

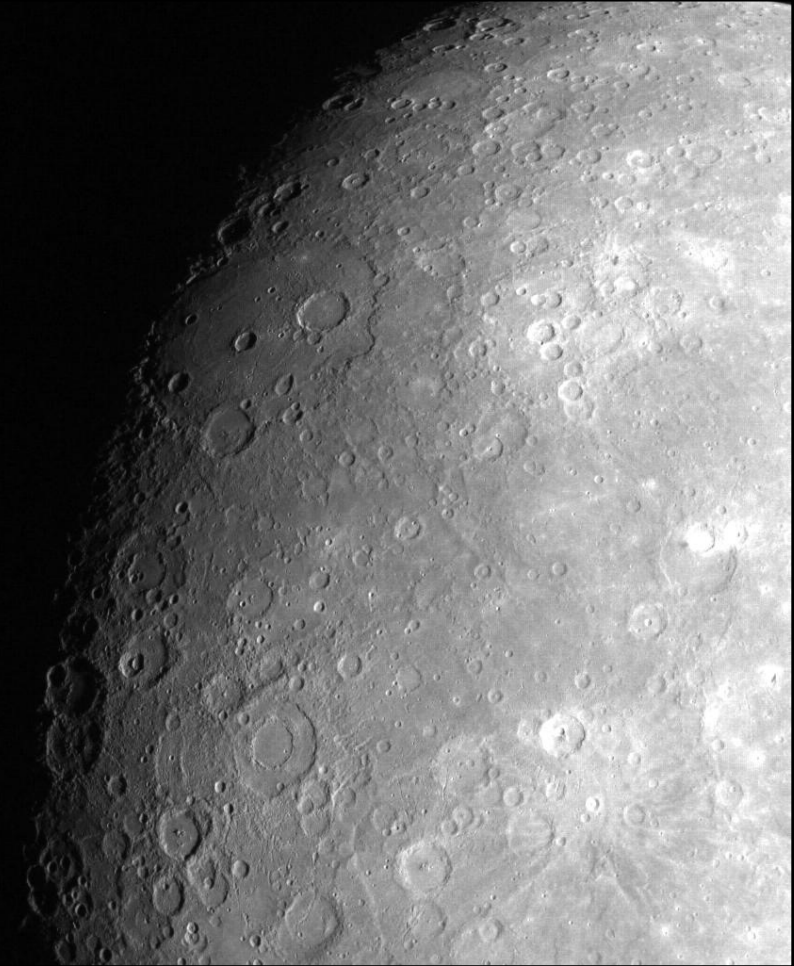


Economic Evaluation of Lunar Mining Projects

From Speculation to Strategy

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3 June 2025



The Value of Economic Analysis

Why?

Commercial Viability:

- Reduces costs for science missions
- Accelerates development
- Lowers entry barriers
- Reduces dependence on political cycles



Credit: NASA/Rocket Lab

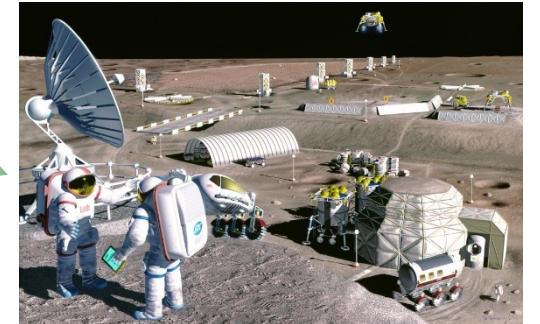
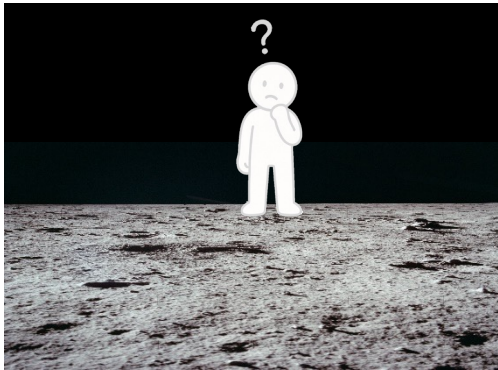


Credit: NASA/Planet Labs

The Value of Economic Analysis

Why now?

Not proving profitability, but exposing the path to it.



- Identify the critical path
- Attract investments



- Ask the right questions
- Identify key variables
- Set Viability Thresholds



Evaluation of Mining Projects

Discounted Cash Flow

Net Present Value

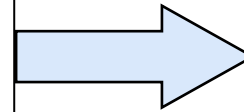
$$\text{NPV} = \sum_{t=1}^N \frac{R_t - C_t}{(1 + r)^t} - C_i$$

