



## *Technology and Innovation Driving Mining Forward*



22<sup>nd</sup> Annual MDEC Conference  
October 4-6, 2016  
Hilton Toronto Airport Hotel, Toronto, Ontario, Canada

Michael MacFarlane

## Context & Overview

- 1. The prevailing mining model is breaking down and operating financially sustainable operation is more difficult than ever.*
- 2. What is the problem?*
- 3. What does the pathway forward look like?*
- 4. New design rules for the mining industry.*
- 5. In practical terms where should we start?*
- 6. Who can we learn from to speed up the improvement? Case studies.*
- 7. Roadmap moving forward.*

## Big miners write off \$US200 billion over five years

PwC head of mining, Chris Dodd, said the miners appeared to have "written off" a large chunk of the value of the boom by writing down \$US53 billion worth of assets last year after buying mines at the top of the cycle.

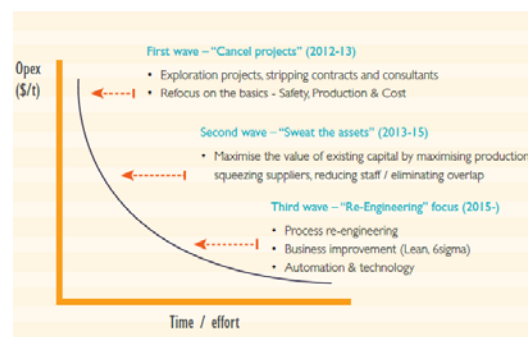
BHP Billiton Ltd. ADR  
NYSE: BHP



OVERVIEW PROFILE NEWS CHARTS FINANCIALS HISTORICAL QUOTES ANALYST ESTIMATES



### - The Three Waves of Cost Cutting



... and now it's time to turn to the strategic application of technology.



CHAMBERS AND THORNTON  
For mining companies, digitization is  
the next gold rush

JOHN CHAMBERS AND JOHN THORNTON  
Special to The Globe and Mail  
Published Monday, Sep. 19, 2016 5:00AM EDT  
Last updated Monday, Sep. 19, 2016 5:00AM EDT

Fool's Gold the Only Find for Barrick Going High Tech: Gadfly -  
by David Fickling (Washington Post/Bloomberg - September 13,  
2016)

## MINING

TRENDING Apple | Bank of Canada | Oil | Loonie | Housing Market | Gold | CPP

### Barrick turns to Cisco to drag gold mining into digital era

07:59 EDT Monday, September 12, 2016

TORONTO, ONTARIO and SAN JOSE, CALIFORNIA--  
(Marketwired - Sept. 12, 2016) - Barrick Gold Corporation (NYSE:ABX)(TSX:ABX) (Barrick or the "company") and Cisco today announced they will partner for the digital reinvention of Barrick's business, bringing together cutting-edge technology and expertise to unleash the full potential of mining

- *Technology is strategic.*
- *You can't buy transformation.*
- *Deposits are not the differentiator.*
- *Low risk mining locations.*

There's a warning in that for Barrick, which arguably has the world's best large gold mines .... **let other players shoulder the risk of developing new technologies.**

Right now, Barrick has a prized geological endowment few can hope to match. Extending that resource base further would be a much better use of capital than innovating to level the playing field.

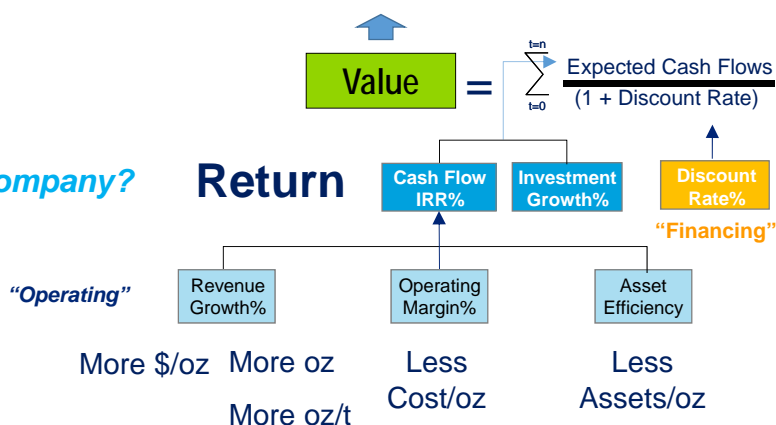
# What does it mean to focus on VALUE?

