seemingly were not aware of was that although *they* could not disable the anti-stall feature, the aircraft computers – the fly-by-wire system – *can* disable this feature and had done so. [Note: there were in fact stall warnings and warnings of inconsistent pilot inputs displayed on the aircraft screens. It is not known exactly why these warnings were not heeded].

The two noteworthy characteristics of this accident are:

- Airmanship of the pilots was seriously lacking, and
- The pilots didn't understand how the automation worked, i.e. what elements of flying the plane were (still) under the control of the automation/computers and what elements were no longer automated and therefore had to be controlled manually.

We've all heard the term: "airmanship." Pilots don't get "airmanship" in a simulator or by only flying a big airplane for hours on end following a magenta line across oceans. Airmanship comes only from time spent "at the coal face" – flying solo, flying low, in smaller planes, in less-well-equipped planes, in bad weather, and having to make fast choices based on conflicting, confusing, and sometimes erroneous signals.

3.2 Time "at the Coal Face"

The term "at the coal face" has been chosen deliberately. Even though the mining industry doesn't have a word corresponding to "airmanship" the term *at the coal face* – clearly originating in the mining industry – expresses a similar sentiment. Someone who has done their time "at the coal face" has the fundamental knowledge of how to do something learned not just from formal education but from practical experience and exposure to subtleties beyond what can be articulated in a more formal way.

In my paper "Economics, Technological Change and the Knowledge Problem" (Runge, 1995) I referred to this as the "Knowledge Problem." This paper is also published on my web site at https://ianrunge.com/2017/03/27/the-knowledge-problem/

I can't emphasize this enough: Mining is an industry just like aviation. It is a niche industry that also requires input from knowledgeable people who have done their time at the coal face.

3.3 The Knowledge Problem in Mine Planning – an Example

In the late 1980s I was involved in the planning and development of the Syferfontein Mine in South Africa. This was an open pit coal mine supplying Sasol's coal-to-oil conversion facility.

The entire planning team came from an underground coal mining background, but they were smart, and technologically savvy, and relied on technology perhaps more than most to make up for their shortcomings in direct knowledge about open pit mining.

When I first became involved a preliminary mine plan had already been developed. Figure 7 shows a stylized mine layout with the different directions of mining possible.

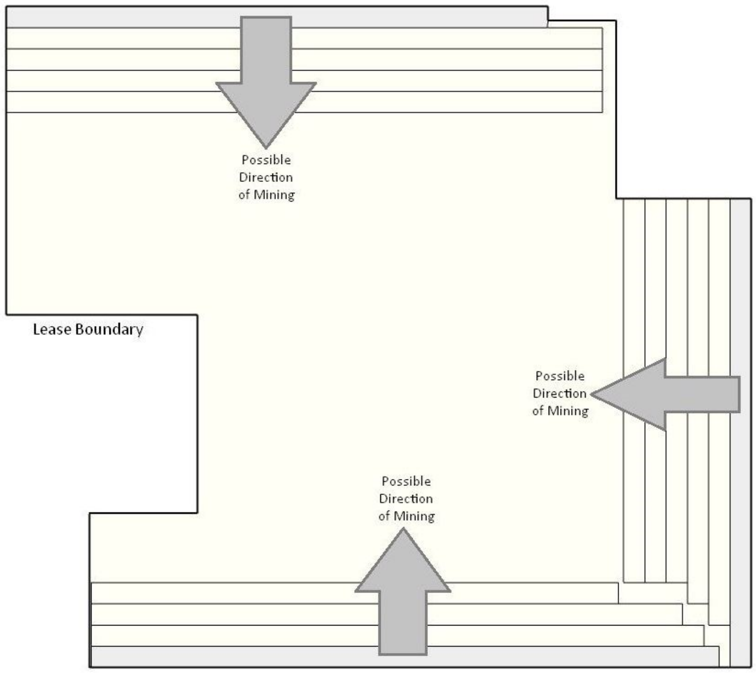

Figure 7 – Stylized Mine Layout with Possible Directions of Mining

Dragline mines always progress in strip-by-strip fashion, because the waste from each strip is placed in the mined-out void from the previous strip. The starting point is usually the coal outcrop or some property boundary. In this deposit the topography was undulating and the coal seam was relatively flat-lying and it extended over almost the whole lease area. There was no outcrop, and no obvious place to start mining.

