Abstract #1693

English

Mining the Moon: A Step-wise Approach

Details to follow

French

No abstract title in French

No French resume

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Profile of Mr. Dale Boucher

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Biographies

Biography submitted with the abstract

Dale Boucher is CEO of Deltion Innovations Ltd., a for profit corporation formed that develops robotic mining technologies for earth and space. Deltion also provides access to space technologies for use in extreme mining environments such as deep mines and high altitude mines. Dale has a long history in heavy industry automation systems, and was a key player in some of the first hard rock drilling automation projects in the early 1990's. He became involved with space mining technologies in 1999 and has since published a number of papers relating to the subject. He has traveled extensively throughout North America and into Europe to speak on the topic of Canadian Mining expertise and its potential use in space exploration. As a recognized international space mining expert, Dale sits as a member of the NASA Mars Human Mission Landing Site selection committee and the International Space Exploration Coordination Group (ISECG) Lunar Volatiles Extraction working group. Dale is Chair of the Planetary and Terrestrial Mining Sciences Symposium and co-chair of the Space Resources Roundtable (US).

Biography in the user profile

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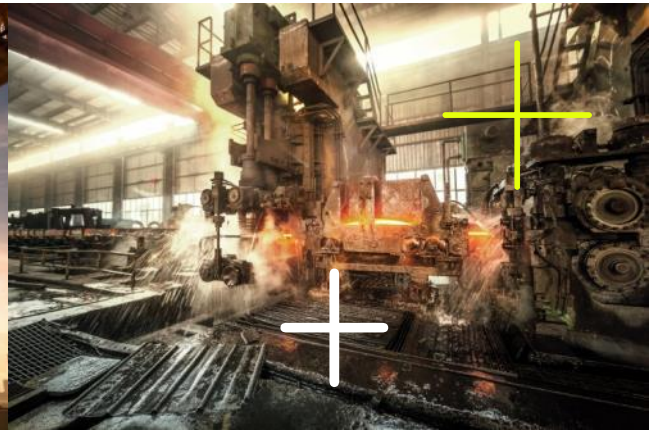
Roadmapping the Lunar Brewing Company

Norm Chen, Hatch Ltd.
Dale Boucher, Deltion Innovations Ltd.





