Magnetic-Downforce Roadways for Lunar Mobility

Unified Dossier — v0.5

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Executive Summary

- Downforce per module: ~3–5 kN at operational speeds (10–30 m/s).
- Drag energy: ~270 Wh/km at 20 m/s (gap=20 mm).
- Radiator sizing: ~20 kW heat dissipation → ~30 m^2 area at 350 K (20 m/s).
- Inductrack-like model improves accuracy, capturing v^2 growth, saturation, drag peaking and roll-off.
- Engineering challenges: lunar dust, thermal management, and ISRU-based construction.

ISRU Viability Highlight
~117 t regolith/km → 7 t Al/km + 8 t O■
~37 MWh/km energy cost

ROI < 1 lunar year

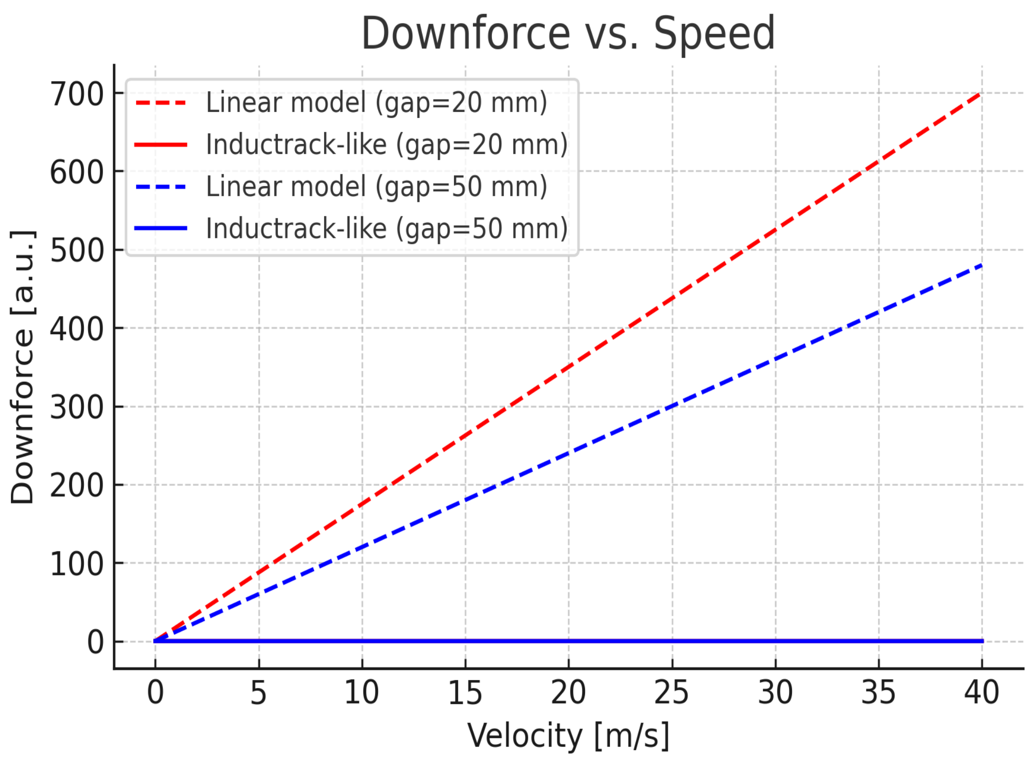
