SURFACE MINING INNOVATION: ROADMAP TO THE FUTURE

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Objectives

- Identify the issues and establish existing design principles and constraints
- Establish areas of opportunity and new design principles
- Envision “what might be possible” and develop new concepts and solutions
- Create opportunities for future collaborative projects

Process

DISCOVER
- Brainstorm the challenges experienced in surface mining
- Identify the design principles that lead to the challenges

SYNTHESIZE
- Brainstorm generalized solution areas
- Define the design principles required to develop solutions

ENVISION
- New connections
- New concepts

CO-CREATE
- New solutions
- Integrated systems design

PLAN
Surface Mining Roadmap – V1

1. Improve ore body knowledge
   - Adopt coil drill techniques
   - Improve real time data analyses
   - Improve blast hole analyses
   - Reduce core sampling requirements
   - Integrate ore sensing at the face
   - Implement multi-disciplinary analyses
   - Develop AI based ore models

2. Integrated mine design, planning and scheduling
   - Integrate all ore body data into one common spatial database & planning platform
   - Integrate common database of all resources and capabilities
   - Integrate operational planning and scheduling with financial systems to model system value

3. Selective mining
   - Explore continuous cutting machines for bulk mining
   - Develop high intensity blasting techniques for fragmentation control
   - Engineer ore sorting at the face and along the mining process to eliminate waste
   - Pre-concentration of ore inside the pit
   - Dedicated ore streams to selective processing to reduce/eliminate blending

4. Alternative hauling technologies
   - Decouple truck and shovel interface with loading buffer (surge loader)
   - Use hybrid air vehicles to transport equipment modules to remote sites
   - Avoid building road/rail infrastructure to remote sites where viable
   - Decouple equipment life from life of the ore body, Relocate equipment
   - Multi-modal system to optimize the flexibility and cost advantage of different technologies

5. Modular mining
   - Develop modular equipment that can be containerized for easy transport and on-site assembly
   - Use hybrid air vehicles to transport equipment modules to remote sites
   - Avoid building road/rail infrastructure to remote sites where viable
   - Mine smaller, richer ore bodies with small footprint

6. Integrated operations with intelligent work environment
   - Develop digital twins of all equipment as well as full mine and operations
   - Link intelligent work place to integrated planning, scheduling and dynamic simulation
   - Remote centers to operate remote equipment
   - Automate the integration and management of renewable energy integration

7. Automation
   - Automate back-office processes
   - Link intelligent work place to integrated planning, scheduling and dynamic simulation
   - Remote centers to operate remote equipment
   - Full autonomous parts of the operations

8. Electrification & renewable resources
   - Electrification of all mining processes
   - Digitally intelligent grid to enable full load control and orchestration at mine level
   - Maximum penetration of renewable energy
   - Use cheap renewable energy to clean and recycle water
   - Zero emissions fully electrified mining operation

9. Transact more efficiently
   - Use Block-chain (BC) to track ore mined throughout the value chain
   - Reward employees and partners with instant payments
   - Track warranties on parts with BC individually
   - Sell metals and minerals directly to end customer with BC (Track, recycle and resell)
   - Fully transparent mining – operations, supply chain and all external stakeholders

10. Improve Water Treatment & Management
    - Implement digital water monitoring and automated management
    - Establish Block-chain logging of water quality
    - Introduce advanced purification and recycling technology to reduce/eliminate tailing
    - Extract valuable minerals from waste streams
    - Zero water environmental impact mining

Users bring this framework to life through collaboration and interactive efforts
Material Haulage – alternate haulage technologies

- **Why is the industry interested? New Design Principles required:**
  - Modular, scalable and flexible design and equipment to increase options over life of mine
  - Optimize mine plans and schedules to maximize value of the mine to all stakeholders
  - Customize processes and equipment to optimize value from ore body
  - Increase the amount of movable assets to create value from any life of mine
  - Minimizing the use of critical resources in mine design considerations
  - Invest to eliminate waste as early in the value chain as possible and add value to what remains

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4. Alternative hauling technologies

- Decouple truck and shovel interface with loading buffer (surge loader)
- Electric, modular truck/truck train (trolley assist/Battery hybrid)
- Remote operation integrated with autonomous hauling
- Explore application of alternative technologies (Railveyor/RopeCon, other)
- Multi-modal system to optimize the flexibility and cost advantage of different technologies
Material Haulage – alternate haulage technologies

Why is the industry interested? Immediate drivers
(Material movement is highest cost in many operations)

- Reduced available capital
- Increase Productivity
- Reduce Unit cost
- GHG / Sustainability factors
- New project viability
Material Haulage – alternate haulage technologies

- How do we propose to tackle this?
  - Discovery: detailed reveal of company technology development plans and requirements
  - Determine collaborative structure
  - Determine agreement terms – consortia, joint development, IP
  - Select project development process – stage / gate
    - Project creation, concept select, technology validation
  - Determine resource requirements for successful development and piloting efforts
  - Developed detailed plan (timing, specific solutions, resources etc.) for each proposal.
Material Haulage – alternate haulage technologies

• **Next Steps**
  – CMIC facilitate discovery session between interested companies.
    • Share technology interests in this area
    • Select collaborative opportunity area(s)
    • Determine type of collaboration
      – Sharing, contribution, joint development
    • Create charter
    • Engage additional companies in the project.
# Project Charter: Material Haulage

<table>
<thead>
<tr>
<th>Opportunity Name: Alternative Hauling Technologies</th>
<th>Total Duration to Complete the Opportunity:</th>
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</thead>
<tbody>
<tr>
<td>Participants:</td>
<td>Sponsors – CMIC</td>
</tr>
<tr>
<td>In Scope / Objectives:</td>
<td>Deliverables:</td>
</tr>
<tr>
<td>Out of Scope:</td>
<td>Key Activities:</td>
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<tr>
<td>Resource(s):</td>
<td>Value/Benefit Targeted:</td>
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<tr>
<td>Details and specifics of the qualifications &amp; skills of the individuals involved:</td>
<td>Governance:</td>
</tr>
<tr>
<td>Details of what will be focused on specifically:</td>
<td></td>
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