Evaluation of Mining Projects

Discounted Cash Flow

Net Present Value

$$\text{NPV} = \sum_{t=1}^N \frac{R_t - C_t}{(1 + r)^t} - C_i$$



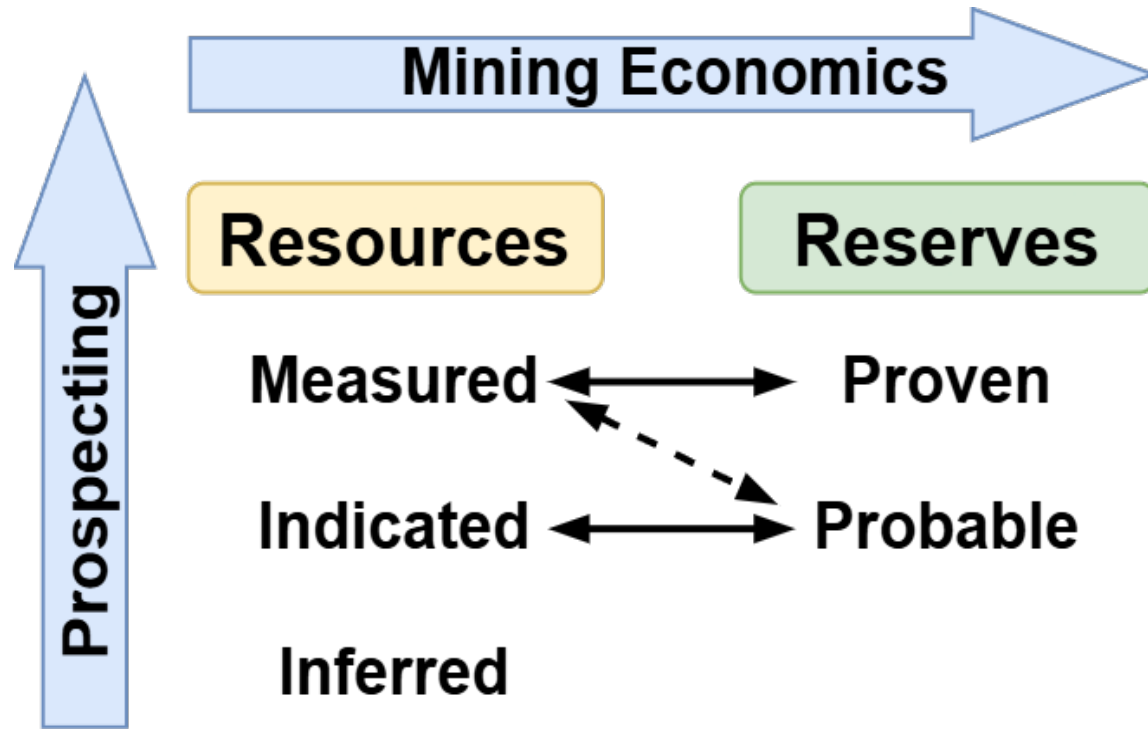
Is this project economically viable?

NPV < 0
No

NPV > 0
Yes

Evaluation of Mining Projects

Discounted Cash Flow



Conceptual Image / Sora

Evaluation of Mining Projects

Net Present Value

$$\text{NPV} = \sum_{t=1}^N \frac{R_t - C_t}{(1 + r)^t} - C_i$$

Evaluation of Mining Projects

Net Present Value

$$\text{NPV} = \sum_{t=1}^N \frac{R_t - C_t}{(1+r)^t} - C_i$$

$$R_t = Q_t \cdot P_t$$

Extracted quantity [kg], price [\$/kg]

Evaluation of Mining Projects

Net Present Value

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Extracted quantity [kg], price [\$/kg]

$$C_t = Q_{\text{extracted}} \cdot (C_e + C_p) + C_{\text{return}}$$

**Excavated quantity [kg], Extraction cost [\$/kg]
Processing cost [\$/kg], Transportation Costs [\$]**

Evaluation of Mining Projects

Net Present Value

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**Excavated quantity [kg], Extraction cost [\$/kg]
Processing cost [\$/kg], Transportation Costs [\$]**

$$Q_t = Q_{\text{extracted}} \cdot F \cdot G$$

**Excavated quantity [kg], Recovery Factor [%]
Resource Fraction (Grade) [%]**

Evaluation of Mining Projects

Net Present Value

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$$Q_t = Q_{\text{extracted}} \cdot F \cdot G$$

**Excavated quantity [kg], Recovery Factor [%]
Resource Fraction (Grade) [%]**

$$C_i = C_{\text{r\&d}} + C_{\text{hardware}} + C_{\text{launch}} + \dots$$

**R&D costs [\$], Hardware Costs [\$],
Launch Costs [\$]**

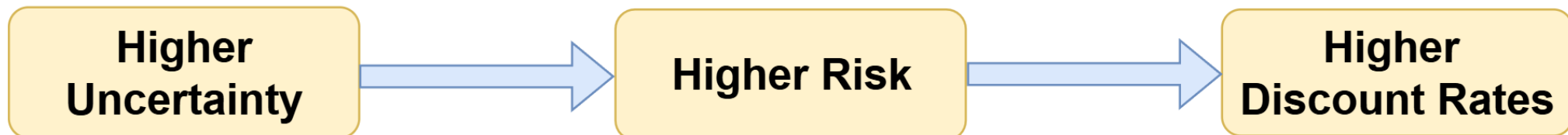
Evaluation of Mining Projects

Discount Rates

$$\text{NPV} = \sum_{t=1}^N \frac{R_t - C_t}{(1 + r)^t} - C_i$$

$$r = r_{base} + r_{tech} + r_{market} + r_{policy} + \dots$$

- **Opportunity Cost**
- **Technology Risk**
- **Market Risk**
- **Policy Risk**



Evaluation of Mining Projects

Exposing Gaps

$$\text{NPV} = \sum_{t=1}^N \frac{Q_{e,t}(FGP_t - C_e - C_p) - C_{\text{return},t}}{(1 + r_{\text{base}} + r_{\text{tech}} + r_{\text{market}} + r_{\text{policy}})^t} - C_i$$

