An Overview of Mining R&D Projects and Strategy at Vale Inco

May 2010
Current R&D Strategy for Mines

› To develop new technical processes that result in improved business results (either by increasing throughput or reducing cost), through the attainment of any of these objectives:

› Reduce stope cycle time (increased mining intensity)
  › At conventional depths
  › In deep operations

› Reduce development cycle times
  › At conventional depths
  › In deep operations

› Reduce the skill required to design, operate, or service mining operations / assets

› Increase the utilization of capital intensive assets
### R&D “Pre-Screening” Filter

#### Project Request

**Site Project Sponsor/Owner**
Name of the Site Sponsor and Project Owner

**Complete one sheet for each proposes initiative**
A brief description of the initiative

**Meets CCRA criteria for R&D tax credits**
Yes / No

#### EVALUATION CRITERIA

<table>
<thead>
<tr>
<th>Estimated Benefits ($)</th>
<th>No impact or undefined improvement</th>
<th>&lt;$100k/year</th>
<th>$100k - $500k/year</th>
<th>$500k - $1M/year</th>
<th>&gt;$1M/year</th>
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<table>
<thead>
<tr>
<th>Resource Requirements</th>
<th>100% of &gt;5 peoples time + some minor team time</th>
<th>100% of 3 peoples time + some minor team time</th>
<th>100% of one persons time + some minor team time</th>
<th>50 % of one persons time</th>
<th>No requirement w ithin 2 years</th>
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<td>3</td>
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<table>
<thead>
<tr>
<th>Strategic Link</th>
<th>No Link to ANY Strategic Plan</th>
<th>Link to Vale Inco Strategic Plan</th>
<th>Link to Ontario Division Strategic Plan</th>
<th>Link to Mines Engineering Strategic Plan</th>
<th>Link to Mines R&amp;D Strategic Plan</th>
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<tbody>
<tr>
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<td>10</td>
<td>20</td>
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</table>

<table>
<thead>
<tr>
<th>Complexity Risk</th>
<th>A lot of variables and uncertainty</th>
<th>Variables not defined but appear manageable</th>
<th>Variables defined - high complexity but manageable</th>
<th>Variables defined - medium complexity - manageable</th>
<th>Variables defined - low complexity - easily managed</th>
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<tbody>
<tr>
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<td>10</td>
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<table>
<thead>
<tr>
<th>Measurable (Data Available / Accurate)</th>
<th>No Data Available</th>
<th>Data can be gathered at a cost</th>
<th>Data can be gathered by modifying reports</th>
<th>Data available but questionable</th>
<th>Good data available with high confidence</th>
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</thead>
<tbody>
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<td>5</td>
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<table>
<thead>
<tr>
<th>Time Frame of Expected Results</th>
<th>&gt; 10 Years</th>
<th>5 - 10 Years</th>
<th>2 - 4 Years</th>
<th>1 - 2 Years</th>
<th>&lt; 1 Year</th>
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<tr>
<th>Funding Required ($)</th>
<th>&lt;$1M</th>
<th>$500k - $1M</th>
<th>$250k - $500k</th>
<th>$50k - $250k</th>
<th>&lt;$50k</th>
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<tr>
<th>Leveragability</th>
<th>No leveragability</th>
<th>To another area</th>
<th>Site Wide</th>
<th>SBU Wide</th>
<th>Corporate Wide</th>
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**TOTAL POINTS**

<table>
<thead>
<tr>
<th>Rank Prioritization Number</th>
<th>Recommended Action</th>
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<tbody>
<tr>
<td>15 Points or less</td>
<td>Drop</td>
</tr>
<tr>
<td>16 to 50 Points</td>
<td>Could be re-evaluated</td>
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<tr>
<td>50-75 Points</td>
<td>Hold</td>
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<tr>
<td>&gt; 75 Points</td>
<td>Complete Project Charter</td>
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<tr>
<td>R0009001 - AMIRA P087 ROES</td>
<td>97</td>
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<tr>
<td>R0010001 - AMIRA - Mine Automation Design Guideline</td>
<td>98</td>
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<tr>
<td>R0006007 - PRIMO (AMIRA project P864)</td>
<td>67</td>
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<tr>
<td>R0010002 - PRIMO 2</td>
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<td>R0007003 - FERMI/IME</td>
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<tr>
<td>R0007004 - Automated Scaler &amp; Shotcrete</td>
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<tr>
<td>R0006001 - CAMRO/OMRC project support</td>
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</tr>
<tr>
<td>R0007005 - Explosives Free Rock Breaking System (EF-RB) - Phase 1</td>
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<tr>
<td>R0010003 - EF-RB Phase 2</td>
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<tr>
<td>R0008014 - Hydrogen Mining Introduction Initiative (HMI)</td>
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<td>R0009003 - Streaming Mobile Equipment Data Collection</td>
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<tr>
<td>R0010004 - UG Emission Control with Ultralow Sulphur Diesel Fuel - Part 2</td>
<td>125</td>
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<td>R0008009 - International Search to Cutsil Diesel Emissions/NIOSH</td>
<td>125</td>
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<tr>
<td>R0010005 - Creighton Natural Heat Exchanger</td>
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<td>R0008004 - Real Time Geomechanics Risk Management</td>
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<tr>
<td>R0006008 - Geotechnical Risk Analysis of Heritage Drift (McGill)</td>
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<td>R0008007 - Back Analysis of Ground Instability (U of T)</td>
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<td>R0009002 - Radar Imaging for Underground Mapping</td>
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<td>R0010006 - Compressed Development Cycle Time for Support Installation</td>
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<tr>
<td>R0010007 - Self-Heating of High-Sulphide Ore and Tails in Backfill (McGill / UQAT)</td>
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<td>R0010009 - Alternative Binder Research (Canmet)</td>
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<td>R0010009 - Design Guidelines for Underhand Cut and Fill in Paste Fill (UBC)</td>
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<tr>
<td>R0009011 - Ventilation On Demand (VCD)</td>
<td>98</td>
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<tr>
<td>R0007006 - Thermal Management</td>
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<tr>
<td>R0100100 - Ice Stope Project</td>
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<td>R0010011 - Portable Refugio Station</td>
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<td>R0010012 - #3 Shaft Overburden Study</td>
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<td>R0006008 - Fracture Process in Rock w.r.t. De-Stress Blasting &amp; Dilution Control</td>
<td>87</td>
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<tr>
<td>R0011001 - Predictive Blast Vibration for Mining Sites</td>
<td>82</td>
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<tr>
<td>R0007003 - Railways Proof of Concept at Flood Stages</td>
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</table>
International Consortium Projects