Such a case presented a prime target for some new (at the time) mine design, layout, and scheduling technology. Remember this was 30 years ago. At that time analysing just one mine design and layout with several schedules, by hand, was a process that typically would take months. But now, for the first time in such an environment it was possible to try multiple different mine layouts with mining advancing in just about any conceivable direction.

This is what the Sasol team did – analysing every conceivable layout, each one applying multiple schedules. Each layout and each schedule was carried through to production and equipment tables that were then applied with capital and operating costs. The optimum mine plan was the layout and schedule that yielded the lowest cost of coal when assessed on a discounted cash flow, net present value basis. I don't think any of us would disagree with this approach.

Although the personnel involved were experienced mining engineers, they lacked tacit knowledge of truck-and-shovel or dragline operations. They became victims of the "knowledge problem" issue I referred to earlier. They simply failed to examine a set of cases that were (as it turned out) 30% more cost efficient than the best case previously studied. The selected case started with a boxcut in the centre of the deposit (excavated by shovels and trucks) and progressed in two directions outward as shown in Figure 8.

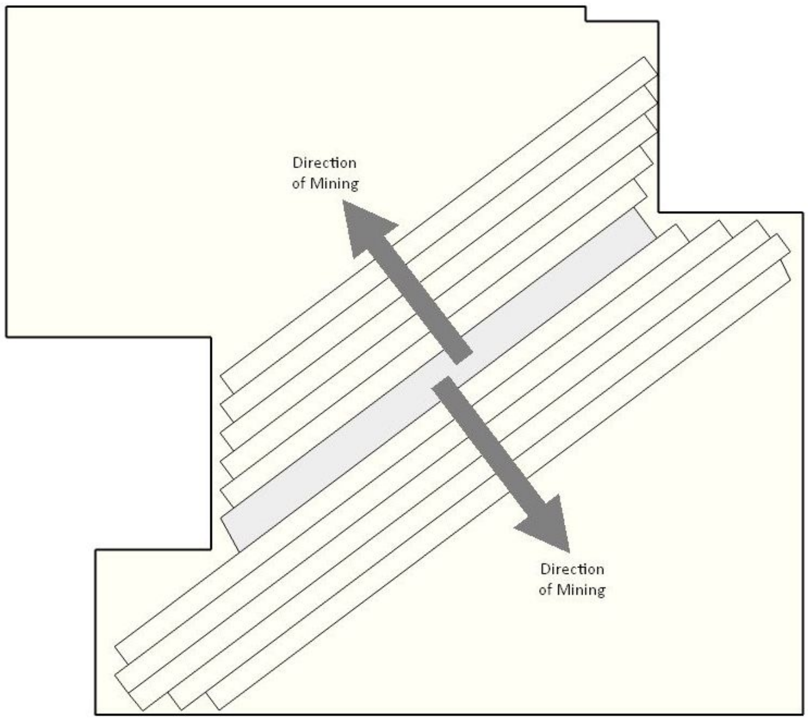

Figure 8   Final Configuration and Mine Layout (Stylized View)

This failing was not a case of "garbage in, garbage out." Nor was it a shortcoming in the computer program – a programmer cannot possibly account for every conceivable deposit and every conceivable way to go about mining it. The issue here was a shortcoming in the *process* of planning a mine – a process that required input from someone who had the relevant experience in this kind of mining. Time "at the coal face."

The lesson is that the task is not something that can be reliably done just by using brute force computing power. It cannot be assigned just to a lesser experienced person simply because he or she is skilled in driving the computer program. And it definitely cannot be delegated to a computer programmer in some distant office who knows nothing about your particular circumstances of time and place.

This example involved perhaps the simplest mine you could imagine – a flat-lying, single seam mine that could be mined in any direction. The deposit was not hard to comprehend. Surely there couldn't be too many alternatives for mining it, you would think? Yet a plan which yielded a 30% lower cost of production didn't even get considered – at least not initially. A significant error.

Fortunately the shortcomings in the mine plan were identified before the mine started and it turned into a very successful mine.

3.4 The Knowledge Problem in Real Life - how do *you* make Choices?

Mine planning problems are just one example of choices which confront everybody every day in real life. In personal cases, *how do we make choices?*

- Assume first that there are a set of choices in front of you: how do *we* trade-off choices between the long-term and the short-term, between importance and urgency, and between risk and return?
- A more important question is: where does the choice set in front of you originate from? Who

thinks up the various choices in the first place?