**What we know
today**



**What we *need*
to know**

Sources of Uncertainty



Critical Path

Geochemical Uncertainty

$$\sum_{t=1}^N \frac{Q_{e,t}(FGP_t - C_e - C_p) - C_{return,t}}{(1 + r_{base} + r_{tech} + r_{market} + r_{policy})^t} - C_i$$

Source of uncertainty

**Geochemical
Uncertainties**

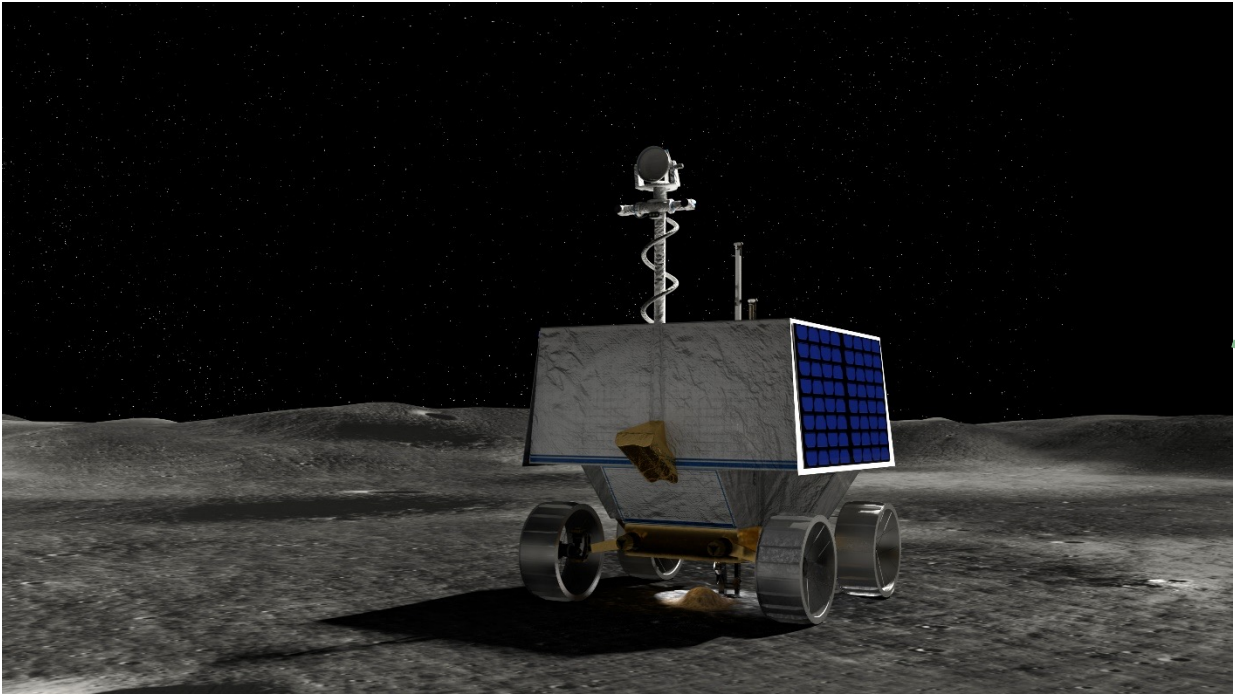
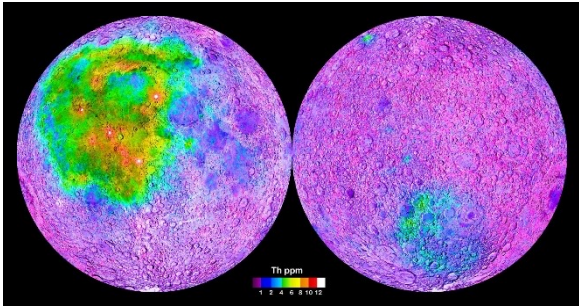
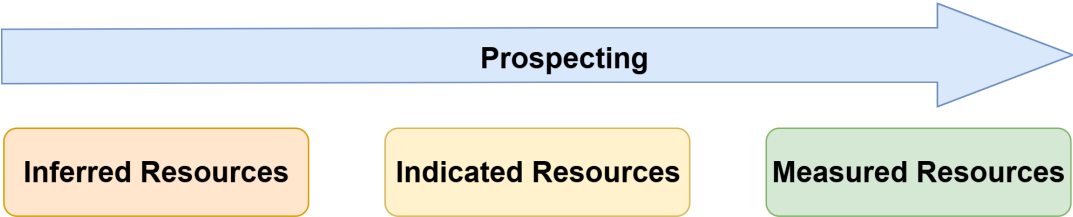
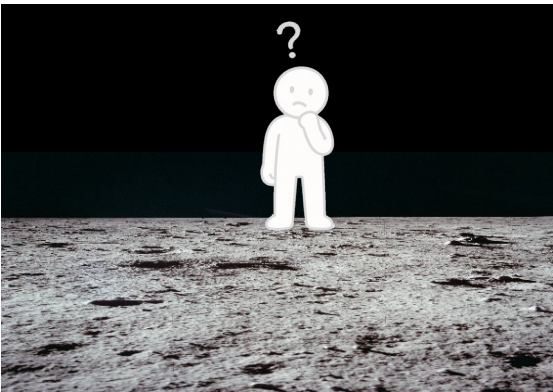