› AMIRA P884 – PRIMO (Planning & Rapid Integrated Mine Optimization) @ 90%

› AMIRA P975 – Real Time Geomechanical Risk Mgmt. @ 50%

› AMIRA P987 – ROES @ 0%

› AMIRA – (Draft ) Mine Automation Design Guidelines @ 0%

› AMIRA P1037 – (PRIMO 2) @ 0%

› Automated HPWS & Shotcrete Machine @ 90%

› Compressed Dev Cycle Time for Support Installation @ 10%

› MGS @ 50%
North American Consortium Projects

- Fracture Process in Rock (UofT) @ 65%
- PERM / IMPE (Mirarco) @ 80%
- Thermal Management (CAMIRO) @ 75%
- Ventilation on Demand (CEMI / Bestech) @ 30%
- HMI - Hydrogen Initiative (NRCan et.al.) @ 10%
- EFRB - Explosives Free Rock Breaking (NRCan et.al.) @ 85%
Government Consortium Projects

- CAMIRO (Canadian Mining Research Organization) membership @ ongoing
- DMRC (Deep Mining Research) membership @ ongoing
- Alternative Binder Research (CANMET) @ 10%
- Research into Gelfill (CAMIRO / McGill) @ 90%
University Based Projects

- Back Analysis of Ground Instability (Laval / UofT) @ 70%
- International Search to Curtail Diesel Emissions (U of Minnesota) @ 50%
- Radar Imaging for U/G Mapping (Carlton / UofT) @ 50%
- U/G Emission Control with Ultralow Sulfur Diesel (U of Minnesota) @ 0%
- Self-Heating of High Sulfide Ore & Tails in Backfill (McGill / UQAT) @ 20%
- Design Guide for Underhand Cut&Fill in Paste Fill (UBC) @ 10%
- Geotech Risk Analysis of Haulage Drifts (McGill) @ 55%
Self Directed Projects

› **Rail-Veyor @ 45%**
› **Streaming Mobile Eqpt. Data Collection @ 75%**
› **Creighton Natural Heat Exchanger @ 5%**
› **Ice Stope Project @ 0%**
› **Portable Refuge Station @ 0%**
› **#3 Shaft Overburden Study @ 0%**
› **Mining Research Admin & Overhead @ ongoing**
International Consortiums

› High Pressure Water Jet / Shotcrete Machine
  › Partners with Rio Tinto and Xstrata nickel. Currently testing at Ni Rim South in Sudbury.
International Consortiums

- AMIRA – P884 “PRIMO” (Planning & Rapid Integrated Mine Optimization)
  - Adding new mine planning tools
  - Beta software available and being tested on case studies
    - Greens Creek (ex Rio Tinto)
    - Prominent Hill (Oz Minerals)
    - Olympic Dam ODO Area H (BHP)
  - New tools include:
    - MIRARCO - SOT (Stope and development schedule optimizer)
    - UofM – DOT (Decline and access network optimization)
    - AMS – PUNO (Stope Design Optimization)
    - AMC – LOBOS (Overall Strategy Optimization)
Government Consortiums

DMRC Projects

- Semi-Synthetic Hoist Rope (D. McIvor)
- Geothermal Energy (M. Ghomshei)
- Heat Stress (Univ. of Ottawa)
- Pocket Rope Conveyor prototype (Metso)
- TSL Thin Spray-on Liner (3M)
North American Consortiums

