# Mining: The Inversion of Industry 4.0

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#### Summary

- Previous CDO Work
  - Advanced Materials, Rise of Microstructural Manufacturing, Merging of Design & Manufacturing
- CDO Extractive Industries
  - Further Upstream: Digitization of Ore Bodies, Mine Operations
- Digital Value Chain from Mining to Metallurgy to Design/Manufacturing
  - Mining 4.0 vs Industry 4.0

## Counter Intuitive: Mining as a Play on the Digital Economy







#### Mining & Digital Economy

- Productivity Paradox
  - We just had a 10 year Metals Supercycle
  - Mining Productivity Declined by 28%
  - Mining at a Tipping Technology Point: Digitization
- Mining and the Digital Economy
  - Digital Economy Needs Mining: Lots of it.
  - EV's batteries and Cobalt
  - Digitalization = Electrification = Copper
- Most of the Materials are Underground
  - Next 10 copper mines are underground mine designs

#### Digital Transformation: Mine Design

Surface Mining (Open Pit)



Underground Mining

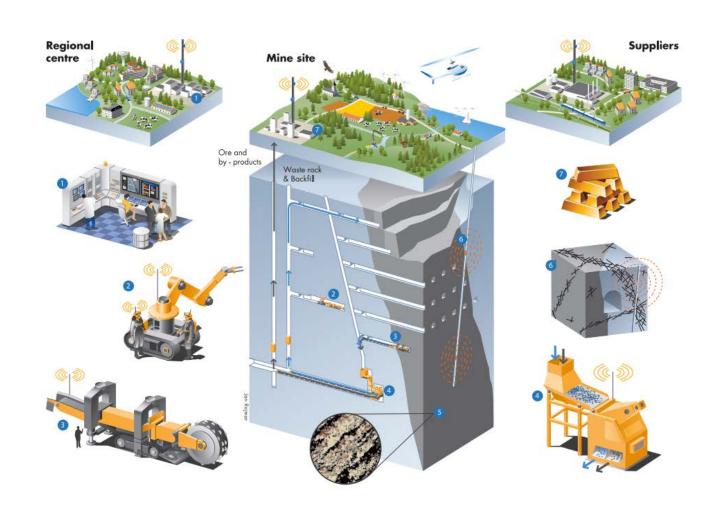


#### Underground Mining Yesterday & Today





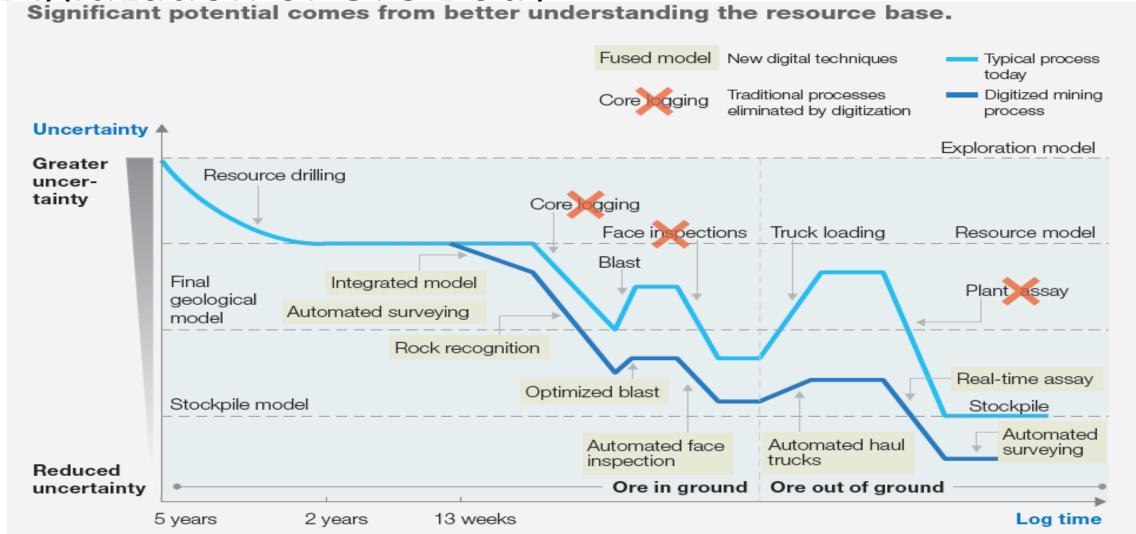
#### Mine of the Future



#### Mining Industry Technology Innovation

- Mine Operations: Lagging, Inflection Point
  - Operating Companies: Little Innovation internally
  - Equipment Manufacturers: Step improvements of bulk mining equipment
  - Supply Chain: Specialized SMEs at the margin
- Exploration and Development
  - Digitization: drones, digital imaging, quantum computing
  - Many innovative SMEs: software, sensors, digital infrastructure

Digitization of Ore Body Significant potential comes from better understanding the resource base.