*Good Investment?*

Total Shareholders Return

*Good Company?*

Return



Source: Deloitte

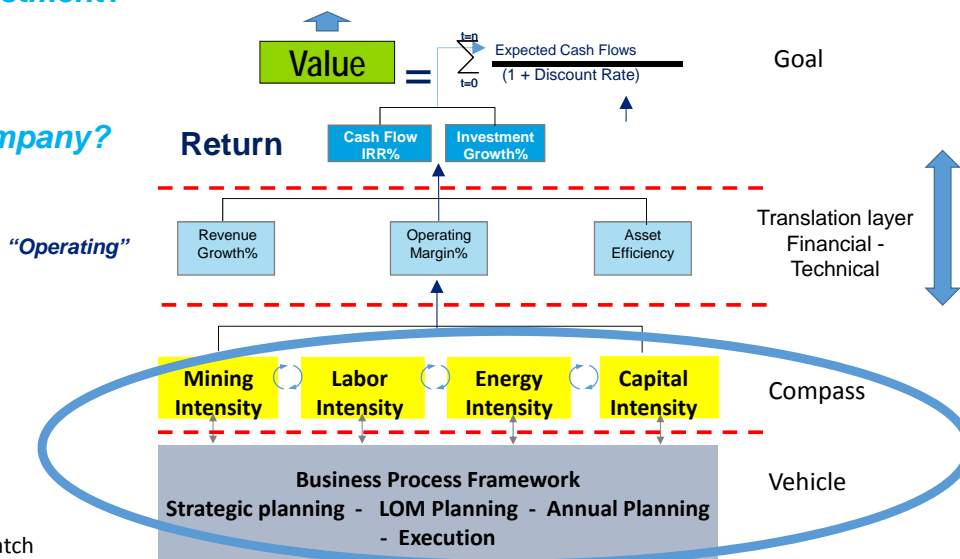
# What does it mean to focus on VALUE?

*Good Investment?*

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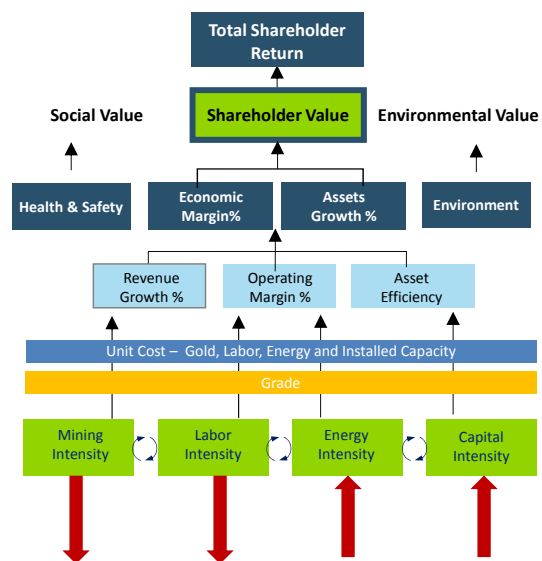
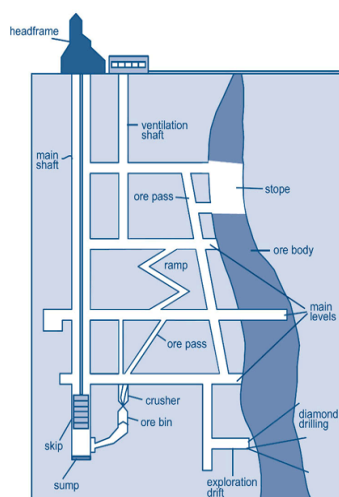
*Good Company?*

