IN SITU RESOURCE UTILIZATION
PLANNING THE MINE
AND MINING THE PLAN

Deltion Innovations
deltion.ca

HATCH
Space Mining is one form of In Situ Resource Utilization (ISRU)
The Mining Cycle

Photos Courtesy Falconbridge Nickel
Lunar ISRU Operations Cycle

Global Resource Identification

Local Resource Exploration/Planning

Communication & Autonomy

Site Preparation

Crushing/Sizing/Beneficiation

Product & Utilization

Processing

Waste

Mining

Maintenance & Repair
What Do You Mean “We got it wrong?”

- Mining Cycle is only a portion of the overall Mine Planning Activity
- Lunar Operations BEGIN after the Mine Plan is executed (Stage 4)
- Failure to plan appropriately yields … unexpected results

To find an new gold mine …

start with an old gold mine
Consumable Production
- Propellants
- Life Support
- Fuel Cell Reactants
- Metal Feedstock
- Plastic Feedstock

Resource Prospecting
- Lunar Ice/Volatiles
- Mars Water
- Near Earth Objects

Energy
- Thermal Storage
- Solar Array Production
- Space-based Solar power Beaming
- Helium-3 Mining

Civil Engineering & Construction
- Civil Engineering:
  - Landing Pads, Roads, Berms
  - Habitats

Using Space Resources
Constellation Program
Notional Shackleton Crater Rim Outpost
Constellation Program

Habitation Zone
(ISS Modules Shown)

Power Production Zone

Resource Zone
(100 Football Fields Shown)

Landing Zone
(40 Landings Shown)

Monthly Illumination
(Southern Winter)

Potential Landing Approach

To Earth

South Pole (Approx.)

Observation Zone

Potential Landing Approach

0 5 km
Conceptual NASA Lunar Surface Architecture

- Power & Support Unit (PSU) (Supports power storage, cargo offloading & lander)
- 10 kW Arrays (net)
- ISRU Oxygen Production Plant
- Logistics Pantry
- Habitation Element
- Habitation Element
- Unpressurized Rover
- Small Pressurized Rover (SPR)
- ATHLETE Mobility System (2)
- Common Airlock With Lander
## Establish Basic Assumptions

<table>
<thead>
<tr>
<th>Client</th>
<th>Mine Site</th>
<th>Production</th>
<th>Life Cycle</th>
<th>Delivery Point</th>
<th>Projected price point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunar Lager Brewing Company Ltd.</td>
<td>Cabeaus Crater</td>
<td>1000 tonnes purified water per year</td>
<td>10 year Production</td>
<td>Lunar Outpost&lt;br&gt;Shackleton Rim&lt;br&gt;Clive’s Bar and Grill – hamburger stand and refueling depot</td>
<td>$500 per kg</td>
</tr>
</tbody>
</table>
Phases of Project

Stage 1
- Concept Development

Stage 2
- Technology Selection and Development
- Feasibility Study

Stage 3
- Execution

Stage 4
- Working water facility on the Moon

Handover
Stage 1 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.
Stage 1 Concept Development
Stage 2 Technology Selection

1. CRS revised to include Level 2 requirements.

2. Mining process selected.
   - Open bench mining
   - Overburden dump site selected for ease of access at later date in support of habitat requirements.

3. Plan revised to incorporate new fusion power system development.

4. Technology development roadmap completed.
   - Contact made with OEM’s
   - Develop target technologies in joint venture/ speculation style sub-projects.

5. Execution Stage (Stage 4) concept will rely upon robotic pre-cursors to develop infrastructure, roadways, maintenance sites.

6. Overburden from mine site will be used as required for fill.
Stage 3 Feasibility Study

1. CRS revised to include Level 3 Requirements.

2. Time-based technology deployment completed.

3. Fleet make up of
   - 2 roadway maintenance rovers,
   - 2 construction robots,
   - 1 mobile exploration drill,
   - 2 Load Haul Dump machines,
   - 4 haulage trucks
   - Deployed in order indicated over 3 years.

4. Refining process to be in situ thermal release of water ice from regolith with water filtration plant for 98% purity.

5. Bulk storage tank farm with auto loaders for pure water storage.

6. Technical risks 80% retired: remaining risks are in the area of long term machine availability.

7. Management risks remain with long term financing and market volatility for end product.
## Stage 4 Execution

<table>
<thead>
<tr>
<th>Step</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Establish project execution team.</td>
</tr>
<tr>
<td>2</td>
<td>Secure launch, cruise and lander contracts</td>
</tr>
<tr>
<td>3</td>
<td>Secure OEM equipment procurement contracts and schedule.</td>
</tr>
<tr>
<td>4</td>
<td>Establish ground based command and control center.</td>
</tr>
<tr>
<td>5</td>
<td>Deploy road building systems to establish landing pads, basic infrastructure, mine pit roads.</td>
</tr>
<tr>
<td>6</td>
<td>Deploy construction robot team.</td>
</tr>
<tr>
<td>7</td>
<td>Deploy LHD robots.</td>
</tr>
<tr>
<td>8</td>
<td>Deploy long-haul trucks.</td>
</tr>
<tr>
<td>9</td>
<td>Commissioning of systems and ramp up to full production.</td>
</tr>
<tr>
<td>10</td>
<td>Hand-over to Client (Operations).</td>
</tr>
</tbody>
</table>