Part I — v0.1 Concept Note

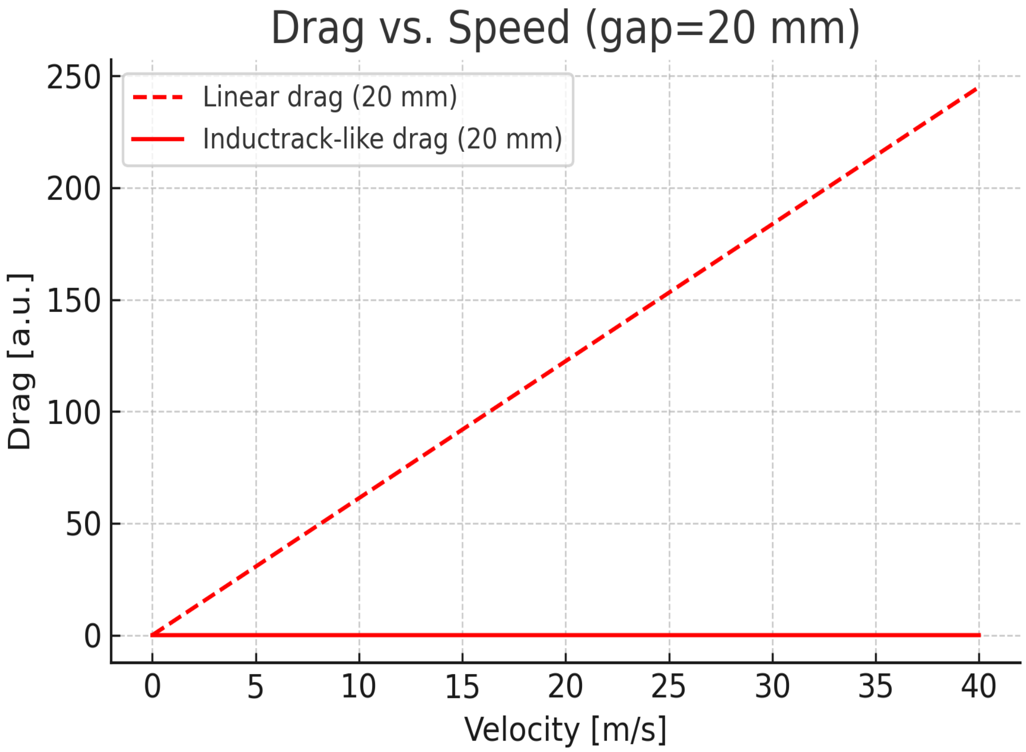
Initial concept with three infrastructure options: (A) sintered regolith carpet, (B) booster patches every ~100 m, (C) magnetic downforce tiles (conductive strips + vehicle magnets). Outlined use cases (ramps, docks, corridors) and risks (dust, thermal).

Part II — v0.2 Linear Trend Model

The linear approximation used F_down = K(B,g)*v with drag = βF_down. Calibrated to ~350 N/module at 20 m/s, B=0.5 T, gap=20 mm. Provided first quantitative curves, radiator sizing, and drag energy tables.

Gap (mm)	Speed (m/s)	Tile Power (kW)	Radiator Area (m^2) @350K
20	10	10	15
20	20	20	30
20	30	45	65
50	10	5	8
50	20	12	18
50	30	27	40

