Digitally Transforming Mining

Dr. Adriana Marais
Empie Strydom

From Earth to Space
28 August 2017
Your Speakers

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Head of Innovation, SAP Africa
Astronaut Candidate, MARS One

Empie Strydom
Vice President, Marketing
MineRP
What the Big 4 are telling CEOs
(Serving mining where it’s going)

Deloitte
(Tracking the trends 2016)

EY
(Top 10 business risks facing mining and metals 2016-2017)

KPMG
(Global Metals and Mining Outlook 2016)

PWC
(Mine 2016 Slower, lower, weaker... but not defeated)

- Operational Excellence
- Cash Optimization
- Focused on costs
- Capital efficiency hits an all-time low
- Low Capex leads to Slow Growth
- Asset sales as mines look to survive
- Commodity prices plunge
- GAP between miners and the broader market widens
- Ratings downgraded
- Extreme volatility
- But not defeated

- Keep the Promise – Stick to the Plan
- Innovate or die
- Portfolios are liquid – but mines can’t cope with the flexibility
- Investors have lost patience – transparency is needed

- China’s Transition
- Productivity
- Invest in R&D
- Portfolio Management - Expanding Market Share
- Adjust inv. to lower cost & access new markets
- Improve Visibility
- Predict Demand
- Productivity through Technology
- Capital efficiency hits an all-time low
- Low Capex leads to Slow Growth
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- Stakeholder & Community Engagement
- Transparency
- Portfolio Management - Expanding Market Share
- Adjust inv. to lower cost & access new markets
- Improve Visibility
- Predict Demand
- Productivity through Technology
- Capital efficiency hits an all-time low
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- Safe, Secure & Healthy
- Innovation
- Cybersecurity
- Portfolios are liquid – but mines can’t cope with the flexibility
- Investors have lost patience – transparency is needed

- Tax Issues
- Access to Energy
- Improve Visibility
- Extreme volatility
- Portfolios are liquid – but mines can’t cope with the flexibility
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- M&A Paradox
- Cybersecurity
- Portfolios are liquid – but mines can’t cope with the flexibility
- Investors have lost patience – transparency is needed
Industry 4.0

<table>
<thead>
<tr>
<th>1800 Industry 1.0</th>
<th>1900 Industry 2.0</th>
<th>1970 Industry 3.0</th>
<th>2015+ Industry 4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanization, Water power Steam power</td>
<td>Mass production Assembly lines Electricity</td>
<td>Computers and IT Automation</td>
<td>Cyber-Physical Systems</td>
</tr>
</tbody>
</table>

**Physical Systems** | **Machine assisted Human** | **Human assisted Machine** | **Cyber-Physical Systems**
## Mining 4.0 in the context of Industry 4.0

<table>
<thead>
<tr>
<th></th>
<th>Artisanal Mining</th>
<th>Most Mining Companies Today</th>
<th>MineRP</th>
<th>MineRP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mining 1.0</strong></td>
<td>Paper</td>
<td>CAD</td>
<td>Enterprise</td>
<td>Real Time &amp; Cognitive</td>
</tr>
<tr>
<td><strong>Mining 2.0</strong></td>
<td>Shovel</td>
<td>People &amp; Machines</td>
<td>Sensors &amp; Human Interactions</td>
<td>Instrument or People</td>
</tr>
<tr>
<td><strong>Mining 3.0</strong></td>
<td>People</td>
<td>Radio</td>
<td>Workflow</td>
<td>Digital Instruct</td>
</tr>
<tr>
<td><strong>Mining 4.0</strong></td>
<td>Never really know</td>
<td>Once a Month</td>
<td>Sensor on demand Human past shift</td>
<td>Millisecond mining &amp; Cognitive</td>
</tr>
</tbody>
</table>