May 2, 2017

Leveraging the Mining Industry

The Mining Cycle

REHABILITATION

PRODUCT

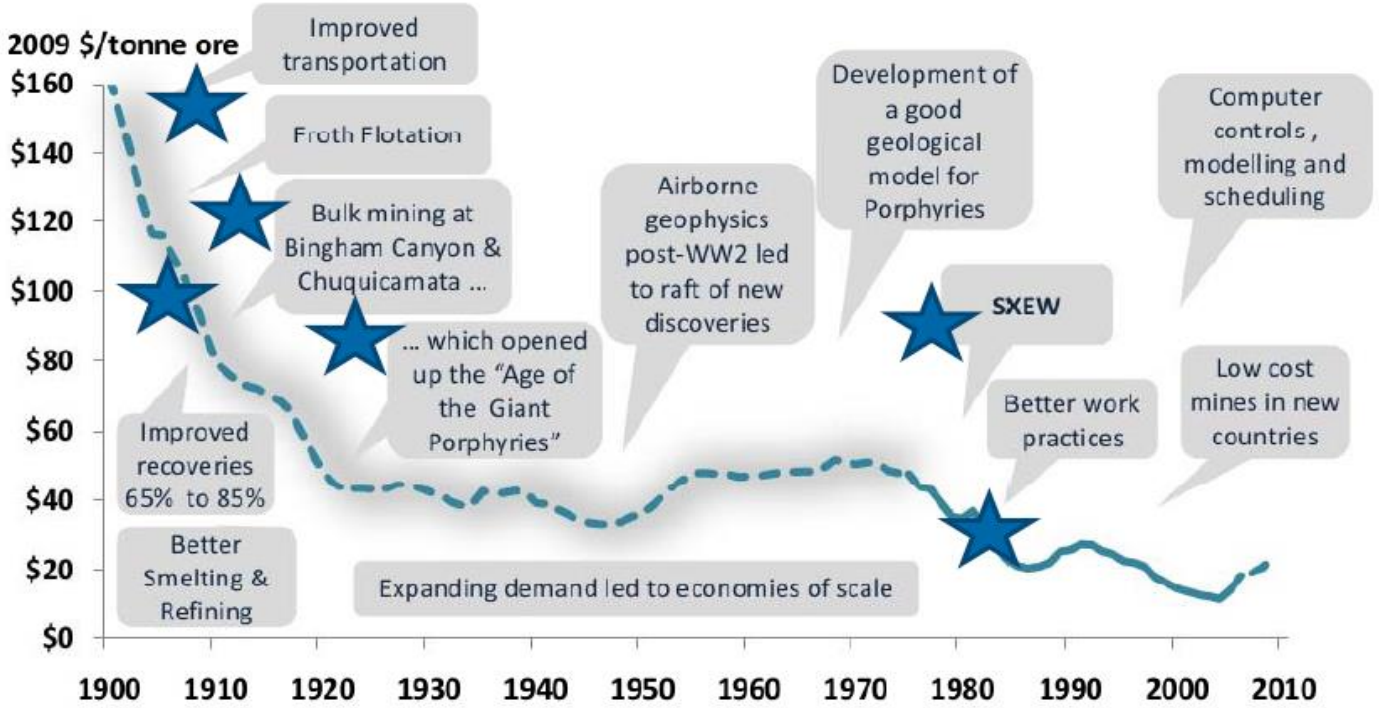
REFINING

MINING

EXPLORATION

Photos Courtesy Falconbridge Nickel

Leveraging the Mining Industry's Body of Knowledge



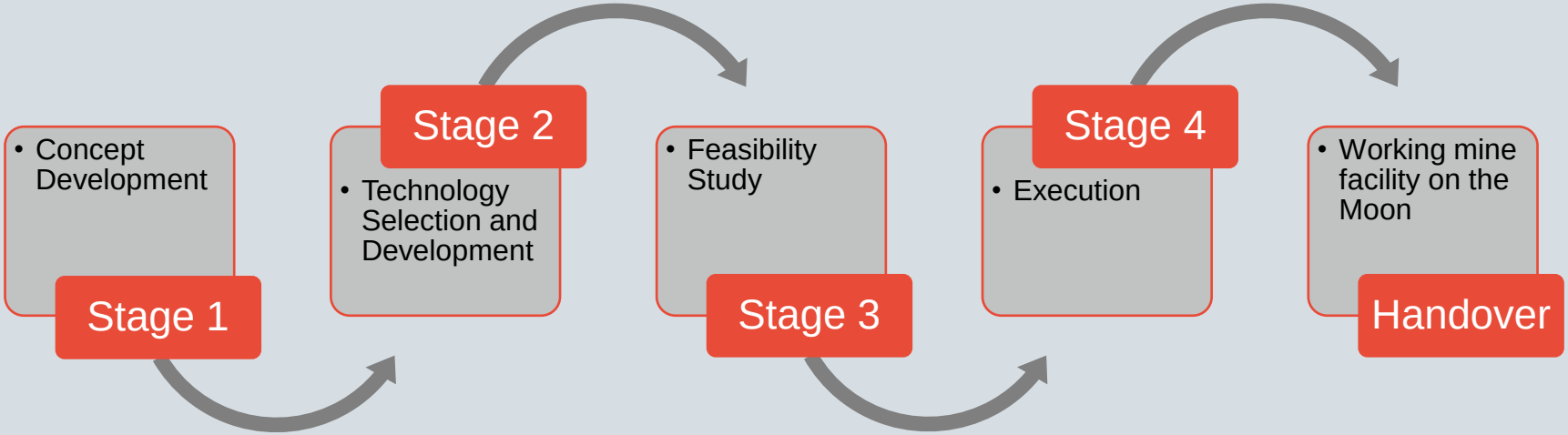
Key Technical Innovations – Estimated Average Operating Costs in the Western World : 1900 - 2009