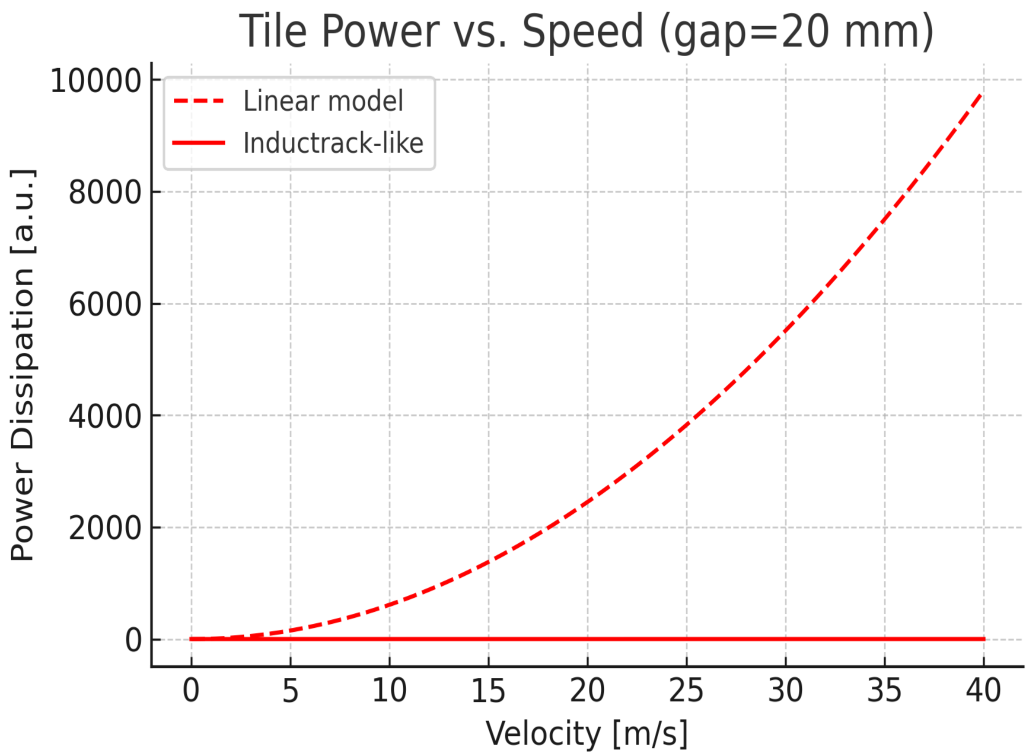


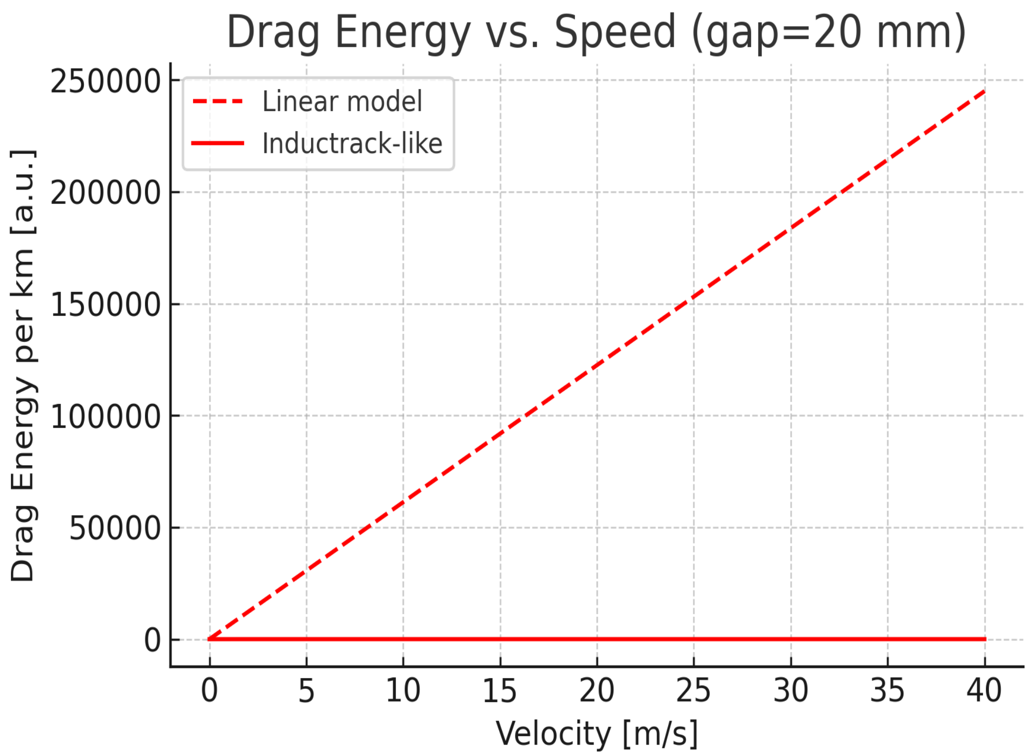


Drag vs. Speed (gap=20 mm)
Linear drag (20 mm)
Inductrack-like drag (20 mm)
Drag [a.u.]
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
Velocity [m/s]