Let's look at a personal example:

Suppose you have enrolled in a part-time MBA program that you consider is important in advancing your career, and a critical assignment needs to be completed over the weekend. Then along comes an invitation on short notice to a company function that, if you attend, will steal the time you had planned to spend on the assignment. How do *you* trade-off your limited resources – time – between these competing objectives?

There are many factors, but the one I highlight here is that choice problems are rarely binary. The choice is rarely black or white. It might look that way at the start, but under pressure your creative mind will envisage new choice alternatives. The problem I highlight isn't: *How do you choose between two competing alternatives?* That is a hard enough problem in itself, but conceptually at least it is a problem that can be addressed analytically. The harder problem is: *how do you envisage what the alternatives are in the first place?*

You might be able to delay doing something else until after your assignment is due, thereby free up time. You may be able to attend the company function but arrive late or leave early. Clearly some people are better at envisaging alternatives than others. Reconciling seemingly irreconcilable alternatives is surely going to increase your stress levels, but often only under such pressure do the best alternatives materialize. Choices made under pressure are time spent "at the coal face." The more time you have spent there the more ideas your creative sub-conscious has to draw on.

In my experience, the ability to envisage something that doesn't otherwise just drop out from the rote approach ultimately adds value far more than the savings gained through automation or refinement of current plans, or just about any other cause.

In mining, how many choices are we now leaving overly much to automation? How many choices are being driven by someone who *hasn't* done their time at the coal face but who is tasked with the job just because they can drive the software? When we use a computer program to analyze something, how well do we understand what decisions are being made by the program, and what decisions are critically reliant on our, the *operator*, input?

Senior managers and boards are not immune to this knowledge problem either: even if someone has spent a lot of time on the *boards* of mining companies this is just the mining equivalent of aviation flight-hours following a magenta line across an ocean. It particularly applies to issues involving risk – something I will get to in the next section.

The insidious thing about the knowledge problem is this: that many people who don't know don't know that they don't know.

Automation and AI can make great contributions to cost reduction, and over time will be able to do even more things reliably, but this contribution is second order. The main job, the most important job, the one that adds the greatest value is in *envisaging choices to examine in the first place*. This requires the considered input of someone who has spent time "at the coal face."

Technology has to be a complement to, not a substitute for, experience.

4 RISK

With two major tailings dam failures in Brazil in the last 5 years, with significant loss of life, the notion of "risk" is top-of-mind in the board rooms of mining companies. And correctly so.

The safety focus in mining in first world countries is not as diligently followed in other parts of the world as shown in Figure 9.

Figure 9 Mining and Safety are not the same everywhere in the World

4.1 Risk and the Efficiency Frontier

The world is not a risk-free place. We can commute to work in a Volvo and this is going to be safer than riding a push bike, but it is also going to cost more. Between the push bike and the Volvo is an alternative that for us represents the most appropriate trade-off between cost and safety consistent with everything else we are doing in the business.

In economics this is referred to as the efficiency frontier. It applies for risk as well as return. The marginal effort must yield the same marginal risk [reduction].

The operator of that Komatsu scaling rocks off the cliff face probably doesn't drive a Volvo to work, carefully never exceeding the speed limit.

4.2 Rational Decisions involving Risk: Aviation Example

There are many facets to the problem of choices subject to risk and uncertainty. The focus in this section is on how to keep risk decisions rational, again using an aviation example.

In December 2001, Richard Reid, a passenger aboard American Airlines Flight 63 from Paris to the USA attempted to blow up the plane using explosives hidden in his shoes. The attempt failed. Nevertheless, ever since, for the last 18 years, everyone who flies in the USA – over 800 million passengers annually – is required to take off their shoes at the security checkpoint.

Figure 10 - Airport Security at Denver International Airport.

To mitigate the risk of someone hiding explosives in their shoes and blowing up a plane – and keep in mind that even in this original instance the plane was not blown up, and not one person was killed – the flying public bears this cost.

Most sensible people would say that if our objective is to save lives the same resources deployed in other areas surely would save more of them. The marginal effort must yield the same marginal risk [reduction]. That is the efficiency frontier applied to risk. That is point one.

Now to point two:

Let's say we all recognize this "shoe removing" pantomime is absurd. Who is going to unwind it and repeal the regulation? Who is going to say that the risk reduction benefit doesn't warrant the cost .. particularly where the cost is spread amongst 800 million passengers annually? The answer is: nobody. Because if such a decision results in just one future attempt at shoe-bombing, the person responsible for repealing the regulation will be pilloried. This is the nature of so many risk decisions. The costs are spread amongst the many, the risk associated with the choice is borne by the few.