**Plan**

**Execute**

**Action**

**Time**

**Never really know**
IMPACT HAZARD
SCIENTIFIC KNOWLEDGE

OSIRIS-Rex launched 2016, sample return 2023

Hayabusa2 launched 2014, sample return 2020

Bennu ~500m

Ryugu ~900m
PROUD TRADITION IN SPACE

SPUTNIK 1957

GAGARIN 1961

ARMSTRONG 1969
100 ASTRONAUT CANDIDATES

Research opportunity of a lifetime!
RESOURCE UTILISATION

Asteroid mining for crewed space exploration

<table>
<thead>
<tr>
<th>Metal</th>
<th>Abundance in metal of average LL-chondrite asteroid</th>
<th>Abundance in good* iron asteroid (90th percentile in Ir, Pt)</th>
<th>Abundance in &quot;best&quot; iron asteroid (98th percentile in Ir, Pt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>63.7%</td>
<td>81-94%</td>
<td>82-94%</td>
</tr>
<tr>
<td>Co</td>
<td>1.57%</td>
<td>0.46-0.80%</td>
<td>0.43-0.75%</td>
</tr>
<tr>
<td>Ni</td>
<td>34.3%</td>
<td>5.6-18.0%</td>
<td>5.4-16.5%</td>
</tr>
</tbody>
</table>

Ferrous metals:

Precious metals:

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<th>Abundance in &quot;best&quot; iron asteroid (98th percentile in Ir, Pt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ge</td>
<td>1020 ppm</td>
<td>0.06-70 ppm</td>
<td>0.05-35 ppm</td>
</tr>
<tr>
<td>Re</td>
<td>1.1 ppm</td>
<td>1.1 ppm</td>
<td>2.4 ppm</td>
</tr>
<tr>
<td>Ru</td>
<td>22.2 ppm</td>
<td>20.7 ppm</td>
<td>45.9 ppm</td>
</tr>
<tr>
<td>Rh</td>
<td>4.2 ppm</td>
<td>3.9 ppm</td>
<td>8.6 ppm</td>
</tr>
<tr>
<td>Pd</td>
<td>17.5 ppm</td>
<td>2.6 ppm</td>
<td>1.2 ppm</td>
</tr>
<tr>
<td>Os</td>
<td>15.2 ppm</td>
<td>14.1 ppm</td>
<td>31.3 ppm</td>
</tr>
<tr>
<td>Ir</td>
<td>15.0 ppm</td>
<td>14.0 ppm</td>
<td>31.0 ppm</td>
</tr>
<tr>
<td>Pt</td>
<td>30.9 ppm</td>
<td>28.8 ppm</td>
<td>63.8 ppm</td>
</tr>
<tr>
<td>Au</td>
<td>4.4 ppm</td>
<td>0.16-0.70 ppm</td>
<td>0.06-0.6 ppm</td>
</tr>
</tbody>
</table>

Asterank asteroid database

Estimation of size, composition & orbit

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>a (AU)</th>
<th>e</th>
<th>Value ($)</th>
<th>Est. Profit ($)</th>
<th>Δv (km/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryugu</td>
<td>Cg</td>
<td>1.190</td>
<td>0.190</td>
<td>82.76 billion</td>
<td>30.08 billion</td>
<td>4.663</td>
</tr>
<tr>
<td>Anteros</td>
<td>L</td>
<td>1.431</td>
<td>0.256</td>
<td>5.57 trillion</td>
<td>1.25 trillion</td>
<td>5.440</td>
</tr>
</tbody>
</table>
Fleets of solar-powered nanocraft probe asteroid belt
SHEPHERD: A Concept for Asteroid Retrieval with a Gas-Filled Enclosure
PROOF

Resources extracted, spectral analysis provides real-time profit estimate
Resources of known value delivered to required location
PROJECT OVERVIEW

Asteroid Retrieval Feasibility Study (2012)

10 year mission
3 bill USD
DID YOU KNOW?

Asteroids brought precious metals to early Earth’s mantle
History tells us that Gold was discovered at the Witwatersrand in South Africa by Mr George Harrison on the farm Langlaagte in 1886.

Source: Africa Museum, Johannesburg
And yet...
A lesson from History

And yet...

