Mechanical Cutting

Samantha Espley
Technical Director, Mining & Mineral Processing
Vale
1. Context
2. Current Status of Mechanical Cutters
3. Roadmap
4. Work Completed & In Progress
5. Path Forward
6. What’s next?
Context
Why do we need to change?

- Injuries remain prevalent in our workplaces. Working environments continue to exhibit potential health hazards.
- Underground mining productivities continue to decline across our operations.
- Capital intensity for mining projects remains high.
- Unit operating costs are increasing.
Why haven’t we done this before?

- We have been *reluctant* to adopt new technologies. Technological-immaturity has been our perception.
- Commercial *availability* has been questionable.
- The recent low commodity prices have *eroded* R&D funding and capital investment opportunities.
Why is this important to Miners and Vale?

• The wave of technological driven change is here, we need to:
  • Reduce exposure of our workforce from the health & safety hazards,
  • Lower overall capital requirements, lower unit operating costs - be early adopters to remain competitive & be relevant.
Current Status of Mechanical Cutters
Current Status of Mechanical Cutters.

All major mining OEMs have mechanical cutting equipment.
Where are they operating?

<table>
<thead>
<tr>
<th>Mining Company</th>
<th>Cutting Location</th>
<th>OEM</th>
<th>Cutter Type</th>
<th>Rock Hardness UCS</th>
<th>Cutting Rate</th>
<th>Unit Cost</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anglo</td>
<td>South Africa</td>
<td>Epiroc</td>
<td>Disc, 22H</td>
<td>220 MPa</td>
<td>700 TPD</td>
<td>$25/tonne</td>
<td>2017 Trial</td>
</tr>
<tr>
<td>Barrick</td>
<td>TR, Nevada, US</td>
<td>Sandvik</td>
<td></td>
<td>150-220 MPa</td>
<td></td>
<td></td>
<td>2017 Ops</td>
</tr>
<tr>
<td>Bergteamet</td>
<td>Sweden, SKB</td>
<td>Epiroc</td>
<td>Disc, 55V</td>
<td>220 MPa</td>
<td>12 m/day</td>
<td>2018 Trail</td>
<td></td>
</tr>
<tr>
<td>TBD</td>
<td>Canada</td>
<td>Epiroc</td>
<td>Disc, 55V</td>
<td>+350MPa</td>
<td></td>
<td></td>
<td>If Sweden successful</td>
</tr>
<tr>
<td>Goldcorp</td>
<td>Ontario, Canada</td>
<td>Sandvik</td>
<td>MX650</td>
<td>Up to 250 MPa</td>
<td>20 m/day</td>
<td>2018 Trial</td>
<td></td>
</tr>
<tr>
<td>Herrenknecht</td>
<td>Germany, TBM</td>
<td>Herren.</td>
<td>TBM</td>
<td>&gt;200 MPa</td>
<td></td>
<td>2017 Ops</td>
<td></td>
</tr>
<tr>
<td>Hecla Mining</td>
<td>Lucky Friday, US</td>
<td>Atlas Copco</td>
<td>Disc, MM 40V</td>
<td></td>
<td></td>
<td>2019-20 Trial</td>
<td></td>
</tr>
<tr>
<td>Vale</td>
<td>Ontario, Canada</td>
<td>TBD</td>
<td>TBD</td>
<td>&lt;100 MPa</td>
<td></td>
<td>2018 Trial</td>
<td></td>
</tr>
<tr>
<td>KGHM</td>
<td>Polkowice, Poland</td>
<td>CAT</td>
<td>Pick, HRM220</td>
<td>TBD</td>
<td>TBD</td>
<td>2012 Trial</td>
<td></td>
</tr>
</tbody>
</table>
Roadmap
Mechanical Cutting Roadmap (Continuous Mining)

**Ready Now Technology**
- Begin to focus on continuous mine processes.
- Apply technology that is available now – continuous mucking and haulage.
- Evaluate mechanical cutting opportunities.

**1-3 Years**
- Trial mechanical cutting machines and build up a knowledge base on cutting.
- Mechanical cutting technically works and being commercialized.
- Understand mine design implications of mechanical cutting.

**5-10 Years**
- Mechanical cutting is now the commercial for most mines.
- The continuous mechanical process is being fully automated.
- Closed look water systems are now available.

**End Result**
- Automation of continuous mechanical cutting is now complete and integrated with real-time information to create the Smart Mine.
Work Completed & In Progress
The Players

AGNICO EAGLE  
BARRICK  
VALE  
GLENCORE  
GOLDCORP
Cortez RFD and TR Production in use cases
Determine NPV Impact

Capital reduction:
- new mine designs (- 25%)
- infrastructure change, new technologies.

Revenue:
- earlier ore due to rapid advance (up to 100% increase for dev.)
- enhanced mining intensity (similar rates using 40% UoA)

Unit Opex reduction:
- consumables reduction (15 to 30% reduction)
  ex. ground support, explosive elimination, energy.
- labour improvements (25% reduction)
Path Forward
Recommended Path Forward – UG Trials

1. Define an ore body trial with rockmass data (rock hardness, abrasivity, tensile strength etc.) for assessment of the system.

2. Simulate the existing mining method versus a mechanical cutting operation for the business case using outputs of rates and process costs.

3. Specify KPIs and time-frame to demonstrate success of a trial.

4. Develop a high level project plan including milestones.

5. Select project management by OEM(s) with a governance process.

6. Arrange funding, leveraging, and agreements.

7. Conduct field trial and measure KPIs relative to requirements.

8. Finalize the trial and report out.
What’s Next?
What’s next?

Six Technology Pillars in a Continuous Underground Mining Process

- Mechanical Cutting Equipment
  - Hardrock cutting of full face tunnels
- Material Handling Equipment
  - Use of conveying horizontal to vertical
- Mine Only Ore & Reduce Waste
  - Keep rock UG and liberate minerals
- Mine Without People UG
  - De-couple people from work & equipment
- 100% Overall Equip Effectiveness
  - Maximize planned production
- 100% Face or Stope Utilization
  - Focus on mining ore 24/7

Outcomes: Increase mining intensity and productivity, and decrease energy and capital intensity.
Thank-you.