Innovation in the Minerals Industry

Celebrate the Past.....Look to the Future

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Celebrate Mineral Processing Innovation!

Mineral Processors are extremely innovative and have unlocked tremendous value for our industry!
We are Innovative!

- Comminution
  - High Capacity Cone Crushing
  - Fully Autogenous and Semi-Autogenous Grinding
    - Large Diameter 12.2 m (40 ft.) SAG Mills
    - Gearless and Dual Pinion 25-30 MW Drives
  - HPGGR
    - Development of Wear Materials and synergistic effects
  - High Capacity Ball Mills
We are Innovative!

- Hydrocyclones (Gmax and Cavex)
- High Capacity Screening Systems (Derrick)
We are Innovative!

- **Vertical and Stirred Media Mills**
  - Fine and Ultra Fine Grinding Milling Technologies
    - Vertimill, SMD, IsaMill, HIGMill, VXP Mills
We are Innovative!

- Flotation
  - *High Capacity Flotation cells*
    - Outotec e630 Cells, FLSmidth Supercell
  - *Column Flotation*
    - Sparger Technology
  - *Smart Kinetic Cells*
    - Jameson Cells, Woodgrove SFRs, Hydrofloat Cells, SkimAir

- Dewatering and Filtration
  - High Capacity Thickeners
  - Pressure Filtration
We are Innovative!

• **Gold and Refractory Gold Processing**
  – Gravity Recovery with Centrifugal Concentrators (Knelson, Falcon)
  – Carbon-in-Pulp, Carbon-in-Leach and Elution technologies
  – Intensive Cyanidation (Gekko, Acacia)
  – Oxygen Assisted Leaching
  – Non-Cyanide lixiviants
    » Thiosulphate, Thiourea, Bromine/Chlorine based
  – POX, Roasting and Albion Process Pre-treatment technologies for refractory gold ores
We are Innovative!

- Process Control and Automation
  - Measure....Control....Optimize
  - Weighing technologies, Load Cells
  - PGNAA Cross Belt Analysis, Thermo Fisher CB Omni and Scantech
  - Mill Feed Imaging Particle Size Measurements (WipFrag and Portage PRC)
  - On-Stream Chemical Assay Analysis
    - X-Ray Analysis (Courier), Thermo Fisher MSA
    - LIBS Analysis (Courier 8) and Thermo Fisher GS OMNI Light Element
    - SABIA systems
  - Froth Imaging Systems (Portage PFC, Outotec FrothSense, Metso VisioFroth)
  - Particle Size Measurements
    - PSI500 and 800 (Lazer Sizing), Sympatec Ultrasonic OPUS
  - Density and Mass Flow measurement
    - Mag Flow, Gamma ,Coriolis, Dopler, Cidra (SONARTrac), Thermal
    - Ultrasonic Level Measurement
  - Moisture Analysis
  - Distributed Control Systems (DCS), PLC Systems
    - Advanced operator interface
    - Remote access, Monitoring and Control
      - PI System
We are Innovative!

- Reagent Technologies
  - Improved understanding of the interaction of mixed collector systems
  - Activators and Depressants
    - *Lime, Cu sulphate, TETA-S, Electrochemical control, CMCs*

- Frother chemistry and mechanisms
  - *Critical Coalescence Concentration (CCC)*
  - *Bubble/particle measurement technologies*
    - Gas Hold-Up, Superficial Gas Velocity, Bubble Surface Area Flux, Bubble Size Distribution
    - Contact Angle (Gonimeter), QCM-D, XPS, FTIR, SECM technologies
We are Innovative!