Affected Variables

- Resource Concentration (G)
- Extraction and Processing Costs (C_e , C_p)
- Total Extractable Quantity ($Q_{e, tot}$)

Critical Path

Prospecting



Credit: NASA

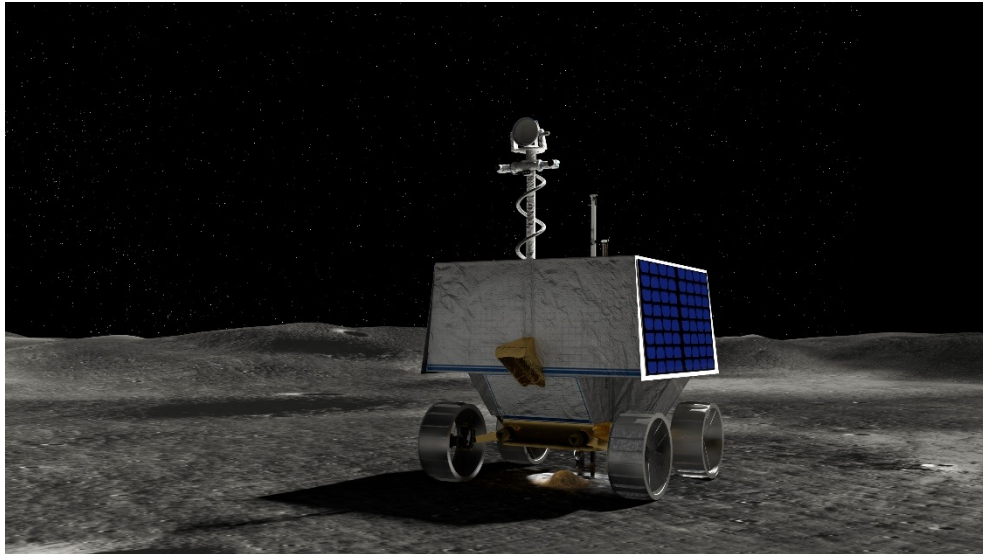
Critical Path

Prospecting

Current Activities

Discrete, one-off mission

Focused on technology demonstration

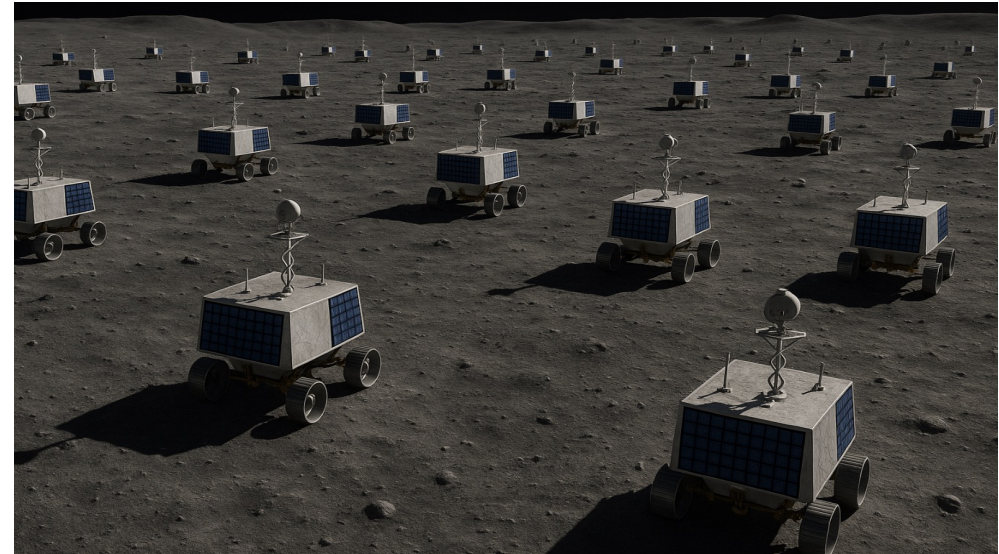


Credit: NASA

Commercial Needs

Large area datasets

Optimal data at minimal cost



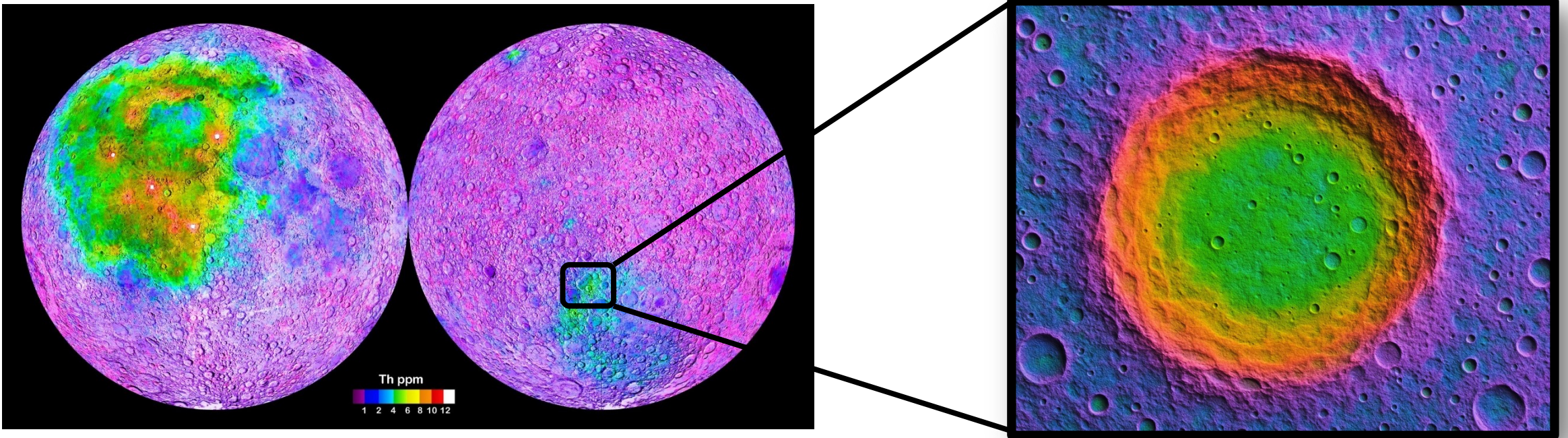
Conceptual Image / Sora

Critical Path Prospecting

**Publicly Funded
Wide Geological Surveys**



**Privately Funded
Detailed Prospection**



Credit: NASA – Lunar Prospector

Conceptual Image / Sora

Critical Path

Market Uncertainty

$$\sum_{t=1}^N \frac{Q_{e,t}(FGP_t - C_e - C_p) - C_{return,t}}{(1 + r_{base} + r_{tech} + r_{market} + r_{policy})^t} - C_i$$

Source of uncertainty

**Market
Uncertainties**



Affected variables

- Quantity (Q_e)
- Price (P)
- Policy Risk Discount Factor (r_{policy})
- Market Risk Discount Factor (r_{market})

Critical Path

Market Development

Motives

