

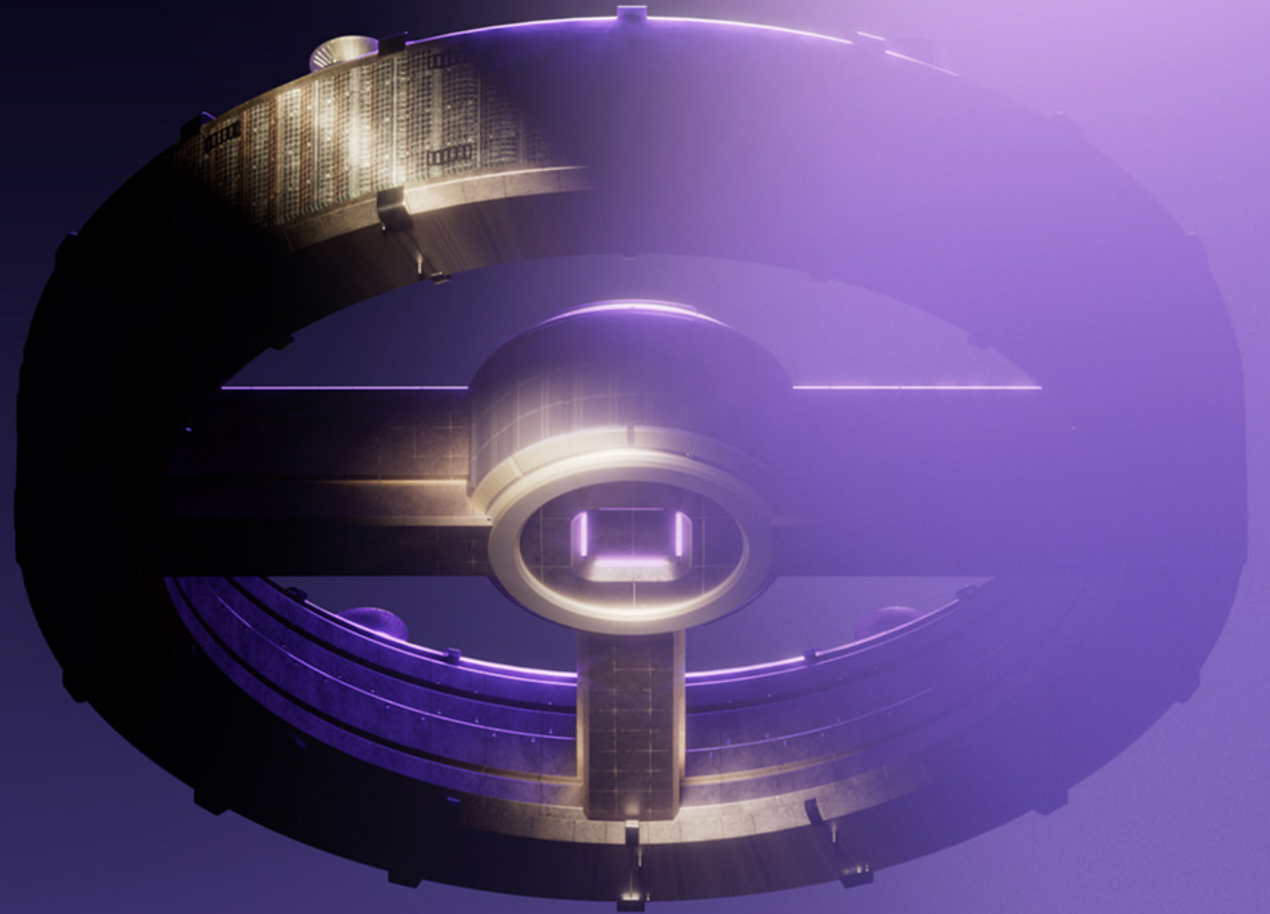
TURION

STARFORGE

A System Architecture for Scalable
Precious-Metal Asteroid Refining

Turion Space | Colorado School of Mines · Space Resources Roundtable

May 2026



Confidential & proprietary information of Turion Space Corp. Architecture overview only — excludes targets, schedule, and economics.

Turion Space

A space-infrastructure prime, building flight hardware, autonomy and orbital operations in-house with capital discipline.

