

# Defining Cut-Off Grades for Lunar **Helium-3:** An ISRU Economic Case Study

Dr. Carlos D. Espejel  
CEO  
[carlos.espejel@space-rs.com](mailto:carlos.espejel@space-rs.com)

Resource Operational Intelligence for National and  
Technical Governance







# SPACERS

WHO WE ARE



# RESOURCE INTELLIGENCE & TECHNOLOGY COMPANY



Headquartered in **Luxembourg**  
Founded in **2024**

Experience | **+24** years mining industry  
**+27** years space industry



## Two Verticals

### 1. Engineering Consultancy

— Mining Industry & ISRU

### 2. Technology

- Strategic Mine Planning Software
- Operational Intelligence Platform (**OIP**)
- Mining Industry
- Governments
- Defence

**Vision:** Unifying Space and Earth intelligence to strengthen global **resource** governance and maximize value for humankind.

# HOW DO WE ADD VALUE?

**23 + years of mining feasibility discipline** — *terrestrial and offworld*



## CUT OFF GRADE ANALYSIS & VALUE CHAIN OPTIMISATION

*Lane (1988) framework adapted for ISRU. Multi-product COG (LOX, He-3, water). Maximises NPV across the value chain.*



## RESERVES EVALUATION

*PFS/FS-grade analysis adapted to lunar resources. Independent assessment for investors and governments.*



## RESOURCE INTELLIGENCE

*Earth observation + mining data analytics + operational intelligence. Bridging Earth and space.*

For **mining operators, governments, and dual-use** .



# Current Customers and Projects

Activities in Australia, Peru, Chile, and Luxembourg

---



**Glencore**

Multi-metal: Antapacay,  
Tintaya + 8



**BHP, Glencore, Teck  
Resources, Mitsubishi**

Multi-metal



**European Space  
Agency**

Lunar Value Chain  
Optimisation



**MMG**

Multi-metal: Las Bambas



**Southern Copper**

Multi-metal: Las Bambas,  
Cuajone



Customers and projects





We perform Cut-Off  
Optimisation for some  
of the most prolific  
mining operations in the  
world.