Reasons to go to space in the first place

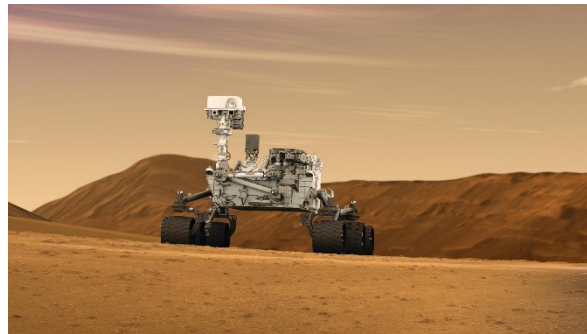
Profit Driven

Rare Resource Return
In-Orbit Manufacturing
LEO Telecoms



Non-Profit Driven

Science
National Pride
Curiosity



Means

Support or enable missions

e.g.: Lunar Regolith



Credits: NASA

University of Zurich | Economic Evaluation of Lunar Mining Projects

NASA 3D Printed Habitat Challenge

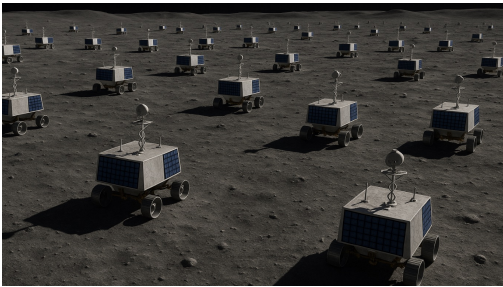
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Critical Path

Market Development



**Earth-supplied
Mission Pursuit**



**Prospecting, R&D
Confidence**



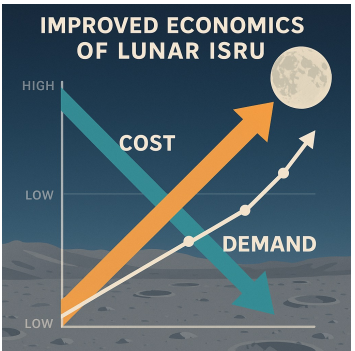
**Locally-supplied
Mission Pursuit**

Real Demand Signals



Conceptual Image / Sora

**Improved ISRU
Economics**



Credits: NASA

Critical Path

Technological Uncertainty

$$\sum_{t=1}^N \frac{Q_{e,t}(F GP_t - C_e - C_p) - C_{return,t}}{(1 + r_{base} + r_{tech} + r_{market} + r_{policy})^t} - C_i$$

Source of uncertainty

**Technological
Uncertainties**



Affected variables

- Extracted Quantity (Q_e)
- Recovery Factor (F)
- Costs (C_e , C_p , C_{return})
- Technological Risk Factor (r_{tech})