2021

FOUNDED

~215

EMPLOYEES

2

OPERATIONAL
SATELLITES

30+

USG CONTRACTS

Heritage in autonomy, manufacturing, sensing, maneuver and in-orbit operations. Today performing on two of the most consequential U.S. space programs — RG-XX / Andromeda and SBI / Golden Dome — with the engineering depth we now extend toward off-Earth resource extraction.

***Operating principle:** every capability stands alone, maps to a real customer, and is validated terrestrially before it scales to space.*

Refining PGMs off-Earth will be hard

01

No resupply

Acids, oxidants and reagents cannot be shipped on a steady cadence. Once processing begins, the chemistry must regenerate its own consumables.

02

Microgravity breaks unit ops

Settling, slurry transport, flotation and distillation all assume gravity. Re-inventing each as a zero-g process is years of orthogonal R&D.

03

Mass is the budget

The refinery has to be compact, autonomous, and self-sustaining, and the ore must be refined to high purity to offset transport costs.

Two bets let us adapt proven refining technology

BET 1

Spin to 1 g

A rotating torus recreates Earth-equivalent gravity inside the refinery — so modified commercial comminution, separation and leach equipment works without decades of zero-g machine R&D.

BET 2

Close every loop

Water, sulfuric acid and the halide oxidant are regenerated in situ. After startup, the process imports only trace makeup mass from Earth.

***The thesis:** adapt a proven terrestrial process — don't invent an orthogonal one.*

Portfolios

Tactical Space

Rendezvous proximity operations-enabled space domain awareness and combat operations in LEO and GEO.

Defense Programs: Andromeda (RG-XX, SG-XX), Space RCO Combat Ops

Commercial Applications: Inspection as-a-service, payload hosting, insurance offering

Geospatial ISR

Long-wave infrared hyperspectral sensing for all-weather GEOINT and chemical detection, plus missile warning / tracking.

Defense Programs: Army/DTRA CWMD, HALO Deimos, SDA Tranche 4/5

Commercial Applications: Oil & gas methane detection, utilities vegetation management, commodities trading

Space Logistics

Orbit transfer vehicles with refueling capability for moving assets from LEO to GEO, refueling shuttle infrastructure, and de-orbiting

Defense Programs: SML OTA, NSSL, RG-XX Shuttle

Commercial Applications: Commercial OTV and refueling service

Mineral Processing

Closed-loop, autonomous, modular bioleaching/hydrometallurgy refining platform

Defense Programs: National Critical Minerals stockpile

Commercial Applications: Mine remediation, tailings processing

Mission Software

Mission control and astrodynamics software for constellation C2, automated tasking, and mission planning / execution.