• Tools and Approaches
  – Process Mineralogy and GeoMetallurgy
    • *Understand the Ore Body and use Mineralogy to design flowsheets and predict process performance*
      – QEMSCAN/MLA Technology, XRD and Microprobe
      – Measurement of modal mineral, grain size, degree of liberation and mineral chemistry
      – Concept of ‘Entitlement’, Modelling of grade/recovery
      – Distribute mineralogy, economic metrics across the ore body
      – Design ‘robust’ flowsheets or design mine plan to maximize NSR and ROR
  – Sampling, Metallurgical Accounting Data Acquisition and Analysis, Benchmarking
  – Mine-to-Mill
    • *Optimize powder factors*
    • *Beneficiation process closer to the mine face…..*
    • *Pre-Concentration and Ore Sorting*
      – *Next ‘Holy Grail’ in mineral processing*
We are Innovative!

• Tools and Approaches
  – Modeling, Design and Optimisation Packages
    • JKSimMet, CEET, FLEET, SAGDesign, GrindPower, Morrell, Functional Performance Metcom
    • Mill Charge Modelling - Metso and Conveyor Dynamics
    • FEM Modeling (Comsol)
    • Outotec HSC Modeling
    • Perceptive Engineering PCAPLS
    • Self- Heating of Ores and Concentrates
  – Control Strategies
    • Layered strategies
    • PID and PI control
      • Dahlin and Smith Predictors for Dead Time Compensation
    • Multivariable Controllers
    • Expert Systems - Portage AwaRE
    • Fuzzy Controllers
    • AI (Artificial Intelligence), Neural Networks
Process Innovation Track Record – Successes……..

SO$_2$ Abatement Technology
- Glencore Strathcona Mill and Ni Smelter
- Vale Clarabelle Mill and Copper Cliff Smelter
Process Innovation Track Record
Successes.....

Furnace Technology

- Noranda Reactor
- Vale (INCO) and OK Flash
- IsaSmelt Furnace
Process Innovation Track Record Successes......

Cyanide Free Gold Recovery
Barrick Goldstrike /Strategic Technology Solutions’
Thiosulphate/Resin-in-Leach Process
What distinguishes these Innovations?

➢ Clear **business** need and/or **demand from society**

➢ **Leadership** with a belief and trust
  - Organizational **culture of Innovation**

➢ **Collaboration**
  - Corporate, Operators, Vendors, Eng.Co., Universities, Collaborative Research Groups, Technology Centres

➢ **Multi – Discipline Expertise**
  - Process Engineers, Technicians, Process Control Experts, Mechanical Expertise, Materials Technology Experts, other industries!
The biggest threat to innovation is internal politics and an **organizational culture**, which doesn't accept failure and/or doesn't accept ideas from outside, and/or cannot change.
So that’s impressive… what’s next….?

- Status of R&D and Innovation?
- What are some of our challenges?
- What are our opportunities?
R&D vs Innovation

- R & D transforms money into knowledge

- Innovation transforms knowledge into money

- R & D without commercialization is Philanthropy

- Innovation are practices, procedures, tools and technologies that change our world

- Innovation is measured by the degree in which it changes how people live.....
Conflicting Views of Innovation…

Is Innovation brought about by…. 

➢ **...dramatic leaps** and not the accumulation of small steps
  → James Dyson – Vacuum Cleaner Salesman (Inventor)

➢ **...continuous improvement** rather than a eureka moment
  → Michael Singleton, Executive Director, Calgary Innovates

*or BOTH?*
„The electric light did not come from the continuous improvement of candles“

(Oren Harari)
Research & Development Investment in Canada

Business Enterprise Research and Development expenditures
Index: 2007=100 (in constant dollars)

<table>
<thead>
<tr>
<th>Sector</th>
<th>2013 R&amp;D, $M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada Mining, Ferrous/Non Ferrous</td>
<td>$522</td>
</tr>
<tr>
<td>Canada Aerospace</td>
<td>$1,822</td>
</tr>
<tr>
<td>Canada Information Technology</td>
<td>$5,000</td>
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<tr>
<td>Canada Oil and Gas</td>
<td>$1,140</td>
</tr>
<tr>
<td>Australia Mining</td>
<td>$2,400</td>
</tr>
</tbody>
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Canadian Mining 2015 - $677M
Mining showed productivity gains in the United States until the demand boom.

