

SINGLE-BODY REPORT

16 Psyche

The metal world: what it is worth, what it is not,
and where the investable opportunity really sits



MEAN DIAMETER · METAL FRACTION (INFERRED)

222 km · $\approx 30\text{--}60$ vol% metal

For space-focused venture investors, mining & aerospace corporate strategy,
sovereign space agencies and family offices.

REPORT + VALUATION MODEL (XLSX)

Orbit of 16 Psyche: $a = 2.93$ au, $e = 0.13$, $i = 3.1^\circ$ (JPL).
Planet orbits for scale; orientation schematic.

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*Research product, not investment, legal or engineering advice. Model outputs are illustrative scenarios driven by stated assumptions.
Every factual figure is sourced (Appendix A) and graded MEASURED / INFERRED / SPECULATIVE.*

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How to read this report

Every key figure carries a confidence grade. **MEASURED** means a direct observation or published measurement with stated uncertainty, such as an astrometric mass, a radar albedo, a dated mission event or a government statistic.

INFERRED means a value derived from measurements, either through a published model or through our own transparent arithmetic; examples are metal fraction from bulk density and delta-v from orbital elements.

SPECULATIVE means an assumption, an analogue or an untested extrapolation, such as platinum-group metal grades borrowed from iron meteorites. **PLANNED** marks scheduled future events.

Bracketed numbers such as [6] refer to Appendix A. Figures labelled **SRI calc** are our own arithmetic from cited inputs; the method is stated in Appendix B. Nothing in the valuation section is a forecast. All model outputs are **illustrative scenarios** computed from editable assumptions in the companion workbook *SRI_16Psyche_Valuation_Model_SAMPLE.xlsx*.

Sample edition. This document shows the format, sourcing standard and analytical depth of a Space Resource Intelligence single-body report. It is not tailored to any reader's mandate, and it does not recommend any security, company or transaction.

PART I

The metal world, measured

222 km

volume-equivalent diameter (measured). Sections 1–4: summary and thesis, key figures, physical profile, NASA mission status.

Every figure is graded MEASURED, INFERRED, SPECULATIVE or PLANNED and traced to a numbered source.

SECTION 1

Executive summary & investment thesis

Thesis in one line: for the rest of this decade, 16 Psyche is the most important *information asset* in space resources. As a *mining asset*, it is close to worthless on any horizon an investor can underwrite. Position for the data, not the ore.

What it is. 16 Psyche is a main-belt asteroid about 222 km across ($278 \times 238 \times 171$ km). Its mass is about 2.40×10^{19} kg and its bulk density $4,172 \pm 145$ kg/m³ [4][5][6] **MEASURED**. That is dense for an asteroid but only about half the density of solid iron-nickel. The most likely explanation is a mix of metal, rock and pore space. The mission science team's 2020 pre-flight assessment put it at roughly 30–60 vol% metal [7] **INFERRED**. A 2026 study sets the 95%-confidence floor at ≥ 16 vol% [10] **INFERRED**.

Why now. NASA's Psyche spacecraft launched on 13 October 2023 and completed its Mars gravity assist on 15 May 2026 [1][2]. Since 28 September 2026 it has been thrusting almost continuously, on course to enter orbit in August 2029 for a prime mission of about two years [1][3] **MEASURED** / **PLANNED**. Its gamma-ray and neutron spectrometer, magnetometers, imagers and gravity investigation are designed to measure Fe and Ni abundance. They should also tell a stripped core from a metal-silicate mixture or a reduced primitive body [7]. Between 2029 and 2031, the key inputs to every metal-asteroid business plan move from inferred to measured.

What it is not. The widely repeated “\$10,000 quadrillion” ($\approx \$10^{19}$) valuation is a 2017 back-of-envelope estimate: mass multiplied by metal market prices. The mission's principal investigator, who produced it, calls it “meaningless in every way”. No technology exists to bring the metal back, and doing so “would immediately render metals valueless on the markets” [27][28]. Our arithmetic agrees. Even at the lowest plausible metal fraction, Psyche contains about 3.8 million years of current world crude-steel output (Figure 6.1) **INFERRED**.