Reserves

Value of the  
operation

Material  
Destination

When to Close the  
mine

Optimum Capacities



# Why do I need to know about Cut-Off Grades ?

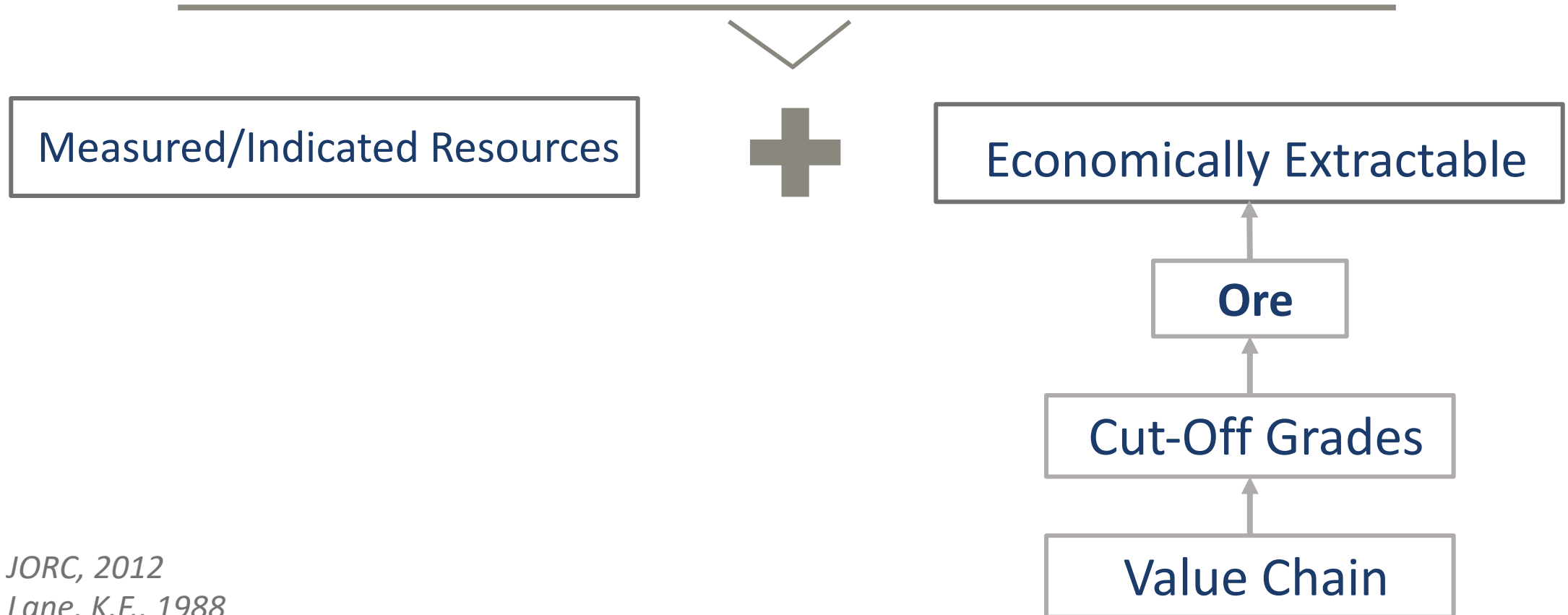
---

- Mining Engineers Love them





# Reserves



- JORC, 2012
- Lane, K.F., 1988