Sources: Brook Hunt, CRU, Historical reports
MinEx Consulting estimates (for 1900-1974)

Near-term developments in the Mining and Space Exploration industries will affect long-term Project planning

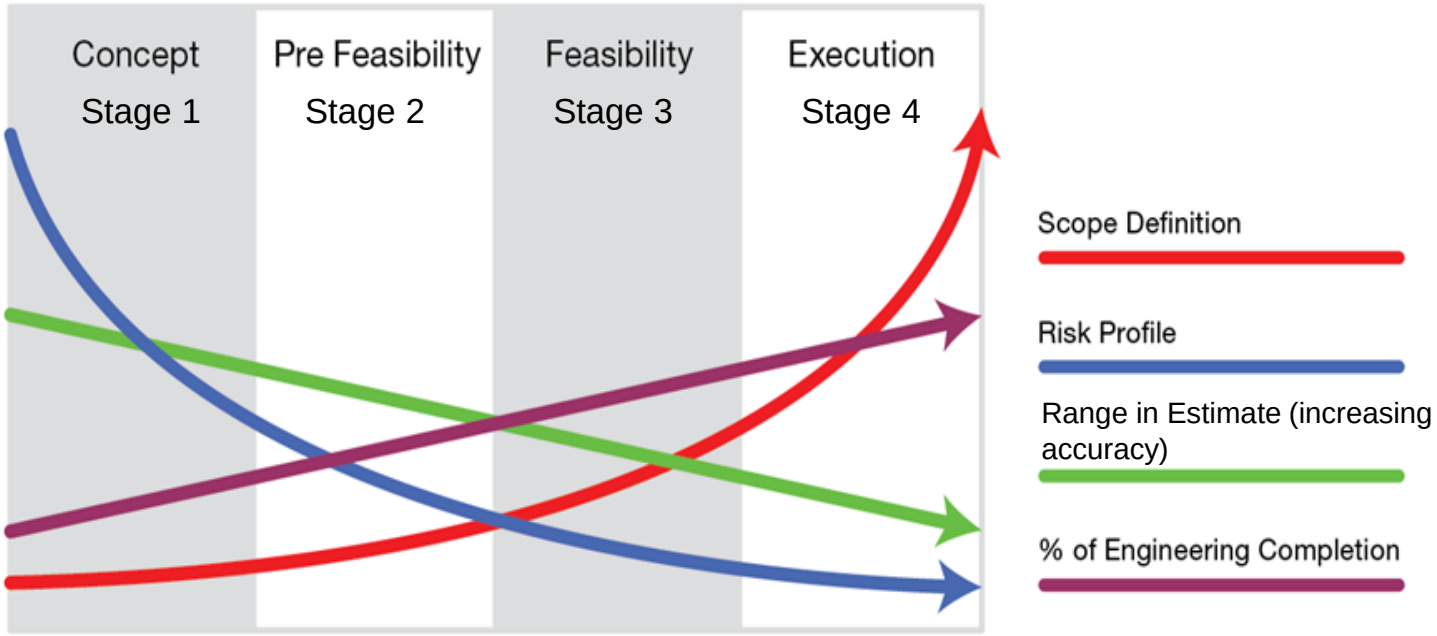
- Innovation in Mining Technology:
  - Experience in developing remote locations;
  - Automation and Analytics;
  - Electrification of Mines.
- Innovation in Space Exploration:
  - Modes of Transport;
  - Earth-based analysis;
  - Space-based analysis;
  - Robotics.

Phases of the Project



- Aligned with Program development in multiple industries.
- Proven methodology for developing a mine.
- Focus on Client Requirements, business case, Value creation, and safe and rapid ramp-up to Production.

