Industry 4.0 for increased mining safety and productivity

Prof. Peter Knights
Discipline Leader Mining, School of Mechanical and Mining Engineering
The University of Queensland, Brisbane, Australia
What is industry 4.0?

The Four Industrial Revolutions

**Industry 1.0**
Mechanization and the introduction of steam and water power

**Industry 2.0**
Mass production assembly lines using electrical power

**Industry 3.0**
Automated production, computers, IT-systems and robotics

**Industry 4.0**
The Smart Factory, Autonomous systems, IoT, machine learning

www.spectralengines.com/articles/industry-4-0-and-how-smart-sensors-make-the-difference
The global market for industry 4.0
2002-2013: Investment boom in mining driven largely by demand from China.


2016 - current: Accelerated investment in digital technologies (Industry 4.0).
Industry leaders; Rio Tinto, BHP, Fortescue Mining Group, NorthParkes mine, Resolute Gold
Current status in Australia

Rio Tinto: ~ 180 Automated Haulage Trucks in the Pilbara (Iron Ore)
Integrated Operating Centres in Perth. Developing RTViz operating system with University of Sydney. State-of-art autonomous Koodatorai mine under construction.

BHP: Around 30 AHTs (recently announced desire to ramp up to 500). Remote Operating Centres in Perth, Brisbane, Santiago (Chile). iMine test site in Arizona. State of art autonomous South Flank mine under construction. Have announced joint venture with Dassault (Geovia).

AngloAmerican Metallurgical Coal: 2 Autonomous blasthole drills, Dawson mine.
Two types of automation:

1. Equipment automation

2. Business process automation

• Both increase productivity - designed to take “people out of the control loop”

• Both can enhance mine safety

• Project and implementation risks need to be carefully considered for technology investments
Equipment Automation – Australian Surface Mines

• Autonomous Haulage Trucks (220)
  • Iron Ore (Rio Tinto, BHP, Fortescue)

• Autonomous blasthole drills (~50)
  • Iron Ore and Coal (Rio Tinto, BHP, AngloAmerican)

Photo source: Rio Tinto - Clayton, B. Group Executive Business Support and Operations, CITI presentation, 8 March 2012 available at www.riotinto.com
Equipment Automation – Australian U/G Mines

• Autonomous LHDs
  • NorthParkes Mine (CMOC)
  • Cadia Mine (Newcrest Mining)
  • (Block caving operations)

• Autonomous Trucks
  • Syama Mine (Mali – Resolute Gold, Australia)

• Autonomous drills
  • Longhole (NorthParkes - development)
  • Jumbos (?)
Remote Operating Centres

- Iron Ore Operations
  - Perth (Rio Tinto, BHP)

- Coal
  - Brisbane (BHP, AngloAmerican)

- Gold/Copper
  - Brisbane (Rio Tinto)
  - Orange NSW (Newcrest Mining)

Photo source: Rio Tinto - Clayton,B. Group Executive Business Support and Operations, CITI presentation, 8 March 2012 available at www.riotinto.com
Industry 4.0 includes “wearables”

Example: non-intrusive operator fatigue monitoring, Measures brain wave (ECG) activity.
Eg. Caterpillar fatigue detection prevents accidents

8M HOURS IN MINING OPERATIONS

40% of nighttime employees nod off

1.5 MILLION distraction events

REPETITIVE DUTIES

63,000,000 miles traveled with DSS

x 5,000 HAUL TRUCKS INSTALLED

Source: Caterpillar – Data for Caterpillar Driver Safety System, 2018
Industry 4.0 – Integrated, intelligent mining

Execution layer
- Orebody
- Drill and blast
- Load and haul
- Stockpile/crush
- Mill/CHPP to train load-out
- Rail and port stockyard

Sensing layer
- Geophysics and drill sampling
- Measurement whilst drilling
- Hyperspectral sensing
- Online grade or quality sensing
- Metallurgical yield / coal quality
- Online grade sensing

Model layer
- Orebody model
- Blast model & design
- Fleet dispatch model
- Stockpile & crusher models
- Process model
- Train dispatch & stockyard models

Control layer
- Feed forward & Feedback control
Opportunity 1: Feed forward (eg. plant optimisation)

Execution layer
- Orebody
- Drill and blast
- Load and haul
- Stockpile/crush
- Mill/CHPP to train load-out
- Rail and port stockyard

Sensing layer
- Geophysics and drill sampling
- Fragmentation measurement
- Hyperspectral sensing
- Online grade or quality sensing
- Metallurgical yield / coal quality
- Online grade sensing

Model layer
- Orebody model
- Blast model & design
- Fleet dispatch model
- Stockpile & crusher models
- Process model
- Train dispatch & stockyard models

Control layer
- Grade/quality
- Lithology update
- Blast design
- Hardness or wash characteristics

Material composition tracking
Opportunity 2: Feedback (eg. rapid resource reconciliation)