- LORS, 2023

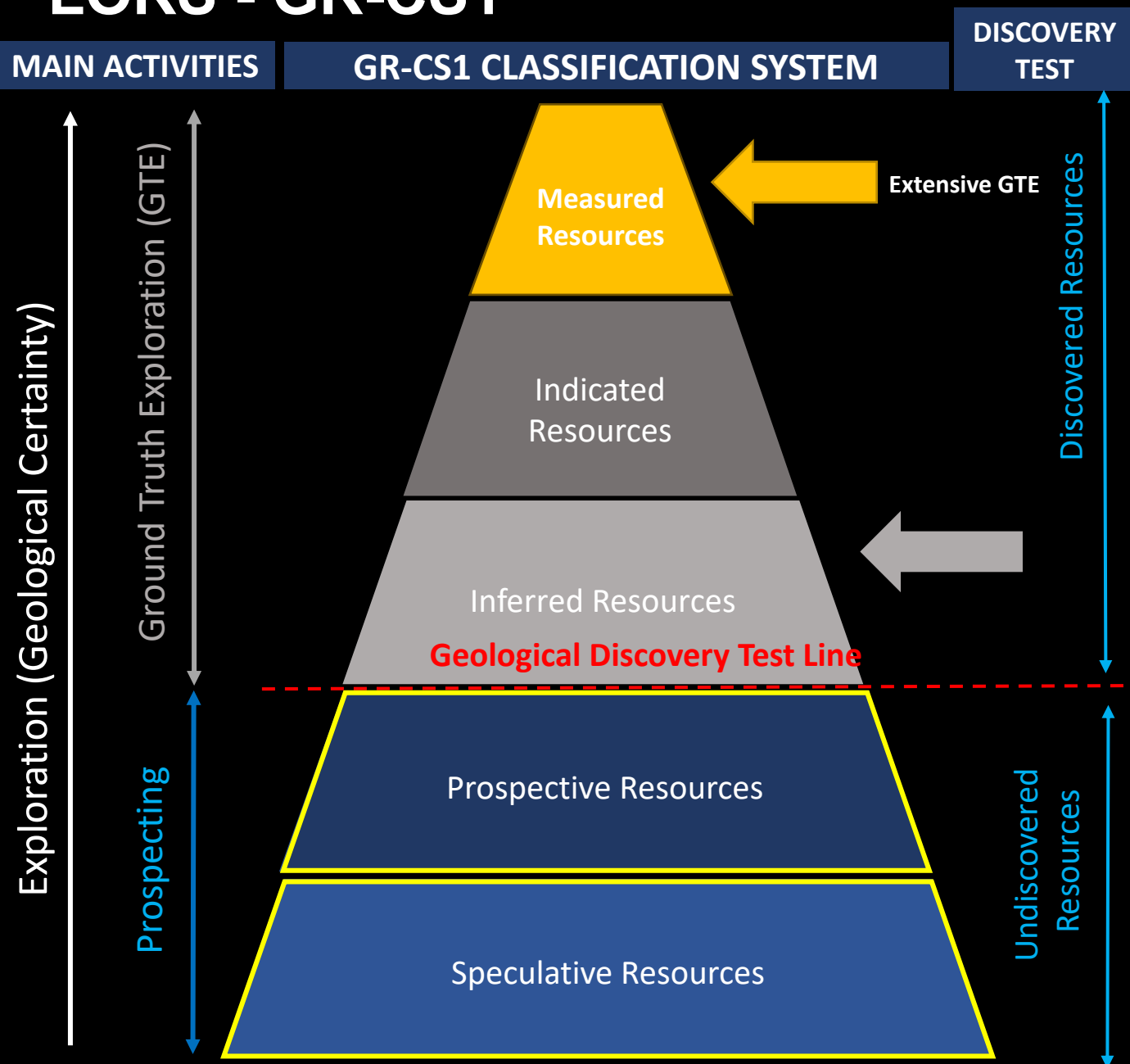
# **Measured/Indicated Resources?**

---

➤ Practical Example



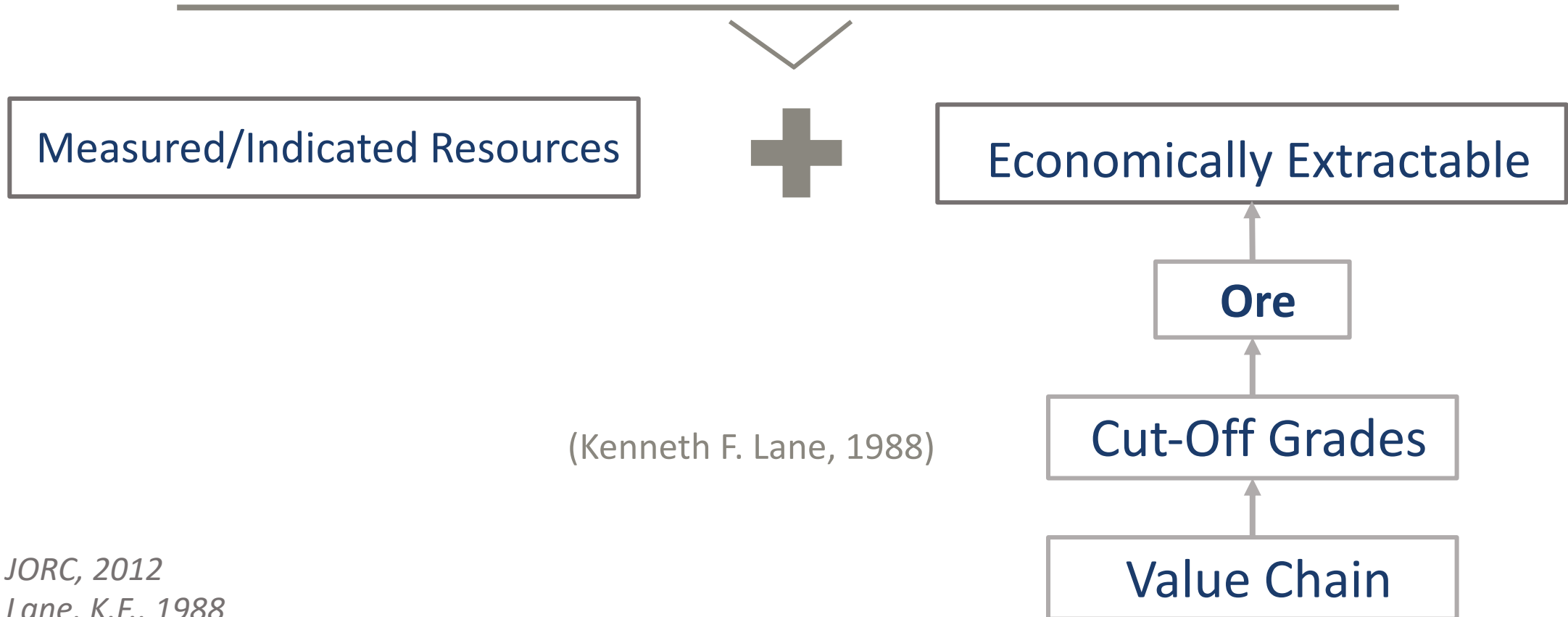
# LORS - GR-CS1



**Standards for report  
Exploration Results**



# Reserves



(Kenneth F. Lane, 1988)