Why LL chondrites

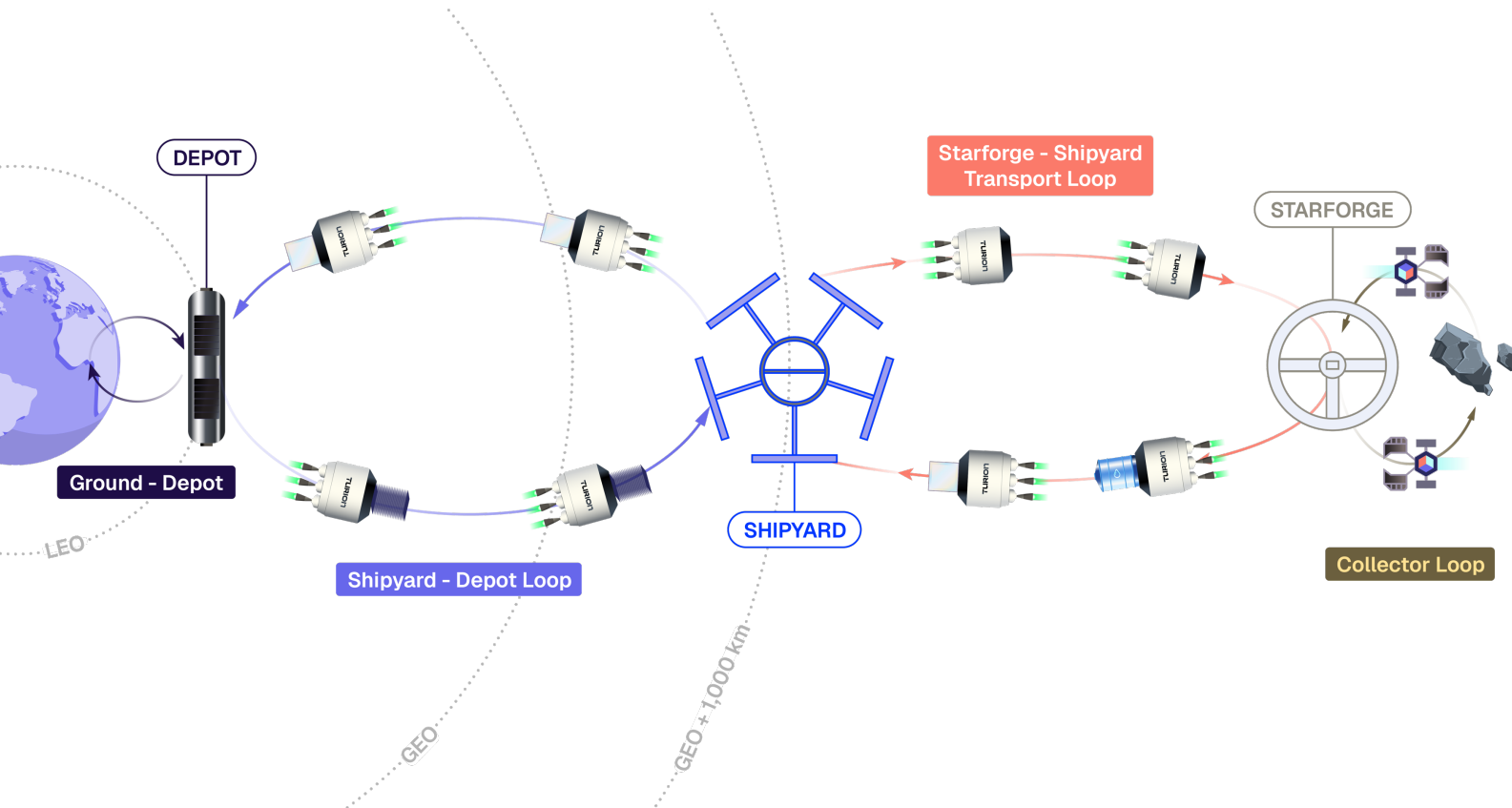
- **Easier comminution** Shock- and impact-brecciated aggregates — already “pre-crushed,” unlike monolithic Fe-Ni bodies that need massive cutting energy.
- **Consistency over grade** Low total metal (~1–5%), but that fraction is strongly PGM-enriched (~50–220 ppm) and repeatable — ore-like, not jackpot.
- **Embedded volatiles** A few percent bound water in hydrated phases — liberated and looped as the process medium. M-types are bone-dry.
- **Abundant & accessible** S-complex bodies are ~⅔ of the NEA population — a broad portfolio of low-ΔV targets.

MAJOR LL CHONDRITE MINERALS

Mineral	Formula	vol %
Forsterite (olivine)	Mg ₂ SiO ₄	~38
Fayalite (olivine)	Fe ₂ SiO ₄	~12
Enstatite (opx)	MgSiO ₃	~18
Ferrosilite (opx)	FeSiO ₃	~7
Plagioclase	(Na,Ca)...	~10
Troilite	FeS	~6

Troilite (FeS) is the acid feedstock; PGMs ride in the minor metal/sulfide fraction.

System Architecture



Steady-state operational architecture: Ground-Depot, Shipyard-Depot, Starforge↔Shipyard transport, and Collector loops.

■ Ecliptic-aligned staging

Shipyard sits just above GEO, inclined to the ecliptic — minimizing ΔV to the NEA population.

■ LEO Depot stages construction

Folded sections and equipment transit through a LEO depot, then up to the Shipyard.

■ Modular in-space assembly

Autonomous DROIDS grapple, weld and integrate Ti-6Al-4V plate sections in parallel at the Shipyard.

■ ISRU propellant closes the loops

Water at the asteroid \rightarrow H_2/O_2 ; fuels the Collector and the Starforge↔Shipyard / Shipyard↔Depot loops.

■ REFINING PROCESS

One spinning structure, four integrated subsystems

A rotating Ti-6Al-4V ring under 1 g, with refining processes distributed around the circumference.

1 ISRU water generation

Microwave dielectric heating liberates bound water to bootstrap the process.