Return

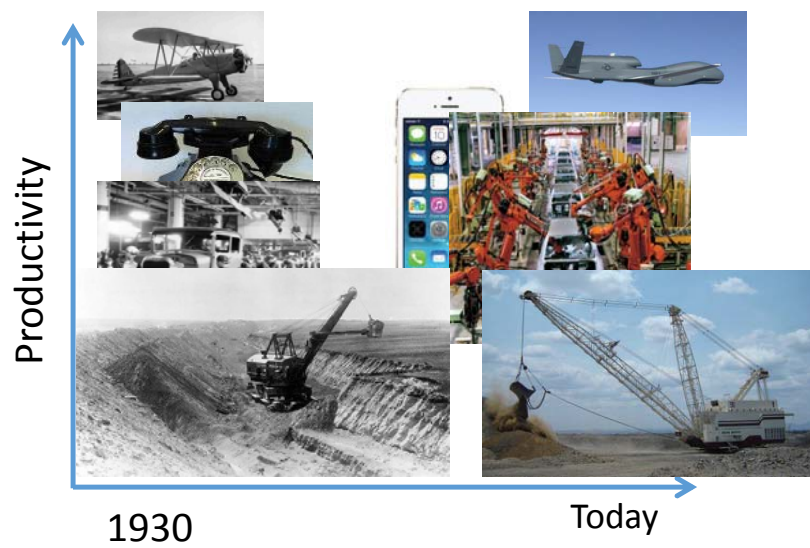


Source: Deloitte/Hatch

## Traditional Mining Design

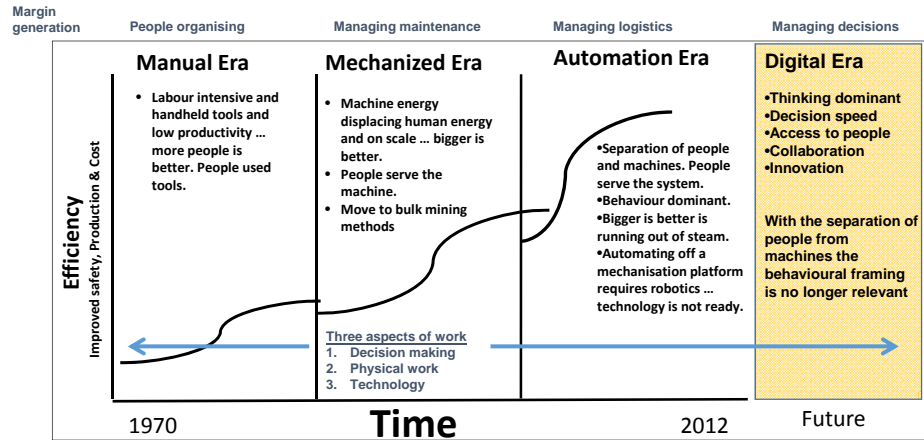


## A century of innovation



## Evolution of Underground Mining

We are trying to automate by extending the thinking from mechanisation ...



... rather than focus on controlling the environment and thinking from the future.

4

## What has the mining industry been trying?

*Manufacturing controls the work environment such that automation is possible...*



... and the mining industry must think the same way in order to automate and drive a step change in **productivity and mining intensity**.

Source: MDM Mining Consulting

# NEW BOLIDEN

Boliden have always viewed technology as being strategic ....



## Technology – Mission

1. Technology drives the development of mine design, methods, processes, plants, and is a corporate resource for Boliden mines and plants.
2. Technology contributes to drive productivity and optimization utilization of mineral reserves by determinedly pursue R&D.
3. Technology is an important link to making Boliden an attractive employer for engineers and managers.

... where senior executives have a significant leadership role in generating value.

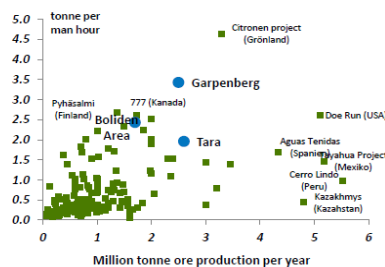


## Mine Automation

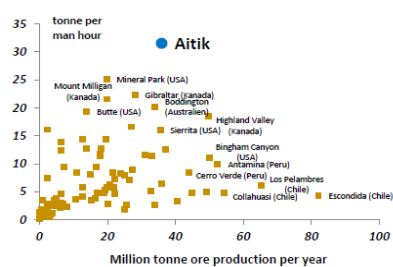
→ Approach and vision for a Mine Operation and Automation Center  
**Highest productivity**



**Zinc - underground mines 2016**



**Copper - open pit with mill 2014**

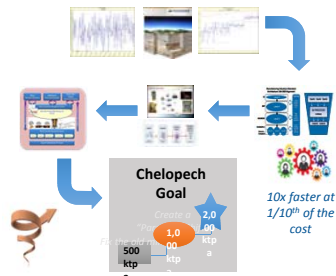


**BOLIDEN**

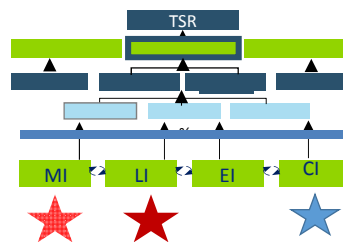
## Reducing process variation is not cost cutting