Where value actually sits. Asteroid metal is economic only where it is used: in space. There, the price ceiling is the cost of launching the same mass from Earth. Today that is $\sim \$1.4\text{k} - \$2.7\text{k/kg}$ to LEO on Falcon Heavy and Falcon 9 (2018 dollars), and $\sim \$7\text{k/kg}$ on published rideshare [22][23]. On Earth, iron ore is $\sim \$0.10/\text{kg}$ and nickel $\sim \$15/\text{kg}$ [25] **MEASURED**. Psyche orbits ~ 2.9 au from the Sun. An idealised impulsive transfer needs on the order of 10 km/s each way from LEO (SRI calc) **INFERRED**, and NASA's own electric-propulsion cruise takes ~ 5.8 years one way [1]. Psyche is the wrong place to supply cislunar demand. Accessible near-Earth M-type bodies are the logical first targets, and Psyche's data will re-rate that whole class, up or down.

SRI view: the thesis, and what would make us wrong

THESIS

- 1. Catalyst, not quarry.** Psyche's investable value is informational. The 2029–2031 data will reprice the metal-rich asteroid class, including near-Earth analogues.
- 2. Headline valuations are category errors.** “Mass × spot price” ignores price collapse, extraction cost and transport. The number's own originator rejects it.
- 3. In-space metal is priced against launch.** The relevant value is avoided launch cost, $\sim 10^3$ \$/kg, not the 10^{-1} – 10^1 \$/kg of terrestrial bulk metals. That value falls as launch gets cheaper, which is the sector's central tension.
- 4. At Psyche-like distances, the illustrative economics fail.** In the companion model's base scenario, a Psyche-distance venture needs $\sim \$3.7\text{k/kg}$ of delivered metal to break even, $\sim 2.6\times$ the assumed launch cost. This is a scenario output, not a fact.
- 5. Exposure worth owning over 5–10 years:** characterisation data and analytics, deep-space solar-electric propulsion and low-cost buses, small NEA prospecting, and in-space processing. Structure these as staged, option-like positions. Avoid theses that need bulk metal returned to Earth.

WHAT WOULD MAKE US WRONG

The case for the metal-rich asteroid class would strengthen materially on any of the following.

First: a measured bulk metal fraction near the top of the range, with Ni above ~ 4 wt% (the team's threshold for a core origin [7]), a coherent rather than rubble-pile interior, and large exposed metal provinces.

Second: a confirmed, durable fall in deep-space transport cost.

Third: a first paying customer for in-space structural metal.

A low metal fraction or silicate-dominated surfaces would do the opposite. Section 10 maps each unknown to the observation that resolves it and when it should arrive.

SECTION 2

Key figures at a glance

All values are sourced. The grade column states how much weight each figure can bear in an investment argument.

QUANTITY	VALUE	GRADE	SOURCE
Volume-equivalent diameter	222 (+4/−1) km	MEASURED	Shepard et al. 2021 [5]; JPL SBDB [4]
Tri-axial dimensions	278 × 238 × 171 km	MEASURED	Shepard et al. 2021 [5]
Mass	$(2.40 \pm 0.03) \times 10^{19}$ kg (GM 1.601 ± 0.017 km ³ /s ²)	MEASURED	Farnocchia et al. 2024 [6]; JPL SBDB [4]
Bulk density	4,172 ± 145 kg/m ³	MEASURED	Farnocchia et al. 2024 [6]
Rotation period	4.196 h	MEASURED	JPL SBDB / LCDB [4]
Semi-major axis · eccentricity · inclination	2.92–2.93 au · 0.134–0.135 · 3.1°	MEASURED	JPL SBDB [4]
Perihelion · aphelion · period	2.53 au · 3.32 au · ~5.0 yr (≈1,830 d)	MEASURED	JPL SBDB [4]
Mean radar albedo	0.34 ± 0.08 (local values ~0.22–0.52)	MEASURED	Shepard et al. 2021 [5]
Bulk metal content	~30–60 vol% (2020); ≥16 vol% at 95% confidence (2026)	INFERRED	Elkins-Tanton et al. 2020 [7]; Cambioni et al. 2026 [10]
Surface composition model	82.5% metal, 7% low-Fe pyroxene, 10.5% carbonaceous chondrite	INFERRED	Cantillo et al. 2021 [11]
Surface hydration (JWST)	H ≈ 250–400 ppm; H ₂ O ≤ 39 ppm	INFERRED	PSJ 2024, JWST data [12]
Surface gravity / escape speed	≈0.13 m/s ² / ≈170 m/s (sphere-equivalent)	INFERRED	SRI calc from GM and 111 km mean radius
Ideal Δv, LEO → Psyche rendezvous	≈10 km/s (impulsive Hohmann, circular-orbit approximation)	INFERRED	SRI calc from [4]
NASA mission: launch · Mars assist · arrival	13 Oct 2023 · 15 May 2026 · Aug 2029	MEASURED PLANNED	NASA [1][2][3]
NASA mission life-cycle cost	\$985M incl. launch vehicle (2022 statement)	MEASURED	NASA via PR Newswire [20]
PGM content of Psyche	Unmeasured; analogue only (e.g., Pt 28.8 ppm in 90th-percentile iron meteorites)	SPECULATIVE	Sanchez et al. 2021 citing Kargel [16]
“\$10,000 quadrillion” valuation	2017 back-of-envelope; originator calls it “meaningless”	—	HowStuffWorks interview [27]

