The Mine of the Future
Current Mine Automation Trends

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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>Years</th>
<th>English System</th>
<th>American System</th>
<th>Tayloristic System</th>
<th>Dynamic System</th>
<th>Numerically Controlled</th>
<th>Computer Integrated Manufacturing</th>
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<tbody>
<tr>
<td>1750</td>
<td>3</td>
<td>50</td>
<td>150</td>
<td>150</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>2000</td>
<td>100</td>
<td>30</td>
<td>100</td>
<td>100</td>
<td>50</td>
<td>30</td>
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</tbody>
</table>

- **Number of Machines**: 3 50 150 150 50 30
- **Minimum Scale (people)**: 40 150 300 300 100 30
- **Staff/Line Ratio**: 0:40 20:130 60:240 100:200 50:50 20:10
- **Productivity Increase**: 4:1 3:1 3:1 3:2 3:1 3:1
- **Rework fraction**: 0.8 0.5 0.25 0.08 0.02 0.005
- **Number of Products**: Large 3 10 15 100 Large

**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
- Repetitive
- Diagnostic
- Experimental
- Learning, Abstracting

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

1750: Mining Production Technology
2000: Manufacturing Production Technology
 Mine Simulators
developed to investigate the potential
What is possible with Telerobotic Operation of Mobile Mining Machines?

Manufacturing Automation Benefits, after Rommel
CURRENT MINING TRENDS
Global Mining
with the use of
Operation Centres
Telerobotic Mining

Key Ingredients

- Mining Equipment
- Underground Telecommunication System
- Positioning & Navigation Systems
- Process Engineering, Monitoring and Control
- Mining Methods
- $
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 AUTOMATION PROGRAM
PROGRAMME d'AUTOMATISATION des MINES
2010

UNDERWATER MINING
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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<tr>
<td>Mines</td>
<td>12</td>
<td>20</td>
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</tr>
<tr>
<td>Ave Mt</td>
<td>12</td>
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<td>Wt %</td>
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<tr>
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<td>1.6</td>
<td>2.1</td>
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<tr>
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<tr>
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<tr>
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<td>21</td>
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<td>Gold</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
Penguin Automated Systems Inc.

NON GPS ROBOTIC MAPPING
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

Diagram showing a system with various coordinates and labels:
- $X_1 Y_1 Z_1$
- $X_2 Y_2 Z_2$
- $X_3 Y_3 Z_3$

Additional labels:
- Atomic Clock
- Equal Length Coax Cables
- Base Station

6/8/2008 Patent Pending
Optical Communication Technology
Teleoperation of an Untethered Robotic Submarine using our newly developed Optical Communication System

Performance:
- 40 Mb/s
- Bidirectional

Latency Requirements: 35 ms
Penguin Automated Systems Inc

TELECOMMAND SPREADER/ROTOPALA
Stacker/Rotopala Telerobotics Project
Penguin Automated Systems Inc.

REMOTE LASER SCANNING AND INSPECTION
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.penguinasis.com
www.gbaiden.laurentian.ca
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