Prospecting Rovers

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Mining Cycle

Exploration

Mining

Rehabilitation

Product

Refining

Photos Courtesy Falconbridge Nickel
ISRU Cycle (Space Mining)

Remote Survey → Resource Prospecting and Definition → Extraction Mining

Resource Prospecting and Definition → Processing → Beneficiation

Product → Waste
Lunar ISRU Operations Cycle

Global Resource Identification

Local Resource Exploration/Planning

Mining

Communication & Autonomy

Site Preparation

Product & Utilization

Crushing/Sizing/Beneficiation

Processing

Waste

Maintenance & Repair
Prospecting 101

• Exploration conducted in a step-wise fashion
  • progresses through stages, each of which moves closer to making a valuation of the ore body.
  • Geological reconnaissance and surface geochemical sampling prevail in the earliest stage.
  • geophysical surveys are typically conducted.
• Following surface exploration, the project moves into the drilling stage.
  • Drilling begins with a small number of exploratory drill holes on select targets
  • Drilling moves to extensive, close-spaced drilling (“development drilling”)
  • pending good results, “reserve drilling” is conducted, which is the type of drilling which makes the final assessment of the deposit before actual mining begins.
• Generally, some amount of drilling will continue throughout the life of the mine,
  • further definition is required
  • new information is obtained
  • used to refine the deposit model.
Prospecting 101

• Exploration Reconnaissance Stage
  • Start with surface bedrock mapping
  • Mapping and sampling
  • Identify and map outcrops, describe mineralization and alteration, measure structural features (geometry), and make geologic cross sections.
• Geochemical methods involve the collection and geochemical analysis of geological materials, including rocks, soils and stream sediments.
  • Results mapping and sampling may suggest patterns indicating the direction where an ore deposit could be present underground or at the surface.
• Geophysical methods focus on measuring physical characteristics (such as magnetism, density or conductivity) of rocks at or near the surface.
  • The measured values are then used to compare with the values and models of known ore deposits.
Prospecting 101

• value of an ore body (or “deposit”) requires determination of
  • “tonnage” (or volume)
    • determined by using drill data to outline the deposit in the subsurface, and by using geometric models to calculate the volume.
    • difficult to delineate because ore deposits often have irregular shapes.
  • “grade” (or concentration)
    • the average concentration determined from numerous assays of drill samples
    • can vary considerably within different parts of the same ore body.
Prospecting 101

• Development
  • extensive, close-spaced drilling
  • outlines the geometry of the deposit in great detail.
  • extensive testing to precisely determine grade of deposit and the “recovery”

• Feasibility
  • final stage before actual mining or extraction
  • actual mining or extraction method is proposed,
  • considers economic variables (commodity price, milling cost, transportation cost
  • decision is made whether to mine the deposit from the surface (“open-pit mining”), or to mine the deposit by tunneling (“underground mining”).
Prospecting 101
3 Dimensional Model from Fused TriDAR and GPR Data
Notional RLEP-2 Type Mission Path

Starting point
(simulated lander location)

- Drill Sites - Operate all Instruments; particularly
  - RESOLVE
  - VAPoR
  - Borehole XRF
  - Mossbauer/XRF on surface
  - CSA GPR

- Short Duration Instrument Stops - Operate
  - MMI
  - Cone Penetrometer
  - CSA Instruments

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Notional ISRU Operations at a Lunar Outpost

- Regolith Excavation Area for $O_2$ Production
  - Crater Rim
  - Down to 0.3 m
  - 100 m
  - 500 m
  - 1000 m

- Spent Regolith Dumping Area
  - 100 m
  - 8000 m

- Water Excavation Area
  - Down to 0.75 m

- Spent Regolith Dumping Area
  - 15° Slope
  - 100 m

- Landing/Ascent Pad Area
  - 100 m

- ISRU Plant – $O_2$ or Water

- 500 m

- 1000 m

- 15° Slope

- 35 degree slope

- 15 degree slope

Model of Dawes Crater (Shackleton analog)
- 22 km diameter at rim - 2 km deep

- Houston Skyline

- Power Production Zone
- Observation Zone
- ISRU Plant ($O_2$ or Water)
- Spent Regolith Dumping Area
- Excavation Area for $O_2$ or Water
- Water Processing
- Landing Zone

- 200 m
- 100 m
- 200 m
- 100 m
- 200 m
- 200 m
- 200 m
- 100 m
- 100 m
- 100 m
- 100 m
Proper Tool for the Job

Utilization of extraterrestrial resources provides potential for unlimited range.
Proper Tool for the Job
Proper Tool for the Job

• Mining Mobility Chassis
  • Specifically designed for the environment
  • Specifically designed for the suite of tasks
In Situ Resource Utilization (ISRU)
Specific Common Carrier Chassis

- Mobility Chassis
  - Basic NORCAT ISRU chassis
  - No modifications required to change payloads
  - Utilizes interchangeable saddle design
In Situ Resource Utilization (ISRU) Specific Common Carrier Chassis