2 Primary refining line

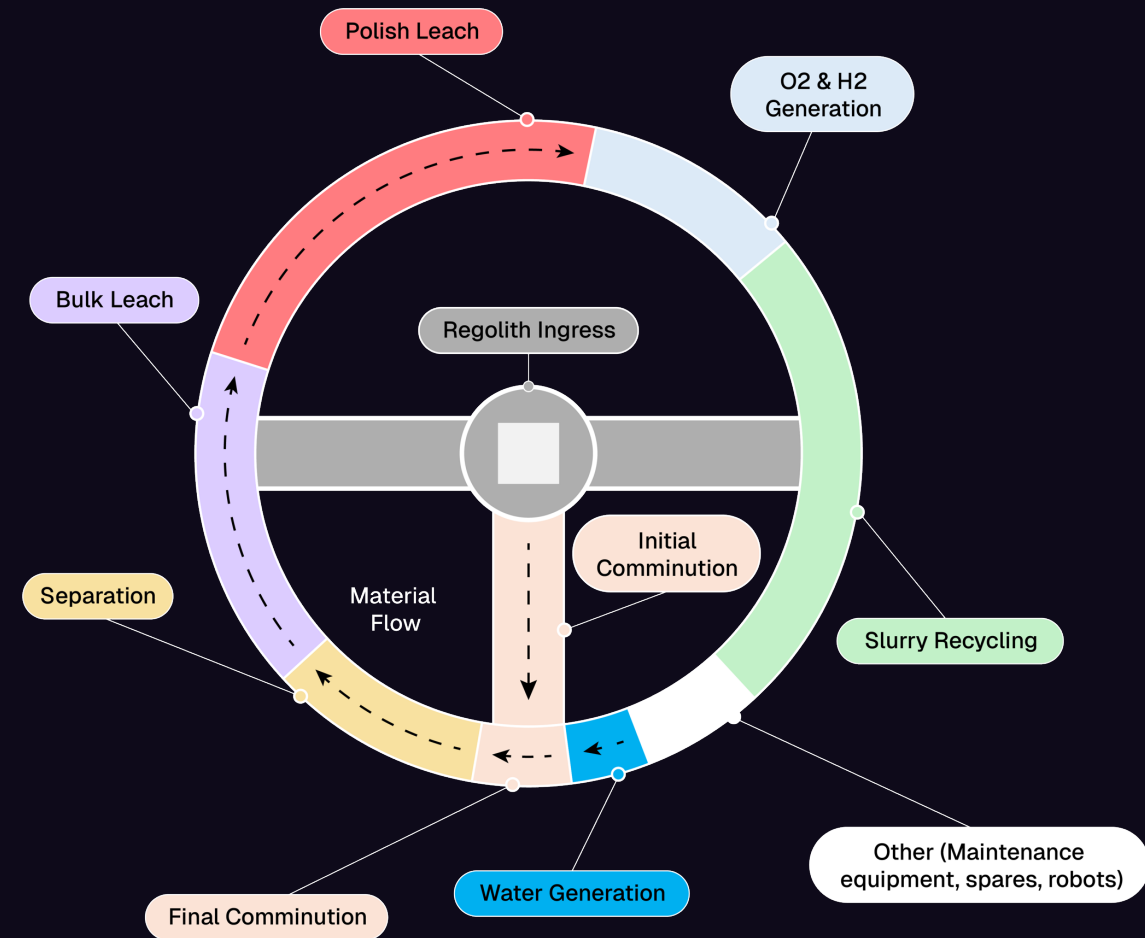
Comminution & separation → leach & distillation under 1 g.

3 O₂ / H₂ electrolysis

Oxidant for bioleach; propellant for the transport loops.