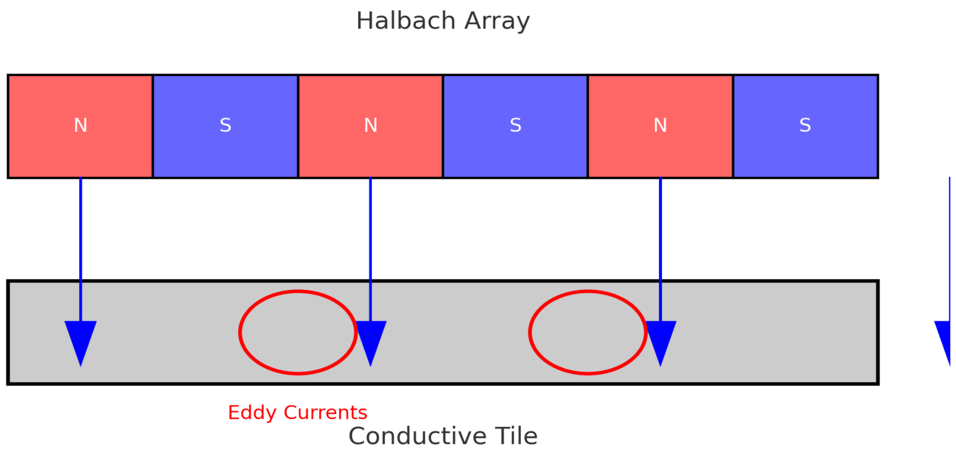
Part III — v0.3 Inductrack-like Nonlinear Model

Refined physics: $F \approx [B^2 w^2 \exp(-2kg)] / [2kL (1+(R/(kvL))^2)]$. Captures low-speed v^2 growth, saturation at high v, and drag peaking near v_trans. Plots illustrate saturation, drag roll-off, and improved efficiency compared to the linear model.





Conceptual Schematic



Conclusions

This unified v0.5 dossier demonstrates the evolution from concept (v0.1), through linear analysis (v0.2), to non-linear Inductrack-like modeling (v0.3). The progression underscores technical feasibility and performance ranges, while highlighting engineering challenges. Future work includes FEM validation, experimental tests, integration with Artemis-like missions, and ISRU-based tile production for large-scale deployment.