Typical Mining Project Implementation



Strawman Summary (the opportunity)

- Lunar Water Extraction;
- Prospecting Mission;
- Define the project and leverage Mining Industry knowledge and current Exploration programs;
- Plan the mining activity;
- Identify Knowledge Gaps.

Establish Basic Assumptions

Client	Mine Site	Production	Life Cycle	Delivery Point	Projected price point
• Lunar Lager Brewing Company Ltd.	• Cabeaus Crater	• 1000 tonnes purified water per year	• 10 year Production	• Lunar Outpost • Shackleton Rim • Clive's Bar and Grill – hamburger stand and refueling depot	• $500 per kg

Stage 1 Objectives (Concept)

- Provide the client with the information to test the business concept against the investment hurdle criteria for concepts;
- Identify the business need and establish the Client Requirements Specification (CRS);
- Establish the key input, process and output production, or throughput parameters;
- Establish a number of alternative approaches to meet the defined project objectives;
- Develop a workable plan and cost for taking the concept through the Stage 2 phase.

Stage 1 – Strawman Concept Development

1. • Cost cap budget for project set at $1600 million

2. • Early results indicate
   - 7% water ice by weight average over mining site of 100 hectares.
   - Average depth is 2 m;
   - overburden is 40 cm desiccated material.
   - Rubble field geology requiring handling of large (1 m) rubble as overburden and embedded waste.
   - Estimates show that 40% of the available area is accessible; remainder is under excessive rubble or trapped by rock outcroppings.

3. • Technology Development State of Art
   - Small ISRU-specific mobile platforms (500 kg) are reasonably mature and can be used to provide most mobile services.
   - Sampling technologies well developed for detailed ore body definition.
   - Refining systems are at early TRL stages.
   - Storage of product can be evolved from known technologies.

4. • Technology development plans
   - excavation systems,
   - command and control with Direct To Earth (DTE) link or via specialized orbiter or crater rim emplaced links.
   - Power systems to be RTG stacks and/or crater rim mounted solar voltaic cells.

Key considerations in Stage 1

Activity
Establish Study Context
Set-Up
Project History
Exploration Results and Geological Context and Background
Mineral Resources and Mineral Reserves
Mining
Process Definition
Engineering Development
Project Layout
Process Plant, Site Development and Infrastructure

Activity
Project Schedule
CAPEX and OPEX
Health, Safety and Environment
Human Resources
Business and Project Systems
Market Analysis
Financial Analysis and Evaluation
Risk Management
Legal and Commercial
Execution Plan

Drivers of Stage 1

Option Drivers	Context
Technology	What technologies, or technology combinations, are available to deliver the project objectives?
Capacity	A capacity analysis should be considered for a number of discrete plant capacities to assess the economic viability of the entire plant, and of each plant production train. The latter applies when multiple production trains might be required.
Products or intermediates	Definition of whether the plant produces a single product or a suite of products, in varying quantities, grade and specification might lead to developing alternative plant configurations to manage production of the quantity of each product type.
Site selection	Site options require definition and analysis to assess the sensitivity of the project to the site location. A preliminary site selection analysis should be completed for an agreed suite of project sites.
Project configuration	Where a project might need a geographically spread context, options for project configuration need to be considered, developed and analyzed.
Execution approach	Options for the execution approach should be considered.
Implementation timing	Options for the project development sequence should be considered. Permitting and approval options and their impact on the total development timetable and sequence for the project should be defined.
Others defined by the specifics of the project and the client.	Our major clients have developed detailed criteria and specifications outlining their requirements for the nature and quality of work to be completed, to evidence completion of a FEL1 or concept study project phase.