In practice there is probably only one person in the USA who can make this call – the President. He reportedly has a sign on his desk that says "the buck stops here."

4.3 Rational Choices involving Risk in Mining

The same is true of corporate decisions involving risk. Ultimately it is the CEO and the Board who take responsibility.

Risk choices have to be made by someone with the right experience to understand them; someone with sufficient time "at the coal face." That someone also has to be at the most senior levels of management in the company.

The best way to illustrate this is through an example.

I put the proposition that big risk-averse companies <u>shouldn't be running underground mines</u>.

Underground mines have inherent risks that open pit mines simply don't have – it's dark down there, you can't *see* what is happening and often you don't *know* what is happening;

drilling out deep orebodies is much more difficult and costly than with open pit mines so you know a lot less about the ground you are mining in; access is an order-of-magnitude more difficult.

Now imagine some safety-related incident occurred underground – the mining equivalent of the shoe bomber. Maybe, like the shoe bomber incident, no one was actually hurt. But, with such a warning, the incident cannot be ignored either.

What is your approach? Are you going to force a new rule on all of your operators forever and a day about how they are to conduct their affairs within the mine?

In underground mines inappropriate constraints add complexity and cost that can multiply many-fold, much more so than is the case in open pit mines.

Without senior management rational understanding of risk, judiciously applied, very quickly you will find your rule has caused costs to blow out of all proportion, production to decline, and economics undermined [pun intended]. And once in place, these rules are extremely hard to reverse.

How many deep underground mines are being run by big risk-averse mining companies? I pose the question: How many of these mines are perennially underperforming?

I leave this as an unanswered question.

This is where the mining industry is not being well served at the most senior levels of management. Ever since management started treating mining just like any other industry, under-rating the importance of time "at the coal face" as an essential requirement, these kinds of decisions have failed us.

Technical personnel rightly deserve an apology. Technical people spend much of their lives working on more efficient ways to plan and operate mines. They rightly feel proud when these efforts save $1 million, or $10 million or even $100 million in costs. At the same time, at board level, the company closes some mine or exits some ill-considered mining investment and in the process writes off an amount of money far exceeding any efficiency gains achieved by technical personnel. In the case of the Ravensthorpe Nickel Mine BHP spent $2.2 billion on mine development but after one year of operation closed the mine and then sold it for $340 million. In the case of their Mozambique Coal Assets, RioTinto spent $3.9 billion to acquire the assets and later sold them for $50 million.

Clearly the initial decisions were flawed, and seemingly didn't appreciate the risk or some other aspect of the projects.

5 DIVISION OF LABOUR

In the previous two sections I've highlighted what I consider two serious issues inhibiting implementation of better mine plans and operations – the dangers of automation dependency, and a poor understanding of risk – both issues relating to declining industry experience levels. In this last section I focus on the division of labour as the key institutional vehicle for capturing the *gains* of increased efficiency.

My first job after I graduated as a mining engineer was at the Saraji Mine in Central Queensland, operated at that time by Utah Development Company. This was in 1974 and it was also the early days of computers. At Saraji we had a Hewlett Packard 9830 computer for our use, and we were excited at the scope to use it to improve mine efficiency. For example, the task of calculating dragline rehandle and productivity and optimizing pit designs was far too complex a job to do manually but we all had a gut feel that if we could use the computer to understand these things better we could improve the efficiency in overburden removal by 10% or more.

Yet we struggled to get support from senior management for resources to devote to this work.

Their answer was that just a few days strike from the unions would amount to much more production loss and cost than any production gains or cost savings that we could come up with. Also, drilling and blasting, and dragline operations might have been a big cost at the minesite, but for the operation as-a-whole the exorbitant rail freight being charged by the Queensland Government at that time totally overwhelmed these on-site costs. These two over-arching issues blunted all incentive to chase efficiencies elsewhere.

Was Utah Development Company right in this approach?

In one sense they were.

Everyone is endowed with limited resources – money, energy, time – and if resources could be directed to addressing the union issue, or the rail freight issue, then the return from this effort could potentially be much higher than the return from focussing on the dragline or drill-and-blast efficiencies.