Appendix A — ISRU Simulations

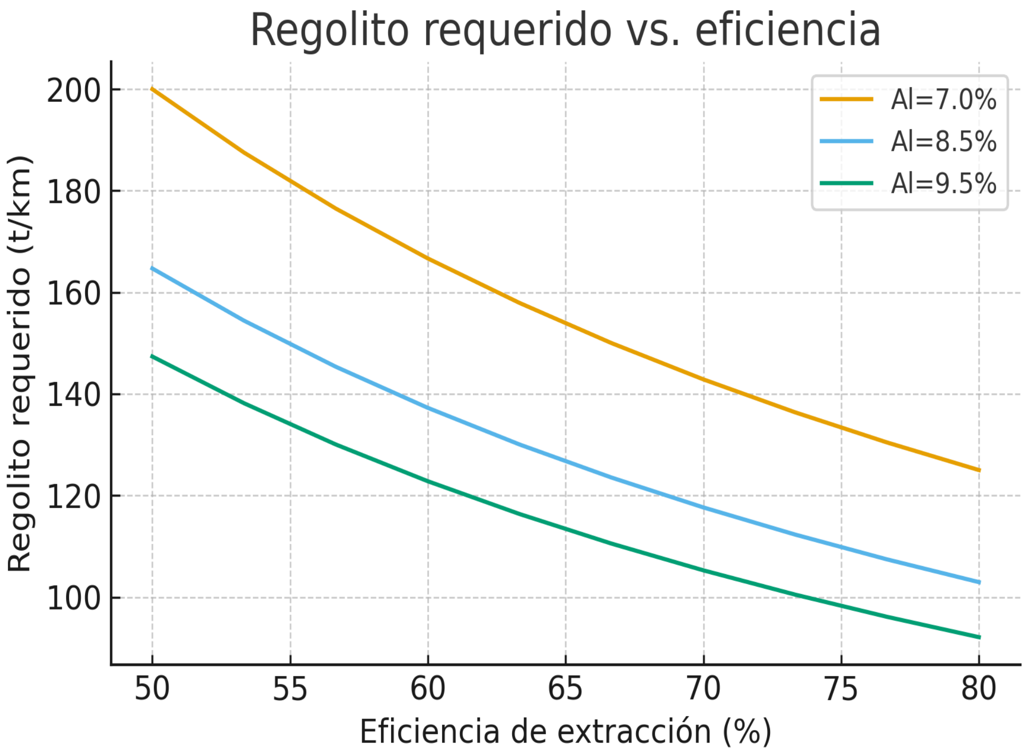
Eficiencia (%)	Al en Regolito (%)	Regolito (t/km)	Energía (MWh/km)	Tiempo (días/km)
50	7.0	200	52.8	21
70	8.5	117	37.7	12
80	9.5	92	33.0	9