Reading the grades: size, mass and orbit are about as solid as remote astronomy gets. Composition is still inferred; it is the largest open variable and the one NASA's mission is built to resolve. Every statement about precious-metal content is speculative today, and may remain so after the mission. Psyche's gamma-ray spectrometer targets H, Fe, Ni, Si, K, S, Al, Ca, Th and U, not platinum-group metals [7].

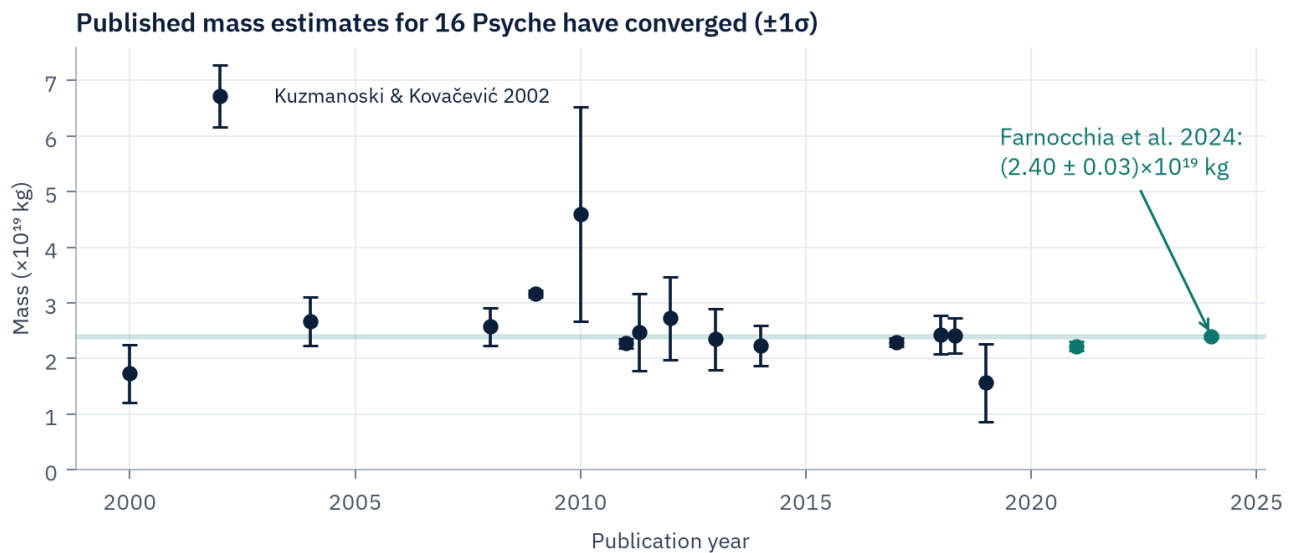
SECTION 3

Physical & compositional profile

Size and shape. Occultations, adaptive-optics imaging and Arecibo radar have converged on an equivalent-volume diameter of ~222 km. The shape is broadly a triaxial ellipsoid of $\sim 278 \times 238 \times 171$ km [5]. The early IRAS estimate (~253 km) was higher because Psyche was seen pole-on at the time, not because the method failed. Several large depressions and craters have been reported, but not all of them appear in every independent shape model [5].