US labor productivity,\(^1\)
indexed, 1987 = 100

\(^1\)Real gross domestic product divided by number of hours worked.


‘Productivity is not a big thing……

…it’s the only thing’

Doug Morrison, CEMI
The MineLens Productivity Index reveals that mining productivity globally has declined 3.5 percent per year over the past decade.

MineLens Productivity Index,
indexed, 2004 = 100

Source: Company annual reports; McKinsey analysis
Key Recommendations of the McKinsey Report

- **Reduce** and control capital and operating expenditures
- **Extract** more value from the existing asset base
- Focus on **Innovation**
  - **Embed** effective operating systems
    - Achieve *operational performance excellence*
    - Practice *continuous improvement*
Technology Tightrope....

- How do we balance the development costs with the benefits of innovation?

- How do we overcome the *first* to be *second* mentality?
XPS Example

- XPS started as a corporate research group funded by Falconbridge Ltd.
  - 2003 FTC merged with NTC
  - Captive, in-house R&D
  - Mandated to develop and support new process technology and operations

- Falconbridge Ltd. was acquired by Xstrata PLC in 2007 and then Glencore in 2013

- In 2007, XPS was converted to an autonomous business, working collaboratively and developing innovative solutions for our internal and external clients
Process Innovation Modular (Phased) Approach

- Perform the pre-requisite steps in testing, piloting and risk mitigation
- Build it modular
  - Prove the technology in Phase 1
    - *Generate cash*
  - Expand capacity in Phase 2 (Brownfields)
  - Challenges ROI
    - *Economies of scale?*
    - *Reduces start-up, scale up or technical risk*
- Examples
  - Chinese Ni Pig Iron industry
    - RKEF Technology – Tsingshan
  - Mag One – Asbestos, Q.C.
    - MgO and Mg Recovery Project
  - TMAC Hope Bay
    - Modular Gekko Plant
Collaborative Programs/Leverage R&D (Canadian)

Significant industry involvement and sponsorship

- CMIC – Towards Zero Waste Mining
- CEEC – Energy Efficient Commination
- CEMI including UDMN
- Mirarco/Laurentian Mining, Innovation and Technology
- CAMIRO
- COREM
Resources....

- Sources of expertise/funding.....
  - NRC Mining, Energy and Environment – ie: Eureka
    ‘High Efficiency Mining Program’....
  - CANMET Mining – GMIAC (Green Mining Initiative Advisory Committee)
    ‘...national collaboration strategy for the mining industry…’
    Plus other programs and activities such as Rare Earths and Chromite
  - CAMESE Innovation Forums
  - NORCAT
  - Metals Bulletin and Mining Strategic Alliance
  - University/NSERC and Chair Programs across the country
  - Funding.....Investissement Quebec, IRAP, Northern Innovation Program and many others
Opportunities

- IOT (Internet of Things, Big Data) in new mine design
  - *Where are the applications in Mineral Processing?*
    - Ie: PCAPLS – Process Modeling and Fault Detection
- Beneficiation at the mine face
  - *Mineral Processing….as soon as possible…..*
  - *Pre-Concentration to reduce energy costs in transport, comminution and reduce risk and cost of surface tailings*
- Process Mineralogy and GeoMetallurgy
  - *Continued use of Quantitative Mineralogy for Mine/Plant Design, Ore Entitlement and Process Optimisation*
We are in a Renaissance ....

Amazing opportunity for step changes in the way we live and do business....

Is our effort too fragmented?....

...Will we realize the full potential...?
Key Opportunity and Risk……

- Look to COSIA as a possible model

- Canadian Oil Sands Innovation Alliance

- To date, COSIA member companies have shared 936 distinct technologies and innovations that cost almost $1.33 billion to develop
Leave you with a thought......

- Collaboration between mining companies, vendors, SMEs, engineering co., government, research groups, corporate technical resources, other industries and universities is essential to our success....

- Foster and develop Open Innovation (Innovation Eco Systems)
Thank you......Enjoy the Conference!!