Execution layer
- Orebody
- Drill and blast
- Load and haul
- Stockpile/crush
- Mill/CHPP to train load-out
- Rail and port stockyard

Sensing layer
- Geophysics and drill sampling
- Measurement whilst drilling
- Hyperspectral sensing
- Online grade or quality sensing
- Metallurgical yield / coal quality
- Online grade sensing

Model layer
- Orebody model
- Blast model & design
- Fleet dispatch model
- Stockpile & crusher models
- Process model
- Train dispatch & stockyard models

Control layer
- Grade/quality
- Blast design
- Lithology update
- Hardness or wash characteristics

Material composition tracking

- Geophysics and drill sampling
- Measurement whilst drilling
- Hyperspectral sensing
- Online grade or quality sensing
- Metallurgical yield / coal quality
- Online grade sensing

Grade/quality
- Blast design
- Hardness or wash characteristics

Lithology update
The age of data

An autonomous truck collects data from 180 sensing points

Collects around 2.5 TeraBytes ($2.5 \times 10^{12}$) of data per day

What happens to this data?

Mining companies use only a fraction of their data.

Operational information

Data capture
Data not captured

Infrastructure
Data not streamed or stored

Data management
Data not accessible

Analytics and automation
Data not analyzed

Visualization
Data not communicated

Data not used in decision making

<1%

Execution

McKinsey & Company “How digital innovation can improve mining productivity”, 2015
The value at stake for the mining industry is sizable.

McKinsey Global Institute estimates\(^1\)

<table>
<thead>
<tr>
<th>Applications</th>
<th>Description</th>
<th>Potential economic impact of sized(^2) applications in 2025, $ billion, annually</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations management</td>
<td>• Deeper understanding of the resource base</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>• Optimization of material and equipment flow</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Increase in mechanization through automation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Monitoring of real-time performance vs plan</td>
<td></td>
</tr>
<tr>
<td>Equipment maintenance</td>
<td>• Improved anticipation of failures</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>• Reduced unscheduled breakdowns</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Longer equipment life</td>
<td></td>
</tr>
<tr>
<td>Health and safety</td>
<td>• Minimized exposure to dangerous conditions</td>
<td>10</td>
</tr>
<tr>
<td>Equipment supply</td>
<td>• Improved purchasing analytics</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>• Internet of Things–enabled R&amp;D into cost-efficient equipment design</td>
<td></td>
</tr>
<tr>
<td>Human productivity</td>
<td>• Augmented reality (built on better human-machine interaction)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>• Task-based activity monitoring</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>370</strong></td>
</tr>
</tbody>
</table>

\(^1\)Estimates based on high-adoption-rates case (80% in operations management and 100% in equipment maintenance).

\(^2\)Sized applications are those applications for which the economic value has been analyzed.

Source: McKinsey Global Institute
Porter’s value chain for mining
What happens to this data?

SUPPORT ACTIVITIES

Human Resources, Finance, Business planning

Environmental Management

Procurement & Stores

SUPPORT ACTIVITIES

Mineral exploration & Orebody modelling

Planning & construction

Supply chain: inbound outbound

Mining operations

Mineral processing Process Analytics

Smelting & Refining

Marketing & Sales

PRIMARY ACTIVITIES

Logistics integration

Enterprise analytics

Engineering, Technology and Maintenance

Human Resources, Finance, Business planning

Mineral processing Process Analytics

Supply chain: inbound outbound
Maturity scale

NPV potential vs. Level of integration:

- **Process Analytics:** Maintenance
- **Process Analytics:** Performance
- Logistics integration
- Enterprise integration (Feed forward)
- Enterprise integration (Feedback)

<table>
<thead>
<tr>
<th>Rewards</th>
<th>Reliable processes</th>
<th>Efficient processes</th>
<th>Less working capital</th>
<th>Reduced capital</th>
<th>Enhanced resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation</td>
<td>Avoid breakdowns</td>
<td>Avoid rate queue losses</td>
<td>Avoid delays</td>
<td>Eliminate rehandling</td>
<td>Enhance value</td>
</tr>
</tbody>
</table>
Artificial intelligence – eg. optimising fuel consumption

Example: CAT 793D Specific Fuel Consumption (Soofastael, 2017)
Why do we need this...

...when we have these?

Photo source: Rio Tinto - Clayton.B. Group Executive Business Support and Operations, CITI presentation, 8 March 2012 available at www.riotinto.com
The future is portable!

Embrace the skill set of the **millennial** generation

**Networks** for decisions (the power of groups!)

The new iROC: **Portable** everywhere.
Conclusions

Over the next 5 years we will see great changes in digital connectivity and intelligence via Industry 4.0 technologies being adapted and developed for mining.

Humans will also be “instrumented” via wearable technology.

This will enhance safety, financial, environmental and social performance of the mining industry (eg. Energy/water efficiencies, regulatory transparency)
Gracias!
Prof. Peter Knights
School of Mechanical and Mining Engineering
The University of Queensland
p.knights@uq.edu.au