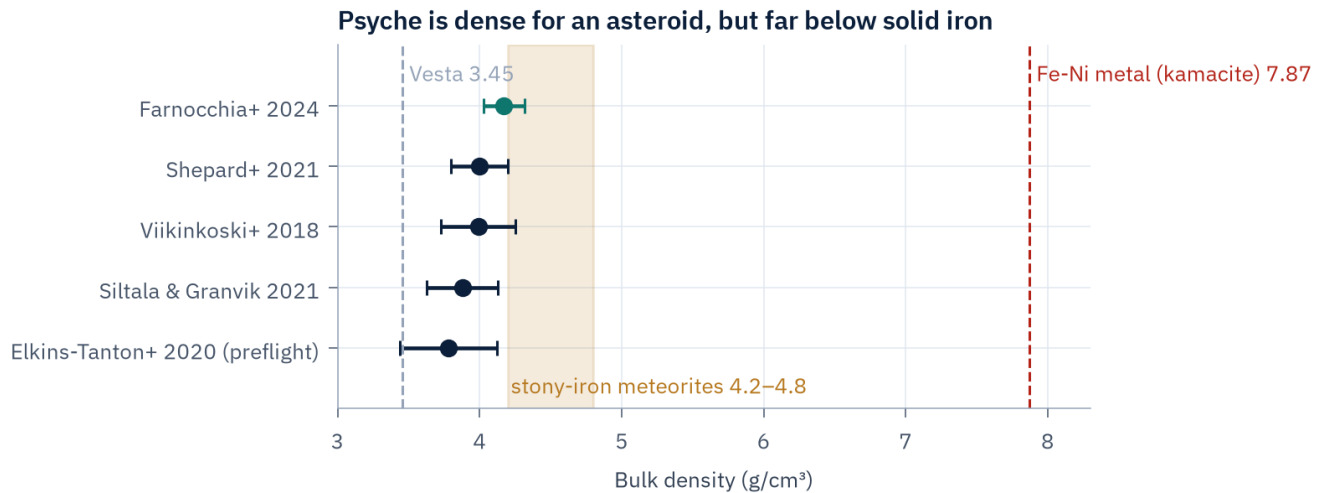
Mass and density: how the estimate moved. For two decades, published masses ranged from ~ 1.5 to 6.7×10^{19} kg (Figure 3.1). Combined with volume, they implied densities from $\sim 2,500$ to above $7,000$ kg/m³ [7], a spread wide enough to sustain the “solid iron core” narrative. Estimates have since tightened. Baer & Chesley (2017) found 2.29×10^{19} kg. Siltala & Granvik (2021) found 2.22×10^{19} kg, a density of 3.88 ± 0.25 g/cm³ [8]. Farnocchia et al. (2024), using high-precision Gaia-era astrometry, found $2.40 \pm 0.03 \times 10^{19}$ kg and $4,172 \pm 145$ kg/m³ [6]

MEASURED . A 2025 Gaia-FPR update is consistent with that result [14].



Sources: Elkins-Tanton et al. 2020 (Table 2 compilation); Siltala & Granvik 2021; Farnocchia et al. 2024. Grade: MEASURED.

What the density implies. Solid kamacite (Fe-Ni metal) is $\sim 7,870$ kg/m³, and stony-iron meteorites run $\sim 4,200$ – $4,800$ kg/m³ [7]. A density near $4,200$ kg/m³ fits several quite different bodies: (a) a metal-silicate mixture with modest porosity; (b) a highly porous, mostly metallic rubble pile; or (c) a differentiated body with a metal-rich exterior, for example from ferrovolcanism [7][8]. The 2020 mission-team assessment estimated ~ 30 – 60 vol% metal and judged porosity above $\sim 20\%$ unlikely [7] **INFERRED** . A 2026 study using the 2024 density finds ≥ 16 vol% metal at 95% confidence. It finds a fully metallic Psyche admissible only with 40 – 55% porosity, typical of rubble piles [10] **INFERRED** .



Sources: as labelled; analogue densities from Elkins-Tanton et al. 2020. Grade: MEASURED (bulk density); composition interpretation is INFERRED.