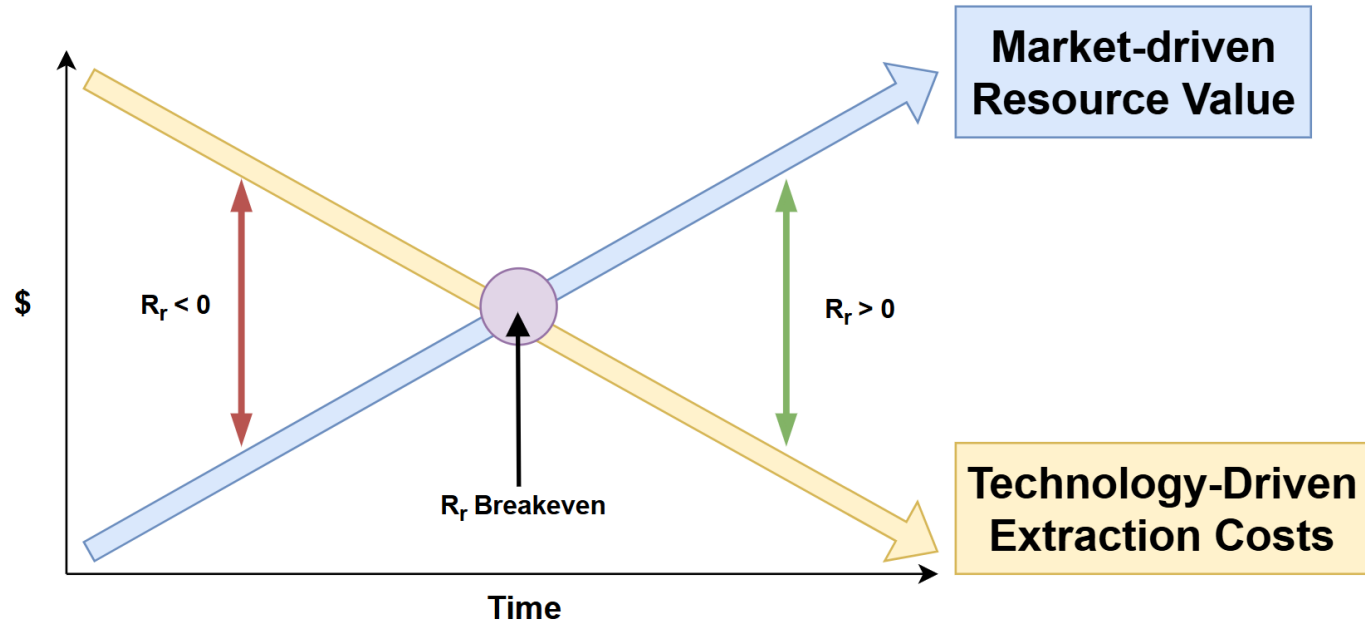
Not only technical benchmarks: also, economic ones

Critical Path

Technological Development

Conceptual Resource Rent Evolution

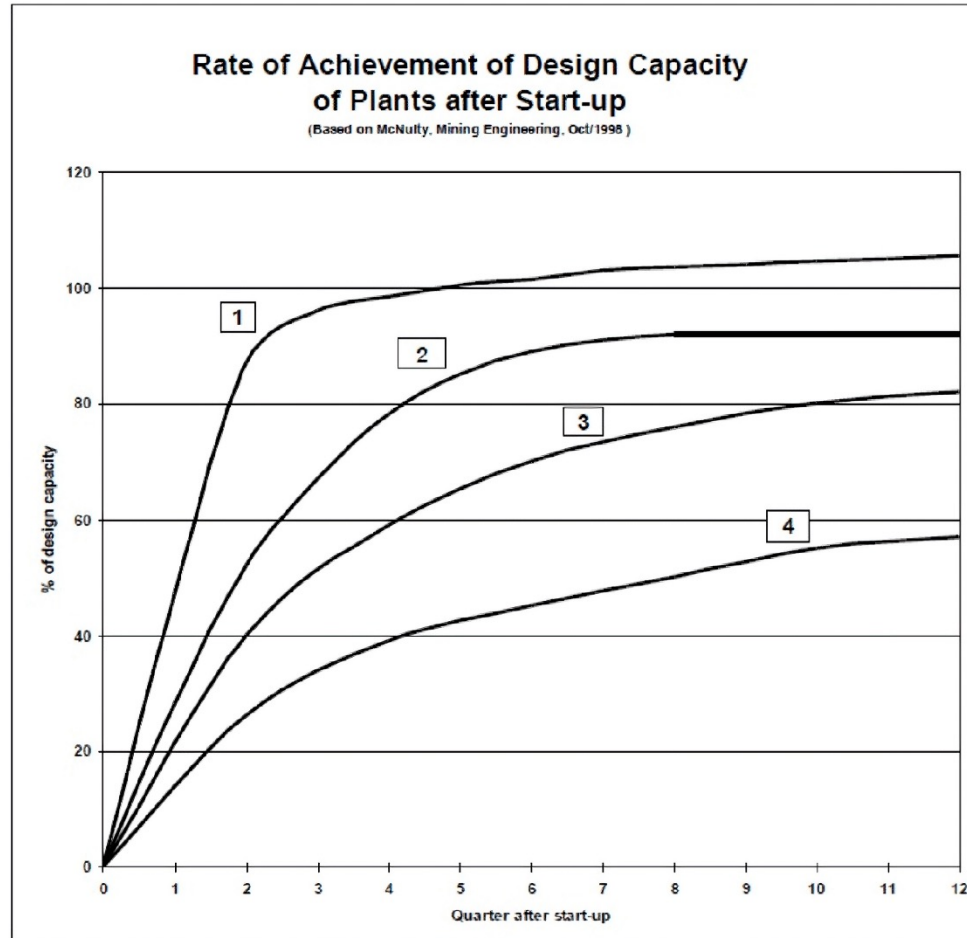
$$\text{Resource Rent} = \text{Resource Value} - \text{Extraction Cost}$$