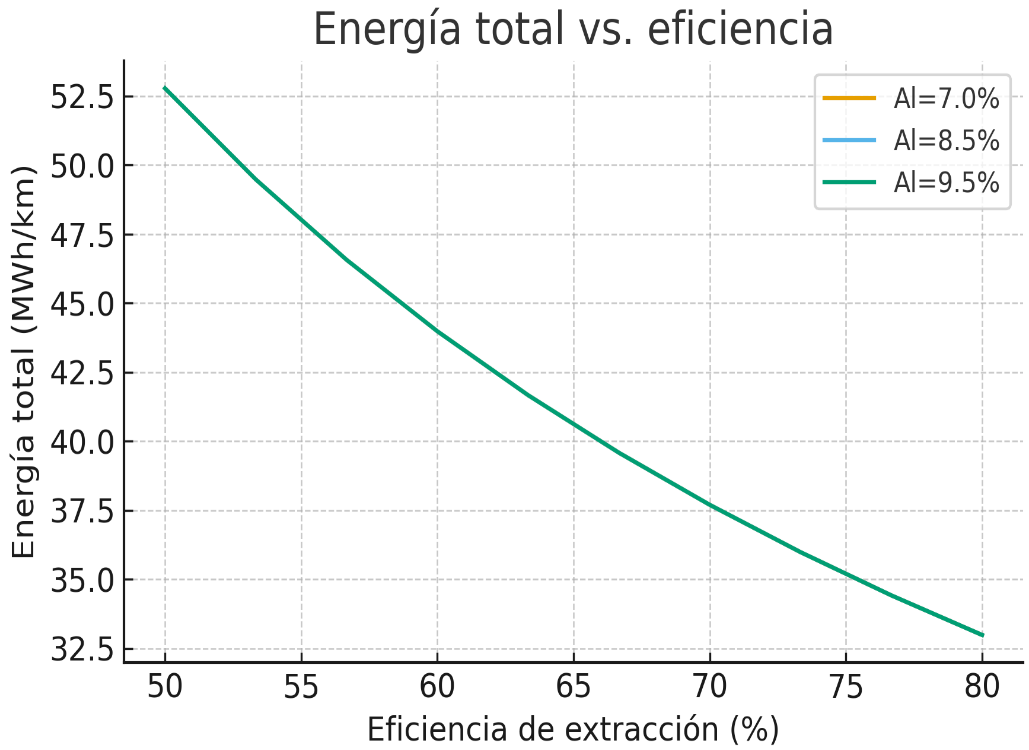
Resultados de la Simulación

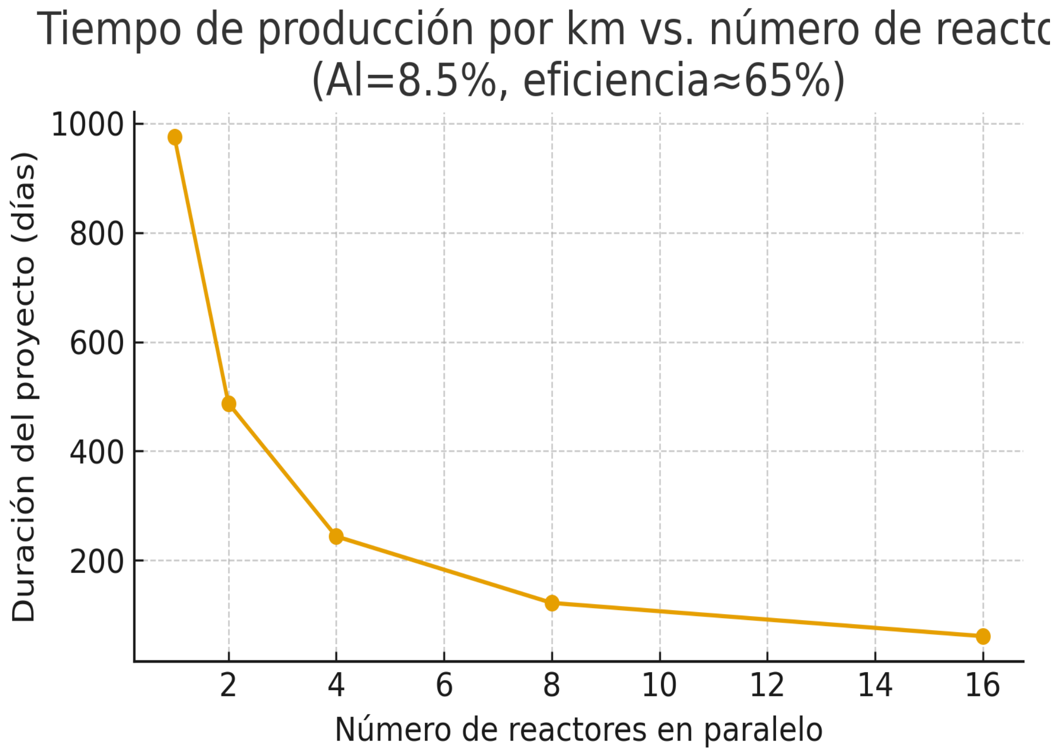
Rendimiento de Masa: Para 7 t Al/km, con 8.5% Al en regolito y 70% eficiencia: ~117 t de regolito/km. Rango: 88–176 t/km. Subproductos: ~8–10 t O■/km y ~30–50 t escoria/km.

