The Mine of the Future
Current Mine Automation Trends

Dr. G. Baiden
Canadian Research Chair – Robotics and Mine Automation
Laurentian University
Chairman and CTO
Penguin Automated Systems Inc.
Future Possibilities to be considered

• Robotics and Advanced Manufacturing Techniques applied to current mining
  – Mine large low grade deep deposits
    • Perfect Safety, Minimize Costs and Maximize Revenues
  – Mine Large Scale Underwater Deposits
  – Begin to look at Space

• Demand for minerals and metals continues to grow
  – 2% growth means the current production on the earth must double every 38 years to keep up with demand!! Or prices will rise.
Mining and Processing Plant Integration

- Mining Unit Operations
  - U/G and Open Pit
  - Understand Unit Process timing
- Computer integrated Manufacturing Techniques applied to mining (Toyota Production System)
- Compared Manual Techniques to Teleremote
The six Epochs of Production Technology

Changes

<table>
<thead>
<tr>
<th></th>
<th>English System</th>
<th>American System</th>
<th>Tayloristic System</th>
<th>Dynamic Controlled System</th>
<th>Numerically Controlled System</th>
<th>Computer Integrated Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Machines</strong></td>
<td>3</td>
<td>50</td>
<td>150</td>
<td>150</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td><strong>Minimum Scale (people)</strong></td>
<td>40</td>
<td>150</td>
<td>300</td>
<td>300</td>
<td>100</td>
<td>30</td>
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<tr>
<td><strong>Staff/Line Ratio</strong></td>
<td>0.40</td>
<td>20:130</td>
<td>60:240</td>
<td>100:200</td>
<td>50:50</td>
<td>20:10</td>
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<tr>
<td><strong>Productivity Increase</strong></td>
<td>4:1</td>
<td>3:1</td>
<td>3:1</td>
<td>3:2</td>
<td>3:1</td>
<td>3:1</td>
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<tr>
<td><strong>Rework fraction</strong></td>
<td>0.8</td>
<td>0.5</td>
<td>0.25</td>
<td>0.08</td>
<td>0.02</td>
<td>0.005</td>
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<tr>
<td><strong>Number of Products</strong></td>
<td>Large</td>
<td>3</td>
<td>10</td>
<td>15</td>
<td>100</td>
<td>Large</td>
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**Engineering Ethos**
- Mechanical
- Manufacturing
- Industrial
- Quality
- Systems
- Knowledge

**Process Focus**
- Accuracy
- Repeatability
- Reproducibility
- Stability
- Adaptability
- Versatility

**Work Ethos**
- Perfection
- Satisfice
- Reproduce
- Monitor
- Control
- Develop

**Required Skills**
- Mechanical Craft
- Repetitive
- Diagnostic
- Experimental
- Learning, Abstracting

**Control of Work**
- Inspection of work
- Tight supervision
- Supervision
- Loose supervision
- No work supervision
- No work supervision

Years

1750

Mining Production Technology

2000

Manufacturing Production Technology
What is possible with Telerobotic Operation of Mobile Mining Machines?

Manufacturing Automation Benefits, after Rommel
What has changed since 1994?
CURRENT MINING TRENDS

2010
Global Mining
with the use of
Operation Centres
Telerobotic Mining

Key Ingredients

- Underground Telecommunication System
- Positioning & Navigation Systems
- Process Engineering, Monitoring and Control
- Mining Methods
- Mining Equipment
- $
Telecommunications Breakthrough was required for Teleoperation

System capability 500 mb/s with near zero latency underground
Automatic Haulage Truck

- 70 ton Truck
- Electric/Hydraulic
- 25% grade capable
- Automatic Steering and Guidance
- Worked in Production for 2 years
- Moved 2 million tons
- Uptime 95%
Mining system to be deployed by Nautilus Minerals

Seafloor Mining Tool (SMT)

Mining to start in Q4 2010 subject to timely permitting

Courtesy Nautilus Minerals and their technical alliance partner, Soil Machine Dynamics

Courtesy Steve Scott
<table>
<thead>
<tr>
<th>District</th>
<th>Hokuroku, Japan</th>
<th>Noranda, Canada</th>
<th>Solwara 1</th>
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<tbody>
<tr>
<td>Mines</td>
<td>12</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Ave Mt</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Wt % Copper</td>
<td>1.6</td>
<td>2.1</td>
<td>7.2</td>
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<tr>
<td>Wt % Zinc</td>
<td>3.0</td>
<td>1.4</td>
<td>0.6</td>
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<tr>
<td>Wt % Lead</td>
<td>0.8</td>
<td>~0</td>
<td>-</td>
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<tr>
<td>g/t Silver</td>
<td>93</td>
<td>21</td>
<td>31</td>
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<tr>
<td>Gold</td>
<td>0.6</td>
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<td>6.2</td>
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Golder Associates NI43-101, 2008. Inferred + indicated (4% Cu cutoff) is 2,170,000 t drilled.
Control Systems
NASA Rokbot
2010

BREAKTHROUGHS
Non GPS Mapping System
Mine Survey using Penguin System
Initial SmartRocks Conceptual Idea

- Create a dynamic sensing system using synthetic rocks to determine location and path of flow within the rock mass of a block cave operation in real time

- Outcomes
  - Material Flow Monitoring System
  - Underground equivalent of GPS

6/8/2008 Patent Pending
Smart Rocks System

Base Station

Antenna

$X_1Y_1Z_1$

$X_2Y_2Z_2$

$X_3Y_3Z_3$

Equal Length Coax Cables

Atomic Clock

6/8/2008 Patent Pending
Wireless Optical Cellular Communication Concept

- Radio Systems have difficulty functioning in surface environments due to regulation.
- Develop a concept that:
  - Consists of a wireless optical network capable of transmitting/receiving multiple video, monitoring and control channels.
- An underwater environment seemed ideal to constrain the problem.

Patent Pending
Optical Communication Technology
Teleoperation of an Untethered Robotic Submarine using our newly developed Optical Communication System

Performance
- 1.5 Mb/s
- bidirectional

Latency Requirements 35 ms
Long Distance Laser Scanning Robot System

• Purpose
  – Travel to unsafe conditions to inspect

• Current work
  – Travel into a mine 1.5 km where ground collapse is possible, no ventilation and no road maintenance

• Perform surveying and cavity scanning to assist the client in determining possibility of collapse
Telerobotic Multi-purpose Robot System

• System consists of
  – Telecommand Trailer with two workstations
  – Communications is done using Cisco Long Distance Antennas meshed with short range broad coverage antennas
  – Two Robots
    • Work Robot - Beaverbot
    • Communications Robot - Combot
Thank You

www.penguinasi.com

www.gbaiden.laurentian.ca