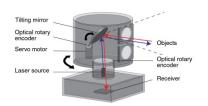


Source: Durrant-Whyte 2015

## Mining by Robots Already



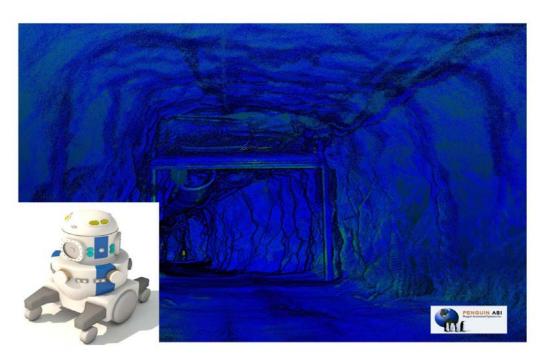
#### Underground Drones: Lidar Technology



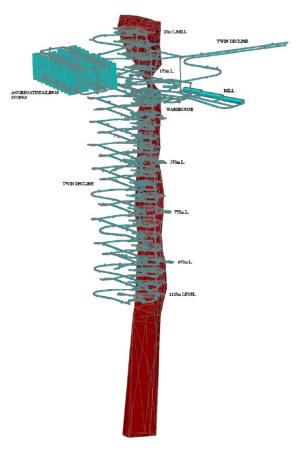




## Positioning Underground

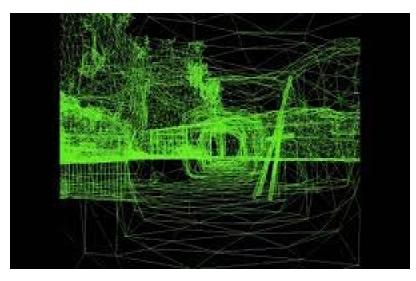






## Digitized Mine Plans





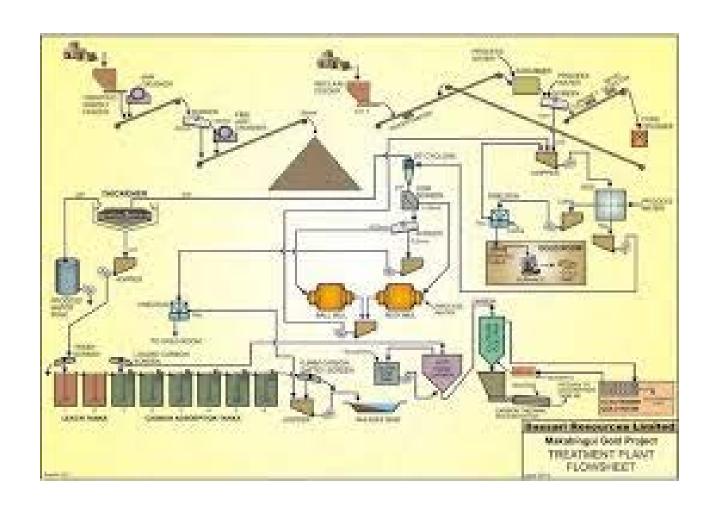


### Optimization by Montreal Gaming Software





#### Connecting to the Metallurgy



## Mining 4 and Industry 4.0 Model

#### Mining Company Perspective

#### Pre-industrial

Manual Era

Hand tools

- Labour intensive
- Low technology
- · Hierarchy to decision making



#### Industrial Age

Mechanization of Physical work

- · Replaces human physical effort
- More technology driven
- Machines can be scaled (drives bigger is better)



· Tech - electrics, hydraulics, new materials

Automation of Physical work



- · Separation of people from machines
- Behaviour dominant
- High level of technology reliance
- Tech PLC's electronics , computers

#### 2nd Machine Age

Automation of Knowledge work



- · Thinking dominant
- Decision speed
- · Expert networks
- Enhanced decision making
- · Integration of the entire business
- · Tech- AI, advanced simulation & opt., big data analytics,

Pre- 1900 1940 1990 Today

#### Mining 4.0: Taking the Lid Off the Mine

"Taking the lid off..."

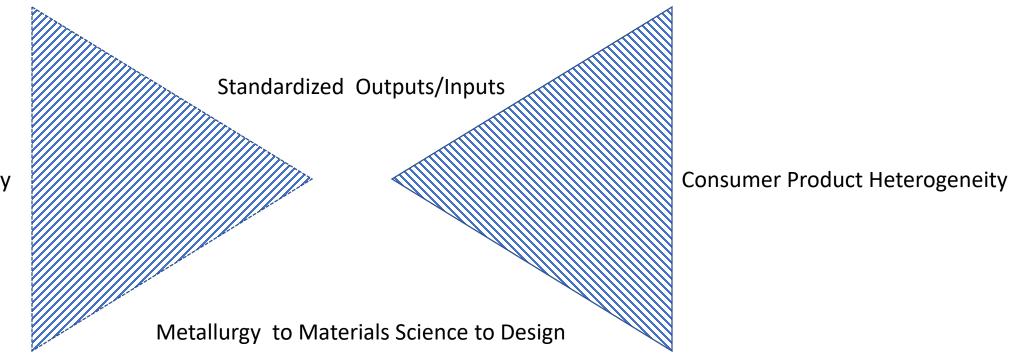




#### What this was all about

- Connectivity for real-time monitoring of processes
- Improved operational control
- Optimizing plan execution & elimination of waste

#### Mining 4.0 vs Industry 4.0



Ore Body Heterogeneity

#### Conclusions

- Three Technology Trajectories:
  - Mining Companies: next to nil
  - Equipment OEMs: Step Functions
  - Exploration & Development: Leading Edge of Digital Technologies
    - SMEs on the Outside: Mining Supercluster
- Technology Lead in Canada by Precious Metals Companies
  - Scale: 1500 TPD vs 10-50K TPD
  - No links to Metallurgy: Financial Economy not the Manufacturing economy
    - Mining-Metallurgy-Materials Science-Design & Manufacturing
- Policy Issue: Can't get There from Here