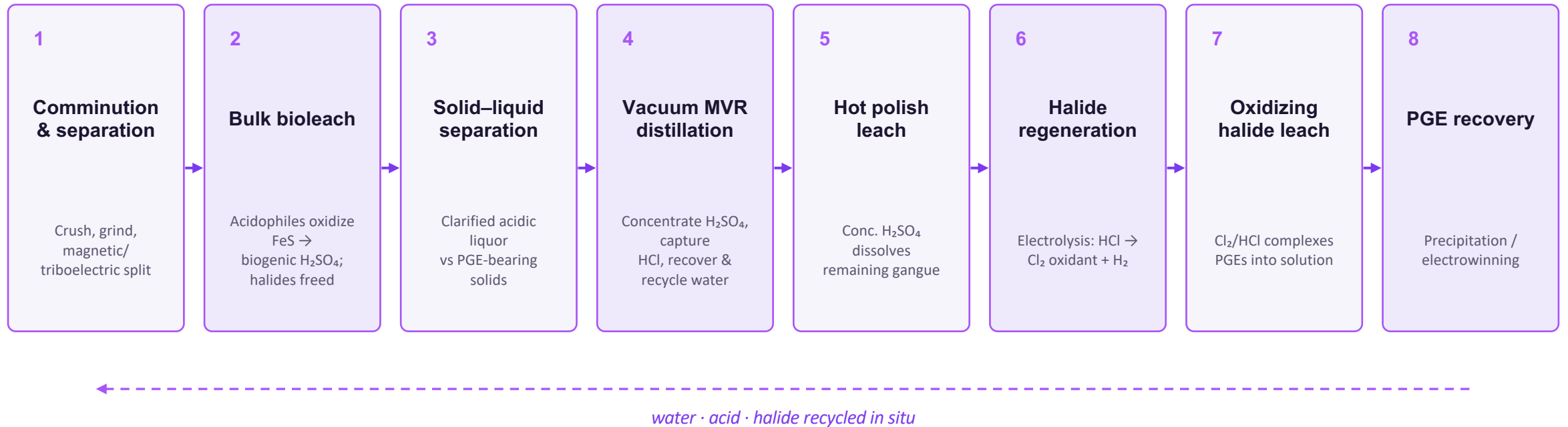
4 Slurry & water recycling

Recovers water and reagents from tailings to keep the loop closed.



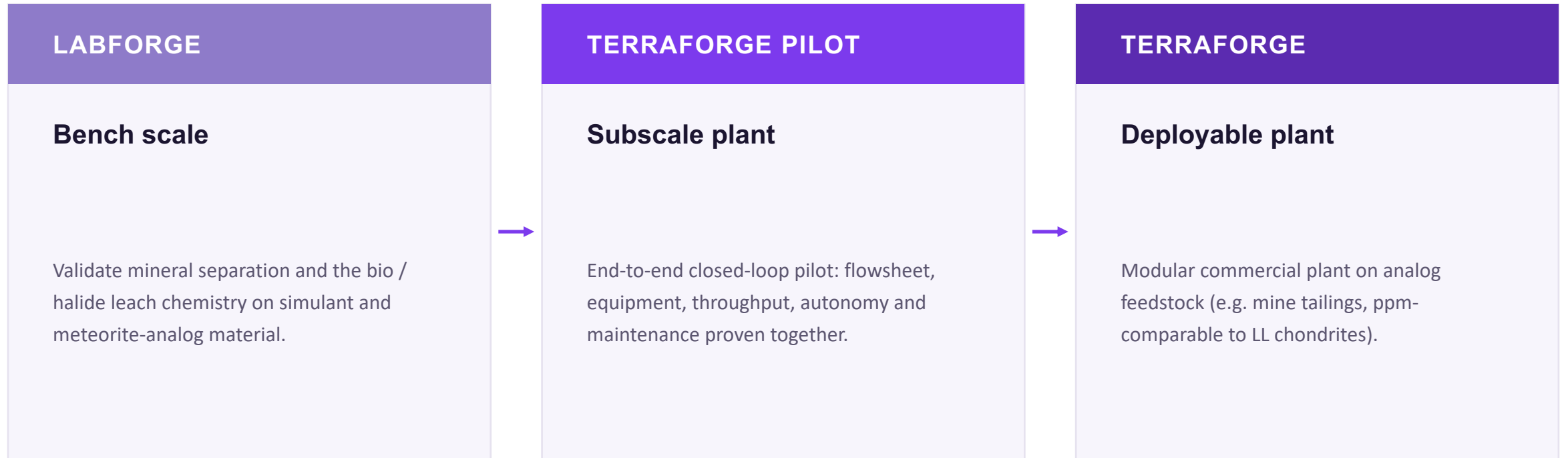
Refining processes arranged as physical zones around the ring.

A consumable-free leach cycle



Bacteria make the acid; distillation + electrolysis regenerate the oxidant; water is recovered — only trace makeup mass from Earth.

We prove the same flowsheet on Earth first



Same closed-loop process, terrestrial proving ground. Generates revenue, operating data and process maturity before anything flies.