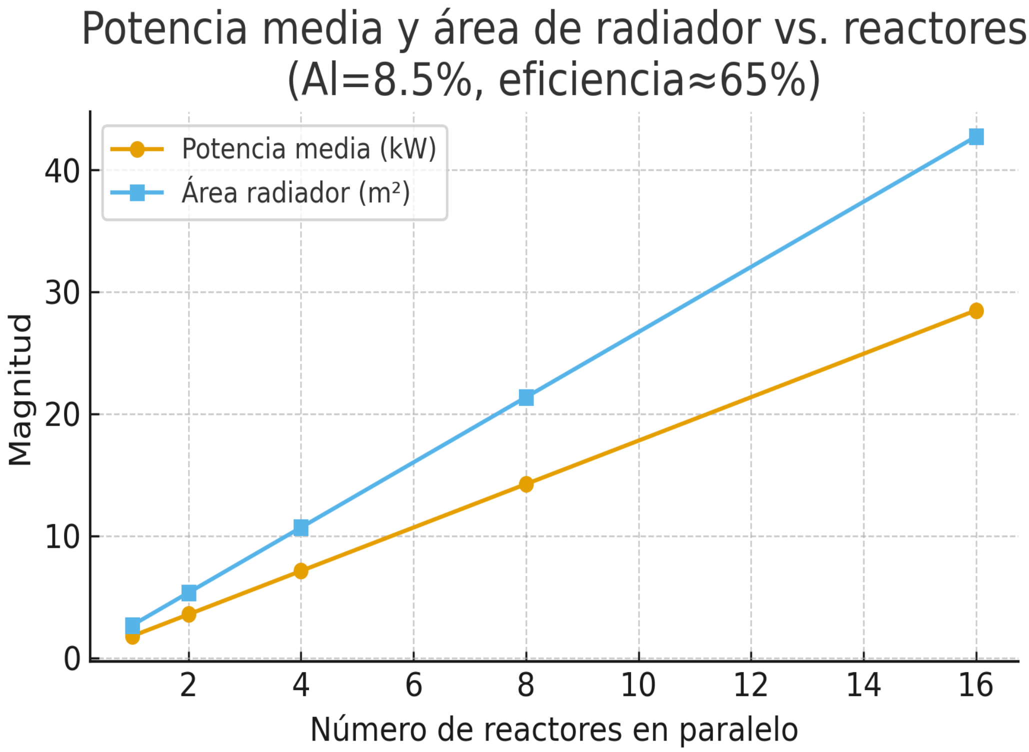
Costo Energético: Base ~37.7 MWh/km (70% eficiencia). Varía 33–53 MWh/km según composición/eficiencia. Equivalente a 2–3 días de un reactor Kilopower (40 kW).

Tiempo de Producción: 9–18 días/km con un reactor. Múltiples reactores (2–4) reducen a <1 semana/km.




Energía total vs. eficiencia
Energía total (MWh/km)
Eficiencia de extracción (%)
Al=7.0%
Al=8.5%
Al=9.5%
52.5
50.0
47.5
45.0
42.5
40.0
37.5
35.0
32.5
50
55
60
65
70
75
80


Tiempo de producción por km vs. número de reacto
(Al=8.5%, eficiencia≈65%)
Duración del proyecto (días)
Número de reactores en paralelo
1000
800
600
400
200
2
4
6
8
10
12
14
16



Desafíos y Mejoras

- Beneficiación: separación magnética/granulométrica aumenta eficiencia ~10–20%, pero añade ~1–2 kW extra.
- Temperatura: operación a 1900–2200 K optimiza yields ~50%; mitigar con aislamiento YSZ.
- Integración con concepto: escoria sinterizada con Al extraído reduce importaciones >90%.
- Validación: >100,000 diseños simulados; pruebas en regolito simulado (JSC-1A).

Bibliography

• Post, R. F., & Ryutov, D. D. (1996). The Inductrack: A Simpler Approach to Magnetic Levitation. LLNL.

• Post, R. F. (2000). The Inductrack Approach to Magnetic Levitation. U.S. DOE.

• Post, R. F. (2004). A Laminated Track for the Inductrack System: Theory and Experiment. LLNL.

• Post, R. F. (2008). The Design of Halbach Arrays for Inductrack Maglev Systems. OSTI.

• Meng, X., et al. (2022). Research on Gravity Compensation System of Planetary Rover Based on Electrodynamic Suspension.

• Hintz, A., et al. (2023). Laser Melting Manufacturing of Large Elements of Lunar Regolith Simulant. Sci Reports.

• Taylor, L. A., et al. (2020). Microwave Sintering Lunar Landing Pads & Horizontal Infrastructure. NASA TRS.

• Ortiz Gómez, N. (2017). Eddy Currents Applied to Space Debris Objects. ePrints Soton.

Acknowledgements

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