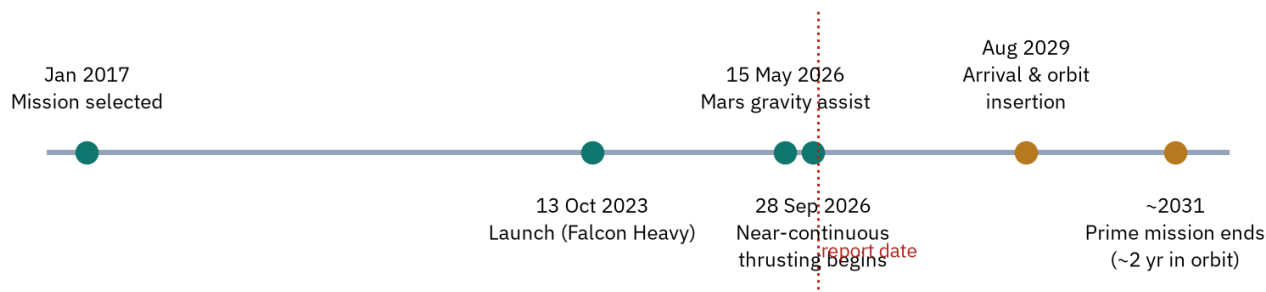
Surface evidence. Psyche's mean radar albedo of 0.34 ± 0.08 is two to four times that of most main-belt asteroids, and it varies across the surface (~ 0.22 – 0.52). That points to a metal-enriched regolith with local high-metal provinces [5] **MEASURED**. Millimetre-wave (ALMA) data indicate a heterogeneous surface with metal-rich and silicate-rich regions [10]. Spectral mixing models give $\sim 82.5\%$ metal, 7% low-iron pyroxene and 10.5% carbonaceous material, probably delivered by impacts [11] **INFERRED**. JWST detected a 3- μ m hydration feature consistent with ~ 250 – 400 ppm hydrogen and set an upper limit of 39 ppm on water [12] **INFERRED**. Investors should note that a featureless spectrum is not proof of metal: the asteroid Lutetia and the planet Mercury also show flat spectra over silicate surfaces [7].

Origin hypotheses (relevant to grade and continuity of ore). Four are in play: (1) a mantle-stripped core, from one hit-and-run impact or several; (2) a disrupted and re-accreted metal-silicate mix; (3) unmelted, highly reduced primitive material resembling CB chondrites; (4) a differentiated body with ferrovulcanic surface metal [7][10]. Each implies a very different spatial distribution of metal. For an extraction business that matters more than the bulk average: it decides whether metal is continuous at depth, patchy, or a surface veneer.

Investor read-across: composition has narrowed from “maybe a solid iron core” to “a metal-rich mixed body of uncertain structure”. The 2029–2031 data should narrow it further. Until then, any valuation that assumes a specific metal grade at depth is speculative.

SECTION 4

NASA Psyche mission: status and catalysts



Sources: NASA mission page; NASA/JPL Mars flyby release (2026); NASA Psyche blog 22 Oct 2026. Teal = completed (MEASURED); gold = planned.

MILESTONE	DATE / VALUE	GRADE	SOURCE
Mission selected (NASA Discovery Program)	4 Jan 2017	MEASURED	NASA release [44]
Life-cycle cost incl. launch vehicle	\$985M (NASA, 2022, at time of launch delay)	MEASURED	[20]
Launch	13 Oct 2023, Falcon Heavy, KSC LC-39A	MEASURED	NASA [1]
Propellant capacity	Up to 1,085 kg xenon in seven 82-L tanks	MEASURED	IEPC - 2024 - 126 [19]
Propulsion	Four SPT-140 Hall thrusters, one operating at a time; ~5.8 km/s Δv delivered by SEP during cruise	MEASURED	IEPC - 2024 - 126 [19]
Mars gravity assist	15 May 2026; 4,609 km altitude; ~1,000 mph speed gain; ~1° plane change	MEASURED	NASA/JPL [2]
Cruise thrusting	Near-continuous from 28 Sep 2026; thrusters on ~90% of the time to arrival	MEASURED	NASA blog, 22 Oct 2026 [3]
Arrival / orbit insertion	August 2029	PLANNED	NASA [1][2][3]
Prime mission	~2 years in a series of progressively lower circular orbits (A–D)	PLANNED	NASA [1]; Elkins-Tanton et al. 2020 [7]
Imaging requirement	>80% of surface at ≤ 20 m/pixel; some areas expected below 5 m/pixel	PLANNED	[7]
Gravity science	Simulated recovery of a degree-18 gravity field (~20 km half-wavelength); bulk density to better than 1%	PLANNED	[7]
Composition payload	Gamma-ray & neutron spectrometer (H, Fe, Ni, Si, K, S, Al, Ca, Th, U); dual fluxgate magnetometers; multispectral imagers	MEASURED	[7]

Why the mission matters to capital allocators

- **Ni abundance is the key number.** The team states that Ni above ~4 wt% would indicate a core origin [7]. A core origin implies metal that is continuous at depth rather than a veneer.
- **The gravity field and topography reveal internal structure:** rubble pile or coherent body, and whether there are dense provinces. This drives anchoring, excavation and whether surface data can be extrapolated downward.