1886  1910

£ 3000  £ 94 809 000 000,00
Value Accrual and Confidence

In Situ
Asset under Construction

Product in Flow
Work in Progress

Exploration Target
Mineral Resource
Mineral Reserve
Product

Inferred
Indicated
Measured
Probable
Proved
Blasted Ore
Ore in Transit
Ore in Process
Metal Produced

Confidence in Geoinventory Reporting

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The Space Mining Value Chain

- Identify
- Investigate
- Launch
- Intercept
- Collect
- Return
- Sell

- Discover
- Establish
- Exploit
- Beneficiate
- Sell
- Rehabilitate
Valuation & Feasibility Criteria

- Position of the NEA on its orbit relative to earth or ACV
- $\Delta v$ Energy requirement to enter / exit planetary orbits
- Exploration method and stage
- Estimated content (Type / Grade / Volume)
- Structure and composition of the NEA / planetesimal
- Feasible Extraction Plan and Capability
- Availability of Capital
As in mining, the problems are technical and financial

<table>
<thead>
<tr>
<th>Terrestrial</th>
<th>Space*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Recovered over Life of Project</td>
<td>7.243Moz</td>
</tr>
<tr>
<td>Initial Construction Capital Cost Estimate</td>
<td>US$759m</td>
</tr>
<tr>
<td>Peak Funding</td>
<td>US$723.8m</td>
</tr>
<tr>
<td>Total Capital Cost over Life of Project</td>
<td>US$1,090.4m</td>
</tr>
<tr>
<td>Capital Efficiency</td>
<td>US$3,312/oz</td>
</tr>
<tr>
<td>After-tax NPV at 5% Discount rate</td>
<td>US$1,550.5m</td>
</tr>
<tr>
<td>After-Tax IRR</td>
<td>20.3%</td>
</tr>
<tr>
<td>Life of Mine</td>
<td>24 years</td>
</tr>
<tr>
<td>Payback</td>
<td>6.9 years</td>
</tr>
<tr>
<td>Cash Operating Costs</td>
<td>6-10 years</td>
</tr>
<tr>
<td>Profit Margin</td>
<td>57.97%</td>
</tr>
<tr>
<td>All In Sustaining Costs (“AISC”)</td>
<td>US$2839m</td>
</tr>
<tr>
<td>All In Costs (“AIC”) US$542/oz</td>
<td>USD 3925m</td>
</tr>
</tbody>
</table>

* Asteroid Retrieval Feasibility Study, KECK Institute for Space Studies, 2012
Millisecond Mining: Disruptively rethinking the way mine planning and execution should be working to enable real-time planning, execution and operational control.
MineRP’s Art of the Possible

STRATEGIC PLANNING

- Technical Mine Plan
  Multiple Design, Sequence and LOM
  Schedule alternatives in minutes

- Financial Plan / Budget
  Create budget alternatives per Mining Scenario, in minutes

OPERATIONAL PLANNING

- Optimised Plan in MTS & ERP
  - Actual Constraints including Derived Activities
  - Production Schedule
  - Production Orders

TACTICAL / BUSINESS PLANNING

YEAR 1-3

- Optimised Master Schedule
- Aligned Master & Discipline Schedules
- Works Orders

OPERATIONAL EXECUTION

- Continuous Automated updating of OEM Statuses
- Sensitivity Based re-planning

MONITOR

- DISPATCH
- CONTROL
- MONITOR
- IOT
Unified Strategic Business Planning

**TRADITIONALLY**

- Design Alternatives take **weeks or months**
- No Integration between technical plan and financial plan
- Planned using **average costs & aggregate grades**

**WITH MINERP UBP**

- Real-time, parametrically generated Design Alternatives
- Fully Integrated technical and financial scenario plans
- Planned using **Actual / Contracted costs & live Geometallurgical Models**
Unified Strategic Business Planning

**Technical Mine Plan**
Multiple Design, Sequence and LOM
Schedule alternatives in minutes

**Financial Plan / Budget**
Create budget alternatives per Mining Scenario, in minutes
The MineRP Unified Business Planning Solution

- Fully Integrated Mining Technical Systems
- Multiple Mine Planning Scenarios
- Multiple Financial Planning Scenarios

Reduce Planning Cycle from Months to Minutes

Year

Days

January 1
MineRP’s Art of the Possible

**STRATEGIC PLANNING**
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Real-time Execution Control and Management

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