What we are still de-risking

Composition uncertainty

Remote sensing sees only the exterior; rubble-pile bodies can vary boulder to boulder. Grade and volatile content carry real error bars until direct sampling.

Separation under spin gravity

Settling and separation efficiency at induced g may differ from true 1 g — a key parameter for the first refining campaign.

Microbial robustness

Acidophile viability, adaptive evolution under site conditions, and contamination control across long autonomous operation.

Long-duration autonomy

Modified COTS equipment needs robotic maintenance, redundancy and spares with no resupply once at steady state.

Adapt proven hydrometallurgy. Close every loop. Prove it on Earth, then scale to space.

Scaling and replication are future work — out of scope today. Happy to go deep on chemistry, the spin-gravity assumption, or the energy budget.

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Thank you · Questions



Nothing critical is consumed

ACID

Biogenic

H_2SO_4 generated in situ from
FeS oxidation by acidophiles

OXIDANT

Regenerated

$\text{Cl}^- / \text{Cl}_2$ halide redox closed
electrochemically

WATER

Recovered

Vacuum MVR distillation
returns process water to reuse

OXYGEN

Electrolytic

From water splitting — feeds
bleach and propellant

Vacuum MVR Distribution

Three-zone column recovers water, concentrates H₂SO₄, and captures hydrogen halides — all in one staged vapor path under reduced pressure.

INPUTS / OUTPUTS

In: clarified sulfate—halide liquor from solid—liquid separation

Out: water (recycled) • conc. H₂SO₄ (→ polish leach) • HCl/HF(aq) (→ halide regen)

STAGED VAPOR PATH

Zone 1 Heated; water evaporates; H₂SO₄ concentrates in the liquor

Zone 2 Intermediate condensation; water collected and returned to process

Zone 3 Cool capture region; hydrogen halides condensed or absorbed

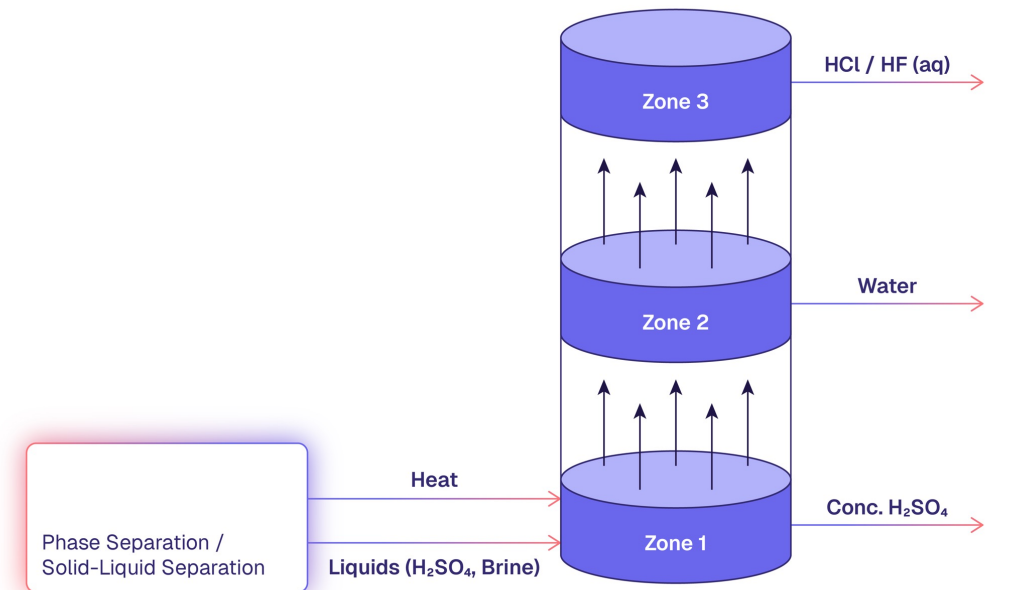
WHY MVR

Mechanical Vapor Recompression recycles the latent heat of vaporization — net energy on the order of 5 x lower than single-pass distillation. Largest single power load in the refinery.

OPEN TRADES

Hickman-type collectors • wetted-wall surfaces • capillary structures • microchannel HX
• direct-contact (spray) condensation

Schematic Illustration of Distillation System



Vacuum evaporation / distillation subsystem (whitepaper Fig. 6).