- **Magnetisation.** Strong remanent magnetisation would favour a mantle-stripped core [10]. Its absence would be ambiguous.
- **What the mission will not tell you:** platinum-group metal grades, extraction cost, or cohesive strength at engineering scale. Those stay speculative.

Programme risk notes: GAO reported ~\$116M in cumulative development cost overruns and a 14-month schedule delay at launch [21]. The spacecraft is in nominal cruise according to NASA [3]. An anomaly before 2029 would delay the catalyst, not remove it.

PART II

Getting there, and what it holds

$\approx 10 \text{ km/s}$

ideal one-way delta-v from low Earth orbit to rendezvous (SRI calc); NASA's own electric-propulsion cruise takes ~5.8 years. Sections 5–7.

Access, resource economics, and comparison with other metal-rich targets.

SECTION 5

Access: orbit, delta-v, travel time, surface operations

Orbit. Psyche follows a stable main-belt orbit: semi-major axis ~2.92–2.93 au, between 2.53 au (perihelion) and 3.32 au (aphelion), eccentricity ~0.135, inclination 3.1°, period about five years. Its minimum orbit intersection distance with Earth is 1.53 au [4] **MEASURED**. It is neither an Earth-approacher nor a hazard.

ELEMENT (JPL SBDB, SOLUTION DATED 2025-02-06)	VALUE	GRADE
Semi-major axis a	2.93 au (SBDB, rounded); 2.92 au (epoch Nov 2025)	MEASURED
Eccentricity e	0.135	MEASURED
Inclination i	3.1°	MEASURED
Longitude of ascending node	150°	MEASURED
Argument of perihelion	230°	MEASURED
Perihelion q / aphelion Q	2.53 au / 3.32 au	MEASURED
Sidereal period	~1,830 d (≈5.0 yr)	MEASURED
Earth MOID	1.53 au	MEASURED
Synodic period vs Earth (launch-window spacing)	≈1.25 yr (SRI calc)	INFERRED

Delta-v (first-order). We computed an idealised impulsive Hohmann transfer from a 300-km circular LEO to a circular, co-planar orbit at Psyche's distance, then added the 3.1° plane change at arrival **INFERRED** (SRI calc; method in Appendix B):

CASE (PSYCHE DISTANCE)	DEPARTURE v_{∞} (C3)	LEO DEPARTURE Δv	ARRIVAL Δv (INCL. 3.1°)	TOTAL ONE-WAY	HOHMANN TIME
Perihelion distance 2.53 au	5.9 km/s (34 km ² /s ²)	4.7 km/s	4.7 km/s	≈9.4 km/s	≈1.2 yr
Mean distance 2.92 au	6.6 km/s (43 km ² /s ²)	5.0 km/s	5.0 km/s	≈10.1 km/s	≈1.4 yr
Aphelion distance 3.32 au	7.1 km/s (51 km ² /s ²)	5.3 km/s	5.3 km/s	≈10.6 km/s	≈1.6 yr

Caveats: real trajectories use Psyche's actual eccentric orbit, planetary flybys and low-thrust propulsion. NASA's mission launched on a Falcon Heavy, used a Mars gravity assist, and needs ~5.8 years one way; its Hall thrusters deliver ~5.8 km/s of cruise Δv [1][2][19]. A laden return needs comparable Δv to reach cislunar space unless aerobraking or aerocapture into Earth orbit is used. For comparison, NASA's NHATS database lists a minimum round-trip Δv from LEO of ~3.5 km/s for the small near-Earth asteroid 2022 OB5 [18] **MEASURED**, about a third of the one-way figure to Psyche.

Launch windows. Earth–Psyche alignments recur roughly every 1.25 years (synodic period, SRI calc) **INFERRED**. Electric propulsion and gravity assists widen and shift the usable windows. NASA's own launch slipped from 2022 to 2023 for flight-software readiness, which forced a different trajectory and a later arrival [20].

Surface environment and operations. From the measured GM and a 111 km mean radius, sphere-equivalent surface gravity is ≈0.13 m/s² and escape speed ≈170 m/s (SRI calc) **INFERRED**. Published shape-based figures are similar (~0.144 m/s² and ~180 m/s; Shepard et al. 2017 [13]), and local gravity varies on such an elongated body. Psyche spins every 4.196 h, so at the long-axis tip (~139 km) centrifugal acceleration is ≈0.024 m/s², about a fifth of gravity (SRI calc) **INFERRED**.