Taking the Lid of the mine



### OPTIMIZE THE VALUE OF EXISTING ASSETS CHELOPECH

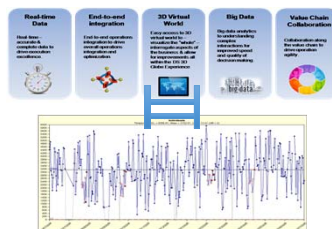


## Technology Roadmap

### Real-time Digital Mine



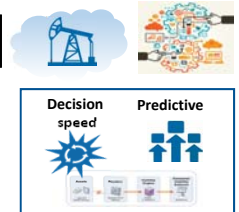
### Enabling Technology



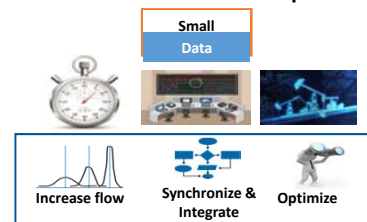
### Agile Value Chain

Parametric Designs

### Strategic Alliances



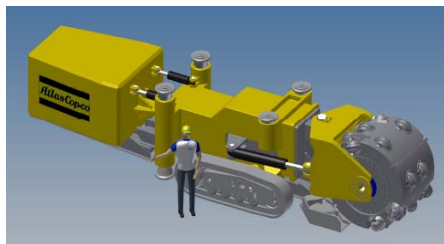
### Continuous Automated Operations



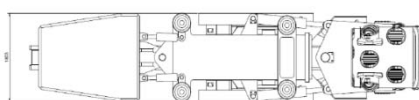


# Early concept drawings

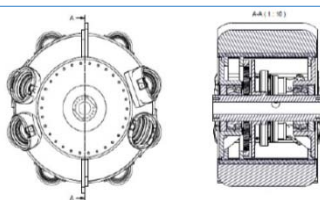
Micro Mobile Miner



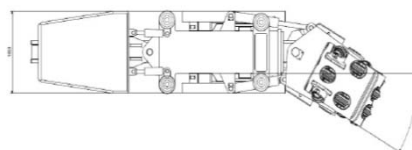
Micro Mobile Miner – Top View Width 1.8m



Micro Mobile Miner – Cutter Head Drive



Micro Mobile Miner – Top View Head Swings 30 deg

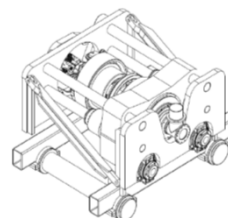


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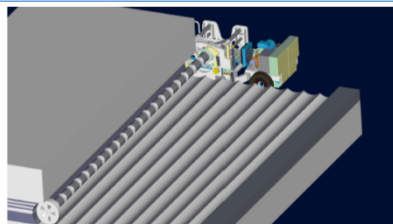
Mini Slot Borer (NB: Picture showing large slot borer)



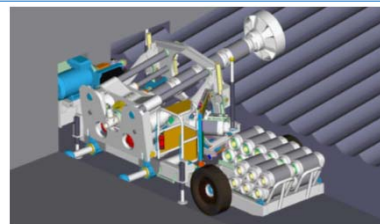
Mini Slot Borer – View From Opposite Side



Slot Borer Application



Slot Borer Application



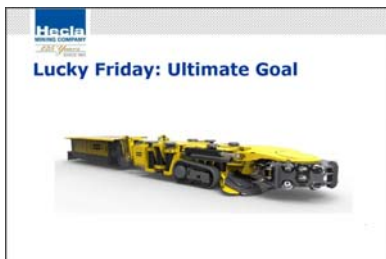


## Think big-test small-scale fast

The key to successful innovation is testing small and thinking end-to-end ....



Sandvik's MX650 will be a mechanical excavation machine applying roller-disc undercutting technology



... and these machines are big – expensive and point solutions!

## JOYGLOBAL

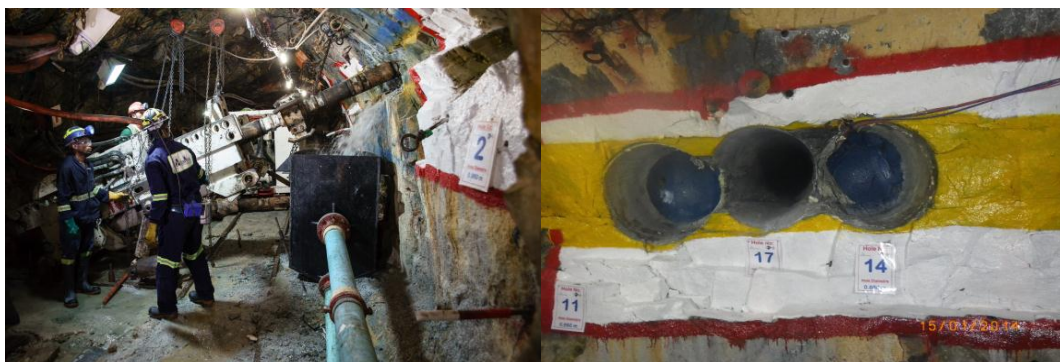
Joy Global introduces DynaMiner prototype featuring DynaCut technology for continuous hard rock mining