Now consider if the company *outsourced* the drilling and blasting to some other company whose sole business was drilling and blasting? *That* company wouldn't be distracted by the rail freight issue. *That* company can bring knowledge and experience from a much wider set of applications. *That* company can develop systems and tools whose cost of development can be spread over a much larger set of applications than just the 4 mines then being run by Utah. And for *that* company every dollar of reduced drill-and-blast cost would result in extra profit reporting straight to their bottom line. Their incentive is completely focussed on efficiency.

The efficiency of using outsourced supply is nowhere more important than with technology.

Many technology products cost very little to produce once developed – all the effort is in developing the product in the first place. Spreading technology development costs over a world-wide market will yield far better economics than an individual mining company can achieve developing the technology itself.

This is what underpinned my decision in 1977 to start *Runge Limited* (now: RPMGlobal Holdings Ltd). This is also the business case that underpins the whole of the METS (Mining Equipment, Technology and Services) sector, a sector that is now a $90 billion annual business in Australia. Specialists working in collaboration with mining companies can deliver efficiencies that can never be matched by mining companies "doing it themselves."

In economic circles this is nothing new. Adam Smith, in 1776, in his famous book the *Wealth of Nations*, literally ascribes the wealth of nations to this same division of labour.

Nevertheless, capitalising on the value-adding possibilities from the division of labour is not all straight-forward. Before anyone can rationally outsource anything there are prerequisites:

1. **Costs**. Firstly: it doesn't make sense to outsource anything unless you are satisfied that the supplier can do it better, faster, or cheaper than you can, so a mining company has to first understand what its own costs are. Mining companies are not very good at this.
2. **Relationships**. Secondly, there has to be a relationship that works – call it collaboration, or partnering, or contractual – to maximize the gains and minimize the transaction costs so that the benefits from the division of labour can be shared by both parties. Mining companies are not very good at this either.

It might seem that I am stating the obvious. Yet in my experience these are the two biggest inhibitors to greater implementation of efficiency-producing change within the industry.

Mining companies are frequently too prescriptive in this outsourcing rather than letting the collaborator/partner do things their way. Some companies are hyper-sensitive about safety, and forego alternative more-efficient ways to doing things that might be equally as safe. Many mining companies seem to have a hang-up about a service provider potentially making a lot of money, even though the mining company might be vastly better off as well.

6 CONCLUSION

I'll finish the presentation by repeating what I said earlier: that now is a good time in the commodity price cycle to be implementing significant change and setting in place solid technical foundations for the next few decades of mining.

Unlike with the boom and bust phases of the commodity price cycle, right now there is no clear direction of the major economic forces at work. The industry seems to focusing not on mining but on peripheral issues. Without firm direction set from within the industry risks being forced into someone else's agenda.

I call upon mining companies to once again be a mining company.

Being a "mining company" means recognizing the idiosyncracies of the industry instead of thinking that "mining" is just like the car industry or the pharmaceutical industry or any other industry. The first step is to re-engage with industry professionals who have done their time at the coal face. Input from such professionals will be the biggest and single best insurance against committing the same investment faux pas as previously.

Obviously there are many more aspects to a rational strategy for "being a mining company", but in this presentation there isn't the time and this isn't the place to address them. Nevertheless, I have set out below a brief appendix of some of the more important aspects of this strategy, and I invite feedback for consideration in the next version of my "Mining Economics" book.

7 NOTES AND REFERENCES

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8 APPENDIX A

Draft for Discussion – Please respond to Author directly

Business Strategy for a Mining Company

….. The businessmen believe that they are defending free enterprise when they declaim that business is not concerned "merely" with profit but also with promoting desirable "social" ends; that business has a "social conscience" and takes seriously its responsibilities for providing employment, eliminating discrimination, avoiding pollution and whatever else may be the catchwords of the contemporary crop of reformers. In fact they are--or would be if they or anyone else took them seriously--preaching pure and unadulterated socialism. Businessmen who talk this way are unwitting puppets of the intellectual forces that have been undermining the basis of a free society these past decades.

There is one and only one social responsibility of business--to use its resources and engage in activities designed to increase its profits so long as it stays within the rules of the game, which is to say, engages in open and free competition without deception or fraud

Milton Friedman (1970) in:
"The Social Responsibility of Business is to Increase its Profits"

8.1 Distinguishing Features of Mining as an Industry

Until a few decades ago, mining was almost wholly a technical business. Mining would start on some outcrop on or near the surface, and would continue deeper and deeper, incurring increasing costs until the return from sale of the products was insufficient to cover the costs. The mine would close. Commodity price declines might similarly lead to mine closure. Commodity price increases might lead to re-opening. The success or otherwise of mining was dependent on the vagaries of the deposit, largely unknown, or the uncertainty of the commodity markets, also largely unknown. There were of course exceptions, most notably the gold market whose price was often fixed by government.