- JORC, 2012
- Lane, K.F., 1988
- LORS, 2023



# Cut-Off Grades for Lunar Helium-3

---

## ➤ Two SRU Lunar Operations

*Same region (mare)/regolith, 2 different strategies*

1

He3 (only) Mine

2

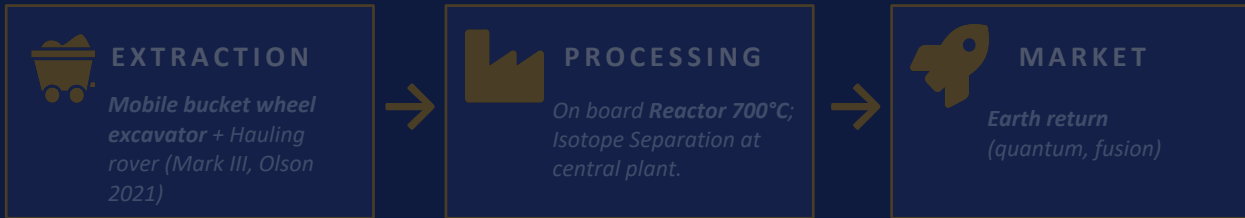
LOX Mine with He3 (byproduct)

# TWO OPERATIONS, TWO COG STRATEGIES

Same regolith, different value chain, different COG

## CASE A | He-3 (only) Mining Operation

Asks: At what **He-3 grade** (ppb) does the **operation pay**?



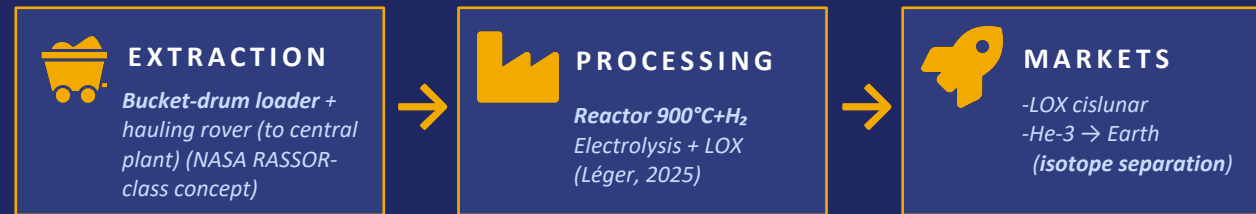
### ASSUMPTIONS

He-3 price	\$22,290/g (market Price)
Throughput	670,000 t/yr regolith
Recovery	75% @ 700°C reactor

Additional references: Schmitt 2005, Sviatoslavsky 1986

## CASE B | LOX-Led Operation (He-3 byproduct)

Asks: At what **oxygen wt%** does **LOX pay**? **He-3** is added **credit**.



### ASSUMPTIONS

LOX price	\$2,500/kg (cislunar)
Throughput	670,000 t/yr regolith
LOX yield (Mare)	24% (beneficiation and reactor)
He-3 byproduct	95% recovery

Additional references : Schreiner 2018, Schmitt 2005

**Methodological note:** We do not claim one case is “correct.” We show how COG analysis answers different strategic questions for each.



# CASE A | HE-3 MINING OPERATION

COG analysis: at what He-3 grade mining pays?

He3 (ppb)	Reference	Net Value (\$/t)	
1	Hypothetical low	-\$3,128	✗
11.8	Apollo 11 (Hintenberger)	-\$3,020	✗
20	Schmitt 2005 reference	-\$2,939	✗
100	8 × Apollo 11 (rare)	-\$2,144	✗
200	17 × Apollo 11	-\$1,149	✗
316	BREAKEVEN	\$0	○
474	1.5× breakeven	+\$1,569	✓
600	Hypothetical very rich	+\$2,825	✓

## ECONOMIC COG ASSUMPTIONS

Mining (m)	\$677/t
Treatment (c)	\$2,461/t
m + c total	\$3,138/t
Refining (r)	\$9,040/g
He-3 price (P)	\$22,290/g
Recovery	75% @ 700°C

## COG (Strategy 1)

**316 ppb** > RESERVES

≈ 27× Apollo grade — not realistic

# CASE B | LOX OPERATION + HE3 BYPRODUCT



COG analysis: at what O2 grade mining pays?