EFRB (Explosives Free Rock Breaking) Consortium

Focus on Microwaves, Plasma Torch, and Ultrasound as assists or “pre-treatment” for mechanical rock breakage methods

<table>
<thead>
<tr>
<th>EFRB Field</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Equipment</td>
<td>Activated cutting</td>
</tr>
<tr>
<td>Button cutting</td>
<td>Impact rippling</td>
</tr>
</tbody>
</table>

- Fluid Application
  - Hydro-fracturing
  - Jet-boring
  - Water pulse rock breaking
  - Foam injection
  - Controlled foam injection

- Electrical Discharge
  - Plasma blasting
  - Electrical blasting
  - Electrical pulse blasting
  - Electrical rock breaking

- Heat Discharge
  - Thermal fragmentation
  - Laser cutting

- Lead
  - Colorado School of Mines
  - CSIR
  - McGill
  - McGill & CSIR

Laval (McGill)

Figure 20. Plasma torch applied in a vertical sweeping motion.
Self Directed Projects

Rail-Veyor – Proof of Concept Work

Purpose: To solve the critical issues that stand in the way of R-V based mine design being considered for future Vale Inco projects

Identified 8 key focus areas (sub-projects):

- Stobie Surface Testing
- Development using R-V
- Fragmentation
- Loading R-V
- Maintenance
- Moving other materials (including people)
- Regulations
- Stakeholder Engagement

Contributes to FEL 2 Study for Upper Kelly Lake
International Consortiums

› AMIRA – P987 “ROES” Mining Method
  › CSIRO Australia based initiative to create a new bulk Mining Method. Expected to kick off Q2 2009.
North American Consortiums

› HMII (Hydrogen Mining Introduction Initiative)
  › Consortium to investigate issues involved in bringing H₂ underground to recharge fuel cell powered equipment
\textbf{Context}

- Ensure that project will provide a strategic advantage to Vale Inco with respect to safety and productivity.
- More mineral resources can be transformed into wealth by minimising disruption to the operation.
- Unexpected ground instability can destroy wealth and result in production issue.
- Underground tour at all mines with Manager.
- From tour, establish needs for mine.
Current Projects

1. Back Analysis of Ground Instability (CCM and Creighton through U of T)
2. Geotechnical Risk of Haulage Drift (Garson Mine through McGill)
3. Real Time Geomechanics Risk Management (Coleman Mine MOB1 through Rocksciences, U of T and CEMI)
4. Stand Up time of stopes (Thompson, Birchtree Mine through U of Saskatchewan).
5. Mine Induced Seismic Periodicity (Creighton through MIRARCO)
6. Rock mass characterization with Radar Imaging (Queens University and Carleton University)
Back Analysis of Ground Instability

Purpose
- Design support system that will maintain opening stability through operation life while minimising or eliminating reconditioning.

Cost
- $305,000

Project Life
- 2 years.

Deliverables
- Design chart as function of support system, expected stress, rock mass conditions and life span of openings.

Status
- 10% completed
Geotechnical Risk Analysis of Haulage Drift

Purpose
- Provide a planning tool that will quantify the risk probability associated to haulage drift with respect to extraction ratio, sequence, support systems and rock mass properties.

Cost
- $420,000

Project Life
- 3 years.

Deliverables
- Key risk factor for haulage drift
- Probability of instability associated with key factors

Status
- 50% completed
Real Time Geomechanics Risk Management

- **Purpose**
  - To develop a system that will help mining companies manage risks arising from the geomechanics challenges

- **Cost**
  - $300,000

- **Project life**
  - 3 years.

- **Deliverables**
  - State-of-the-art wireless instrumentation
  - Data transfer to surface
  - Calibrated 3D models

- **Status**
  - 25% completed
Stand Up Time of Stopes

› **Purpose**
  › Establish the optimum stope size for given in situ stress conditions, rock mass quality and mining method that will maximize production while minimizing dilution.

› **Cost**
  › $100,000

› **Project life:**
  › 1 to 2 years.

› **Deliverables**
  › Site specific design guidelines for stope size with respect to cycle time and geotechnical characteristics.

› **Status**
  › Initiation phase for Birchtree
Mine Induced Seismic Periodicity

› **Context**
  > Long period of inactivity may allow increased store energy leading to a large MN event.

› **Purpose**
  > Prove or disprove that extended mine shutdowns may lead to large RB seismic events upon resuming operations.

› **Cost**
  > $35 000 (from perm)

› **Project life:**
  > 3 months.

› **Deliverables**
  > Proof of Concept

› **Status**
  > 20% completed
Rock Mass Characterization with Radar Imaging

- **Context**
  - Improve methods of defining the rock mass may allow better support selection and design, thus allowing reduction in cycle time. Automatic method of data acquisition and processing may minimise the impact of skill labour shortage.

- **Purpose**
  - Demonstrate the potential of 3D laser imaging for evaluating RMR in an underground mining environment.

- **Cost**
  - $35,000

- **Project life:**
  - 2 years.

- **Deliverables**
  - Proof of Concept

- **Status**
  - 50% complete