The distinguishing features of mining as a business over the centuries are 1) that mining involves a unique and diminishing asset, with its own proprietary characteristics, and 2) "risk[1]."

Proprietary Inputs. Unlike many industries that involve factors of production that can all be sourced in the market, every mine is unique. This means, for example, that economies of scope and economies of scale that characterize the economics of other industries may be unimportant in mining. Small scale mines with suitable (rich enough) deposits can fully compete with large scale mines.

1 "Risk" in this context refers to the common usage of the term, meaning the exposure to the chance of injury or loss. (In the economics literature, "risk" is often restricted to something that can be actuarily assessed – the kinds of uncertainties faced in the mining industry are rarely actuarily assessable).

Risk. The risk follows from two defining characteristics of the industry:

1. **Mineral deposits are rarely well understood**. Removing this deposit risk requires drilling and other testing. For many, perhaps most deposits, the cost of this orebody definition would render the deposit uneconomic. There is *inherent* risk.

2. **Commodity Prices are Variable and Unknown**. Products of mining are classically sold into commodity markets whose prices vary significantly over the life of the mine.

A "mining company" doesn't necessarily have to undertake the mining, or the processing – there are plenty of examples of this being outsourced. Being a "mining company" does however mean two things:

- That the company owns the resource[2], and
- That the company "owns" the commodity price risk

8.2 Owning the Resource

- Responsibility for understanding the resource rests with the mining company once the resource is no longer just an exploration prospect (i.e. once it has been identified as a potentially viable mine). This "understanding" is a function of time and mining schedules. For example, production at the start might be from a high proportion of oxidized ore whereas later production may be from primary ore. This "understanding" will be greater for parts to be mined sooner in the mine schedule. Even with no expected changes in orebody characteristics, there may be other changes as the mine progresses – overburden might get harder as the mine gets deeper, for example.
- There is an option value associated with every resource. This option value is also an asset of the mining company, whose responsibility it is to maximize. For example, a mine might be planned and developed for a certain production over a (say) 20-year life, but if there are more resources available than needed to fulfil this plan, then there is an option to expand production, or extend production past the initially planned life.
- Every deposit is finite. A mining company that seeks to operate as an enduring business has a responsibility to replace each tonne mined with some new tonne found. The new tonne could be physically discovered via exploration, or could be made economic wherein previously it was considered uneconomic (by developing new technology, for example). This is a prime responsibility of a mining company.

Some of the implications and/or strategies for following through on these mining company responsibilities are set out in the following section.

8.3 Owning the Commodity Price Risk

The job of the mining company is to bear the risk of commodity price changes in the market. The selling price of all mining commodities has fluctuated up and down since there was ever a market for them.

[2] The term "resource" in this context implies any deposit whether it is well understood (for example, with JORC characterization as a "reserve") or less-well understood (for example, with JORC characterization as a "resource.").

- Unlike the risk associated with deposit uncertainty, it may be possible to mitigate commodity price risk via the market – gold, silver, for example, or via offtake agreements (in the case of some bulk commodities and industrial minerals). Using market mechanisms to mitigate risk will incur a cost.
- In most jurisdictions mining companies don't actually "own" the deposit, but instead own the right to exploit and sell it as part of a lease agreement. In some of these agreements some commodity price risk remains with the ultimate owner (the government) via (for example) royalties payable as a function of selling price.
- If the price/revenue risk is to be fully borne by the mining company, then this characteristic has to be taken into account in the planning of the mine. Classically, mines are designed for a certain product output, and downstream infrastructure (processing planes, rail and port facilities) are sized for the [nameplate] output[3]. Capital intensive mines therefore have little economic incentive to produce at any rate of production other than design capacity. Changes in production rate offer little scope for managing changes in economics when commodity prices change.
- The mechanism for addressing the economic impact of changes in commodity pricing in most mines involves changes in production *cost*. This is where mines, with proprietary inputs, have scope to respond in ways that other industries cannot. Simply put: if a mine is expected to be viable at a varying-but-average selling price of X, then in times when the selling price is less than X the mine should exploit parts of the deposit whose cost of production is lower (i.e. shallower, higher grade), such actions to be counter-balanced by exploitation of other parts of the deposit (deeper, lower grade) when the selling price is more than X. Not all deposits facilitate such cost-of-production elasticity however. The ability or inability of the deposit to accommodate such change is a critical element in the valuation of a deposit prior to commitment to proceed with development of a mine.
- The capital structure of the mining company must provide for the above changes and characteristics. There is a cost of designing (or, over-designing) a mine to be better able to accommodate commodity price changes. Alternatively where commodity price changes are significant and where the risk associated with this variability cannot be accommodated internally, then the risk remains with the capital markets – shareholders. Faithfully representing the risk to shareholders or potential shareholders is an important task of management, so that the risk via this channel (higher cost of capital) can be faithfully compared to other mechanisms to address the risk.