Sample Roadmap

Activity	Action	Straw-man
Context and Setup		
Establish study context	• Assign study leadership • Identify business need or opportunity • Define scope of study • Define format and methodology • Identify strategic factors • Analyze market factors • Identify project risks • Establish high level operational issues • Identify potential health, safety, environment and community impacts including gate review • Identify stakeholders • Develop evaluation criteria: ◆ Health, safety, environment and community ◆ Sustainable development ◆ Schedule ◆ Risk. Financial objectives and economic criteria (client to lead this activity).	• Prove the resource • From orbital observation • From surface observation • Interpretation of data; public private expertise. • Identify service providers for technology • Review business case and funding. • Regulatory requirements and framework. .

Project History

Activity	Action	Straw-man
Execute and Control		
Project History	Define the: • Project objectives, benchmarks and key performance indicators • Location, regional and country factors impacting the project • Climatic data • Project, land, resource and technology ownership • Intended execution approach from the previous phase • Project development history • Business environment • Strategic case for the project • Incoming business case (i.e., markets, revenue, industry structures and financial performance required of the project) • Summary of any reviews completed to date and actions arising • Constraints and dependencies.	• Gather preliminary data derived from the public domain, specific to the project location. • Define the location for the project facilities (i.e., the project site is often assumed). • Conceptually understand the preliminary views of the business drivers that will support a project of this type. • Define known project constraints.

Exploration Results

Activity	Action	Straw-man
Exploration Results and Geological Context and Background	Define the: • Geological context for the orebody, including the type of deposit • Topography and survey, including the overall site grid(s) • Exploration work undertaken to date • Drilling programs undertaken and their results, including in-progress or planned work • Core data, drilling method, recovery and sampling techniques • Data collected, including: ◆ Drilling spatial and survey data ◆ Such data as geological, lithological, structural, mineralogical and chemical of the mineralized zones and host rock mass ◆ Hydrogeological ◆ Geophysical ◆ Geotechnical (for surface facilities) ◆ Geomechanical (for underground or open-pit mining facilities) ◆ Deleterious component distribution(s) ◆ Overall bulk density. • Assay and test work methods and data • Core data and assay quality control measures applied • Data verification protocols applied in preparation of the geological block model • Deposit geology.	• Assemble initial information that, by the end of a Stage 1 study, would support at least a NI43-101, JORC, or SAMERC Inferred mineral resource classification suitable for a preliminary economic assessment, (or similar), report. • Complete outline regional geology, topography and exploration work, (including QA/QC). • Provide a clear preliminary understanding of the topography, geology, mineralogy and mineralization continuity on a deposit-domain scale. • Identify key technical issues requiring additional subsequent studies, including sampling for metallurgical characterization and testing, site geomechanical data collection and acid rock drainage (ARD).

Mineral Resources

Activity	Action	Straw-man
Mineral Resources and Mineral Reserves	Resource and reserve reporting is usually governed by internationally recognized codes and standards (e.g., JORC, NI43-101, SAMREC and others). Publicly listed companies are required to report against one or more of these codes. Data prepared should be of a level that would allow its use for public disclosure, even if this is not planned. The premise underlying all codes is as follows: • Resources – a reasonable prospect for economic extraction of mineral deposit, considering that the location, quantity, grade, geological characteristics and continuity of a mineral resource are known, estimated or interpreted from specific geological evidence and knowledge. • Reserve – the economically mineable part of a measured or indicated mineral resource demonstrated by at least a prefeasibility study, including adequate information on mining, processing, metallurgical, economic and other relevant factors. These factors demonstrate, at the time of reporting, that economic extraction can be justified, and includes diluting materials and allowances for losses that might occur when the material is mined. • Preparation of resource and reserve statements requires input and statement approval by “competent persons” defined by the codes and standards. Hatch requires senior management input before accepting assignments to act as a qualified person.	• Aim to have at least an inferred resource quality inventory by the end of Stage 1. • Conduct a preliminary assessment of the overall deposit content and continuity to build an initial block model, which includes deposit grade tonnage curves and clear identification of any cut-off grade issues.