Critical Path

Operational Maturity

McNulty Ramp-up Curves: scaling is hard

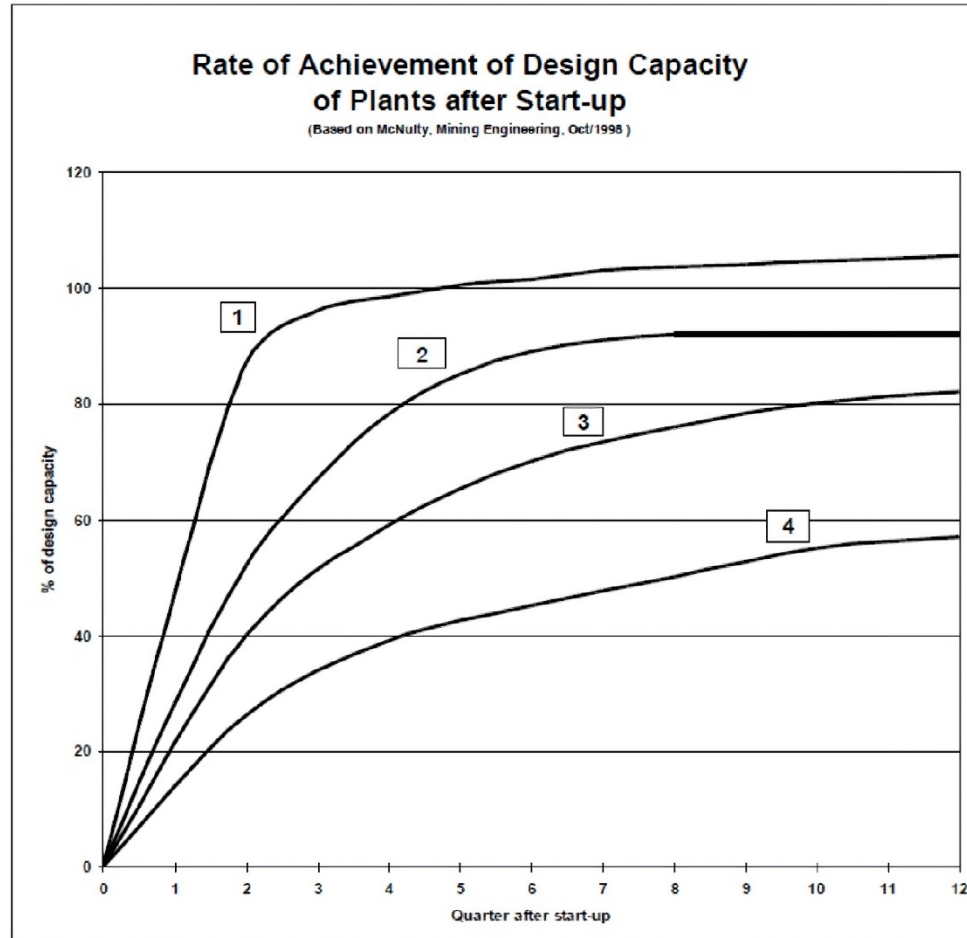


T. McNulty in M.C. Kuhn, *Innov. Technology* 1998

Critical Path

Operational Maturity

McNulty Ramp-up Curves: scaling is hard



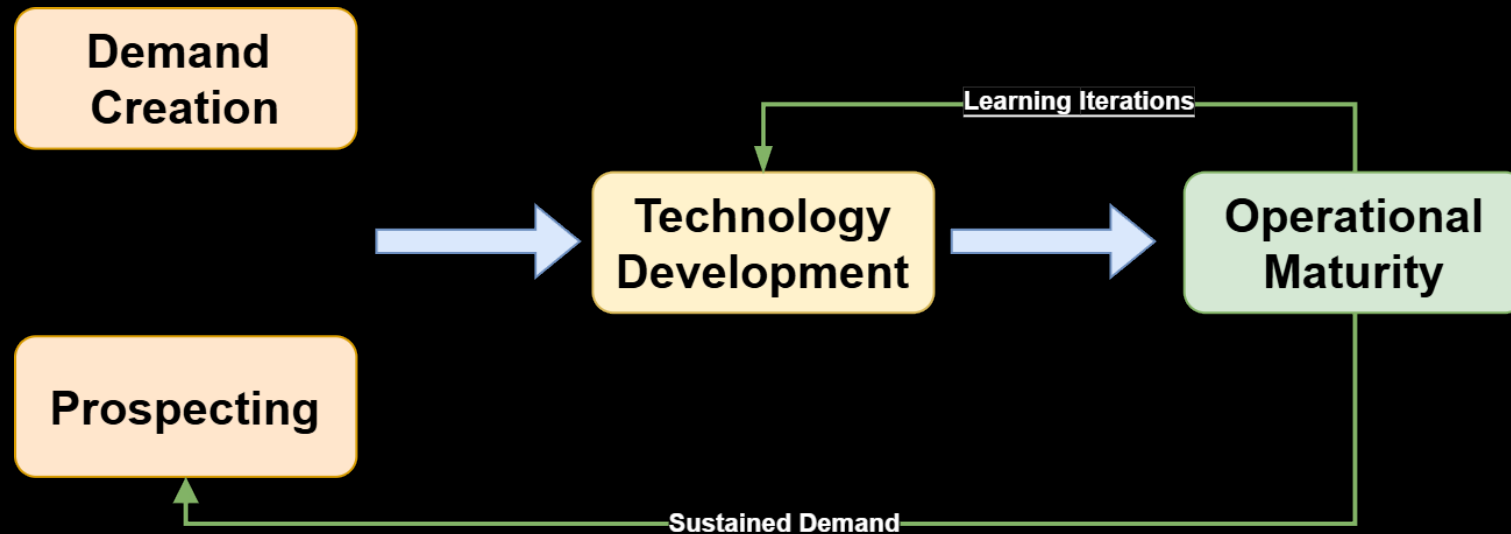
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Ravensthorpe HPAL Plant Example