A mining company that commits to a new mine development without comprehensively understanding what strategy to follow in the event of change is renouncing the very essence of what defines a "mining" company. The ability and resilience of the mine to respond to change has to be understood *before the mine commences.* The lesson learned from our experience over the last decade is that as future mines are brought forward for consideration we have to understand the resilience of the plan better, and then incorporate this in the decision process.

8.4 What have we Learned from the last 20 years of Booms and Busts in the Mining Industry?

- The mining industry, and the people who work in it are classically not very commercially

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[3] This applies to large bulk commodities such as iron ore and coal sold into international markets. Precious metals and high-value metals have a low proportion of their costs associates with transport infrastructure.

savvy compared to many other industries. This is a characteristic of the industry itself: *proprietary* inputs largely insulate most mines from direct competition. This insulation extends specifically to personnel on the production side of the business, whose benchmarks for performance are classically output focussed, not cost or profit focussed. This ill-developed commercial acumen inhibits the ability to collaborate, partner, or more generally to work with suppliers. These are skills that are important in maximizing the value and in capturing the gains from the division of labour. It should be the strategy of any mining company to invest in developing such commercial acumen across the whole spectrum of operating personnel.

- Few large mining companies have well-developed capability in exploration, having long ago passed this role over to much smaller specialist exploration companies. These specialist companies are classically owned by shareholders who have a much greater appetite for risk compared to a mining company. These small exploration companies have proven very efficient in using exploration budgets to find new orebodies, but for such enterprises, availability of capital is a major constraint. The model of totally outsourcing the discovery of new orebodies to the junior exploration sector is not working very well. If mining companies want to have a new big deposit to mine after their current deposits are exhausted, then partnering and collaborating with, or simply investing in such juniors is something that is required much more comprehensively than is the case today. The probabilities of any one investment turning successful are low, so investments like these require a portfolio approach. The responsibility for finding and/or acquiring new reserves is definitely the responsibility of a mining company, and strategic stakes in the junior exploration sector represent valuable options on possible future discoveries.
- Research Institutions. Like exploration companies, the chances of economically viable technologies coming to fruition from research institutions might be low, but so too is the relative cost of supporting such research, and the potential payoff can be huge. Only one "froth flotation" discovery might be needed every century to ensure the minerals cost curve continues its downward march. The world's biggest mining companies today are the ones who a century ago were at the leading edge of this knowledge and capitalized on it.
- Investing "through the cycle." Mining companies are quick to point out that "they are in business for the long term" and that "they invest through the cycle." Yet at the first sign of trouble they are equally quick to retrench people whose short-term value is less evident, and in so doing, often cast aside institutional memories that might be instrumental in avoiding making the same mistakes again. Investing through the cycle means valuing your own intellectual capital and preserving your own institutional memory.
- Knowledge of the industry no longer rests just within any particular mining enterprise – it is dispersed amongst thousands of suppliers and service providers. Investing "through the cycle" also means supporting key partners, suppliers, and technology service providers who may have more knowledge or shared knowledge of mining operations that, if lost, also can result in making the same mistakes again.
- Intellectual Property. The treatment of partners, suppliers, and technology service providers also extends to protection of intellectual property, sometimes proprietary to the provider, sometimes shared. It makes the news regularly about Chinese companies having no respect for IP, but amongst large mining companies respect for the IP of technology service providers often gets similar short shrift. In today's world where technology and innovation are key, a truly collaborative, value-adding partnership requires respect for the intellectual property of each party to achieve the result.