## Reference

O <sub>2</sub> wt%	Ilmenite %	LOX NV (\$/t)	He-3 ppb range	He-3 credit (\$/t)
0.10%	1.0%	-\$2,916	1.0 – 2.0	+\$11 to +\$22
0.30%	2.9%	-\$2,138	2.9 – 5.7	+\$31 to +\$62
0.50%	4.8%	-\$1,361	4.8 – 9.5	+\$51 to +\$103
0.70%	6.7%	-\$583	6.7 – 13.3	+\$72 to +\$143
0.80%	7.6%	-\$195	7.6 – 15.2	+\$82 to +\$163
0.85%	8.1%	\$0 ◀ LOX COG	8.1 – 16.2	+\$87 to +\$174
1.00%	9.5%	+\$583	9.5 – 19.0	+\$102 to +\$204
1.05%	10.0%	+\$777 ◀ Mare High-Ti	10.0 – 20.0	+\$107 to +\$214
1.275%	12.1%	+\$1,652	12.1 – 24.3	+\$130 to +\$260
1.50%	14.3%	+\$2,527	14.3 – 28.6	+\$153 to +\$306
2.00%	19.0%	+\$4,470	19.0 – 38.1	+\$203 to +\$408

Mare High-Ti basalts (1.05%) clear this easily

## ECONOMIC COG ASSUMPTIONS

LOX price (P)	\$2,500/kg
Treatment (c)	\$2,628/t
m + c total	\$3,305/t
Realization r_LOX	\$862/kg LOX
Mining (m)	\$677/t
LOX yield (beneficiation + reactor)	24%

## COG (LOX-led)

8.1% Ilmenite  
> RESERVES

Sources & assumptions: He-3 ppb estimated as ilmenite % × 1.0 – 2.0 (range anchored to Apollo 11 ≈11.8 ppb at ~10% ilmenite, Hintenberger 1970; and Schmitt 2005 high-Ti Mare reference ≈20 ppb). He-3 credit at 48% net recovery (51% beneficiation × 95% release at 900°C). LOX yield 2.5 kg/t @ 1.05% O<sub>2</sub> from Léger 2025 (51% × 47% net process recovery). Real ilmenite ↔ He-3 correlation may be sub-linear.

# DIFFERENT COG->DIFFERENT SCALES OF MINING

COG will define your moved tonnages

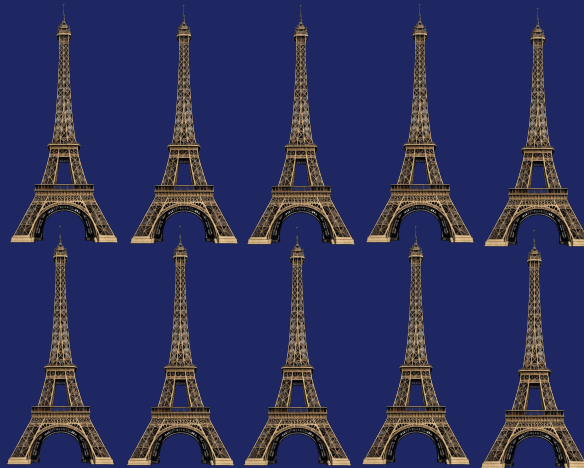
COG 11.8 ppb(He3) @75% yield | Apollo 11

for every 1 KG of He-3

**113,000** tonnes of regolith

11 X Eiffel Towers  
(by mass)

Hintenberger 1970

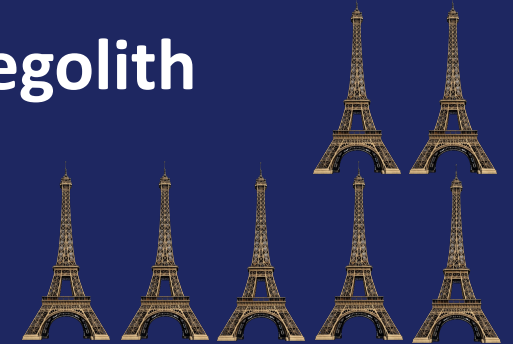


COG 20 ppb | Schmitt 2005

1 kg He-3 = **67,000 t** regolith

7 x Eiffel Towers

High-Ti Mare basalts



COG 316 ppb | Breakeven Case A

1 kg He-3 = **4,220 t** regolith

≈ ½ Eiffel Tower

27× Apollo grade



This is why **COG matters** — not all 113,000 tonnes are economic, and the answer depends on the strategy.



# For Space Miners and Governments: “What is your Cut-Off Grade?”

Carlos D Espejel | Founder & CEO

# Types of Cut-Off Grades (COG)

---



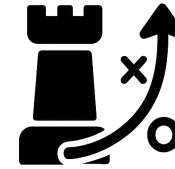
## Economic COG

Used for commercial mining projects/operations.



## Technical COG

For non-commercial mines (e.g., operating a grand science base).



## Strategic COG

National / Defense, as long-term positioning.