The prototype of Joy Global's DynaCut machine, which is believed to be preparing to start trials at a mine site

# This Lays the Foundation for Intelligent Mining

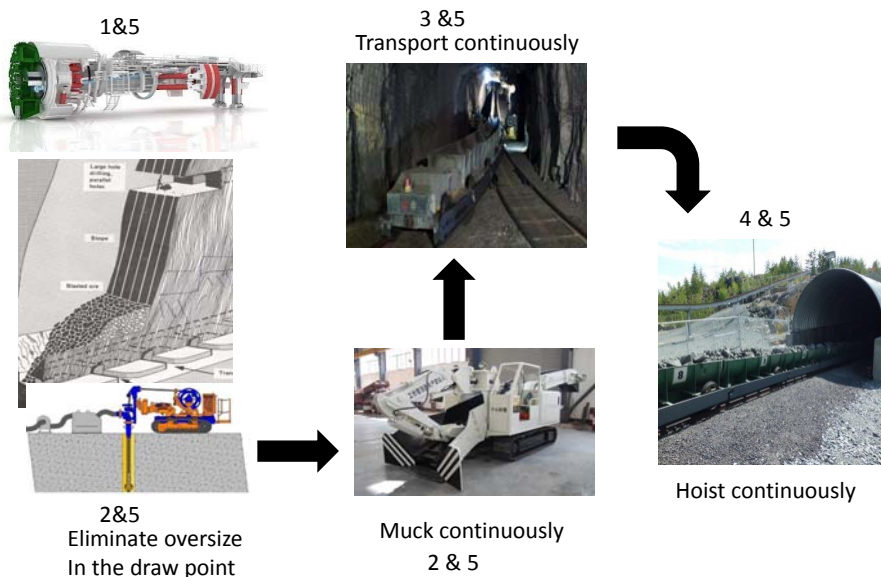
The transformation to continuous Hardrock mining has started in South Africa ....



... and it won't stop there!

Source: AngloGold Ashanti

## Continuous Mucking System



# New Modular Mining

Automated & Modularized – Real-time & Integrated – Scalable & Flexible

## Ore Transportation

- Transportation design sorts ore and delivers zero waste to the mill



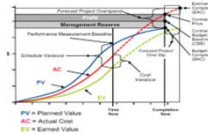
## Modular Mining

- Flexible for complex orebodies
- **Start small and scale up – new economics**
- Enables a transportation ore sorting design



## Operation Modeling and Simulation

- *Prove before execution*
- *End-to-End Integration*



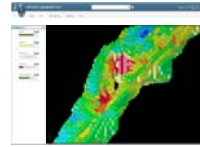
## Modular Processing

- **Zero waste = modular mill**
- Scalable up and down
- Low Capex – Opex & risk
- Full automated = low Opex
- Reusable and portable



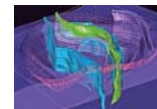
## Geological Modeling

- Real-time blast hole information – **DGI**
- Differentiate - ore/waste in field in real-time to drive **Zero waste to the mill**



## Mine Design

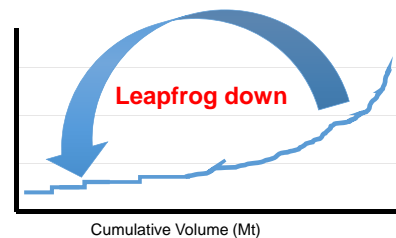
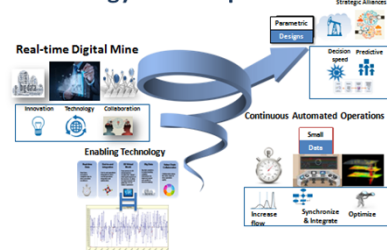
- Rapid flexible designs to deliver **Zero Waste**



## Strategic Application of Technology

How to get to 1<sup>st</sup> Quartile without Big – Low cost – Long life Orebodies?

### Technology Roadmap



Develop technology to focus on value not just unit cost.



*Seeing what others can't see ...*



*... is a huge strategic advantage.*

What can the future look like?