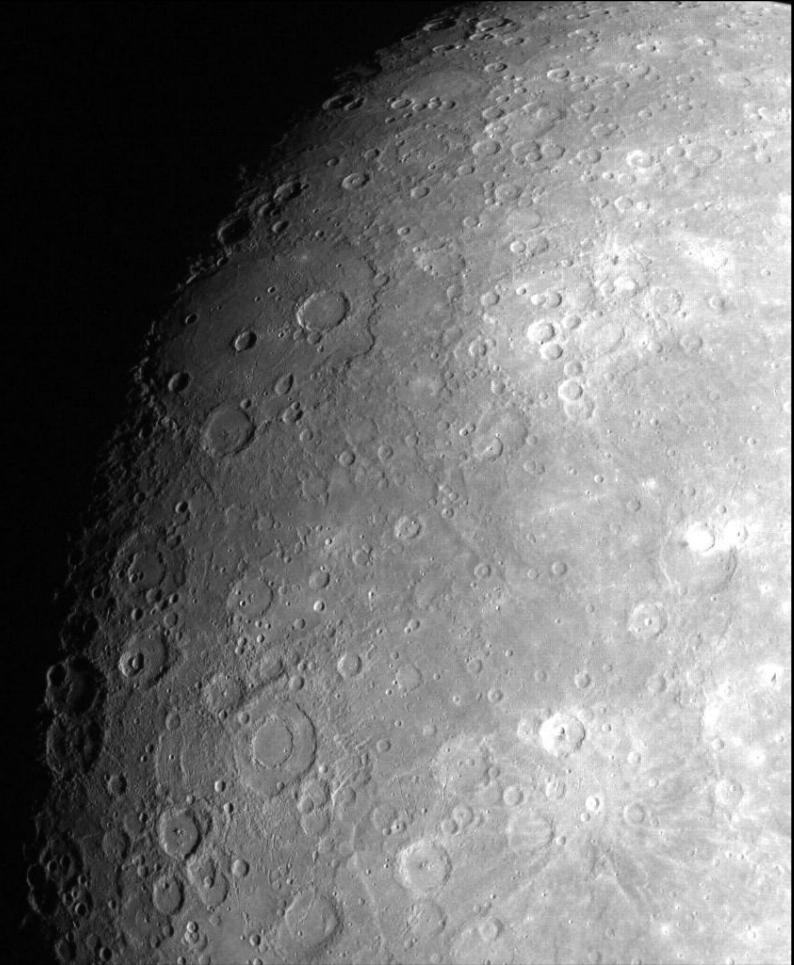
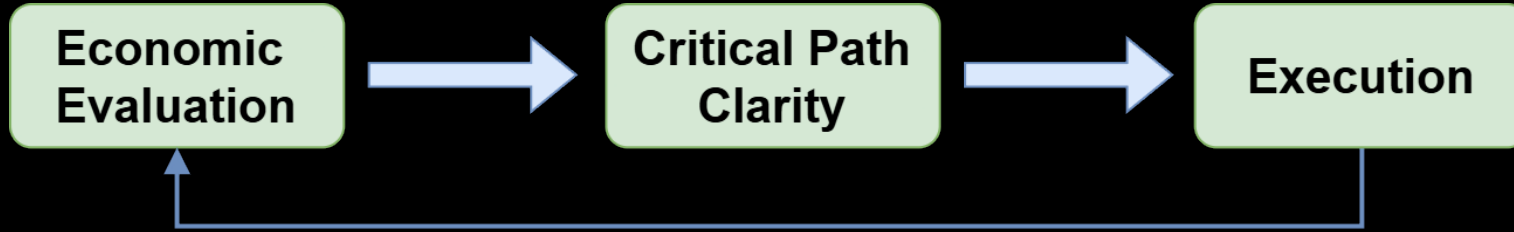


Credit: First Quantum Minerals

Critical Path



Going Forward





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