Psyche is massive enough that landing is a real descent, not a docking, and tools pressing on the surface get meaningful reaction force. Excavated material falls back, which helps containment. The trade-off is ascent: leaving the surface costs a few hundred m/s, versus near-zero for small NEAs. Near-surface regolith properties, and therefore anchoring strategy, stay uncertain until arrival; thermal inertia estimates conflict, from 11–53 up to 243–284 J m² s^{1/2} K¹ [7] **INFERRED**. Laboratory impacts into metal produce deep, sharp-rimmed craters, and meteoritic metal at ~120 K is very strong (~1,300 MPa) [7]. Both suggest that cutting and comminution will be harder than in silicate regolith.

Access verdict: ~10 km/s each way under ideal assumptions, multi-year transits, and launch windows roughly every 1.25 years. Psyche is a destination for science and, eventually, for an established deep-space industry. It is not a first commercial target.

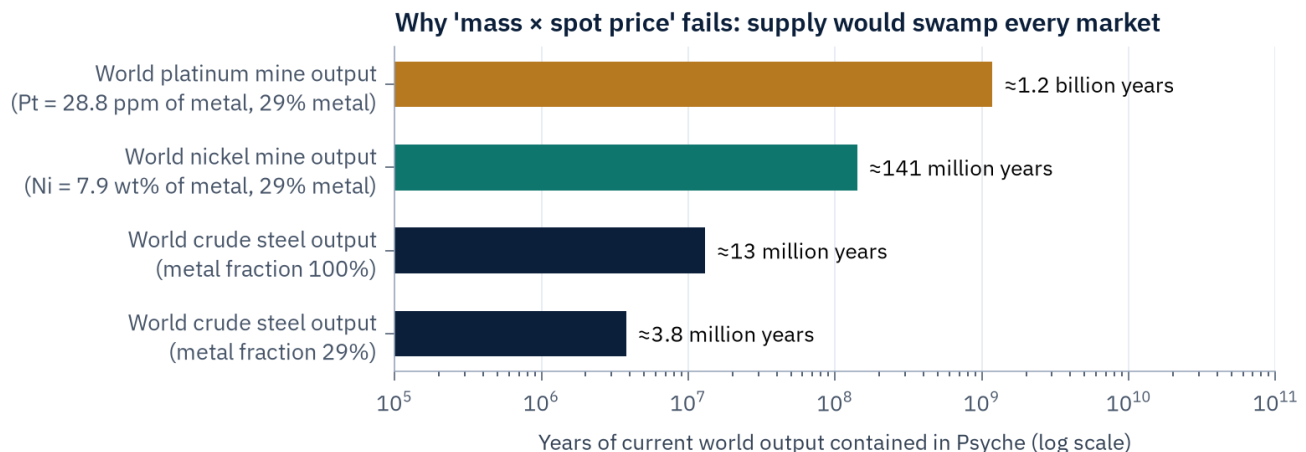
SECTION 6

Resource economics

Why “\$10 quintillion” is misleading

The headline “\$10,000 quadrillion” ($\approx \$10^{19}$) came from a 2017 estimate that treated Psyche's mass as iron-meteorite-like metal and multiplied it by January-2017 market prices [27][28]. The mission's principal investigator has since said: “the estimate is meaningless in every way... we have absolutely no available technology for bringing Psyche back to Earth. And even if we did, the abundance of its metal would immediately render metals valueless on the markets” [27]. Three separate problems make the number unusable:

- **Quantity is not value.** Prices are set at the margin of current supply. In 2025 the world produced 1,849.4 Mt of crude steel [26], ~3.9 Mt of mined nickel and ~170 t of mined platinum (USGS estimates) [25] **MEASURED**. Even the floor case for Psyche's metal equals millions of years of steel output (Figure 6.1).
- **Price collapse.** If demand has constant elasticity of -1 , added supply leaves total market revenue unchanged; the price just falls in proportion. Kargel's analysis of asteroid PGM supply likewise found that market prices would crash [16]. The workbook's *Earth_Return_Check* tab lets you test your own elasticities.
- **Composition is still inferred.** The metal fraction is uncertain by a factor of several [7][10], and PGM grades are unmeasured. The headline number takes the most favourable value for every unknown.



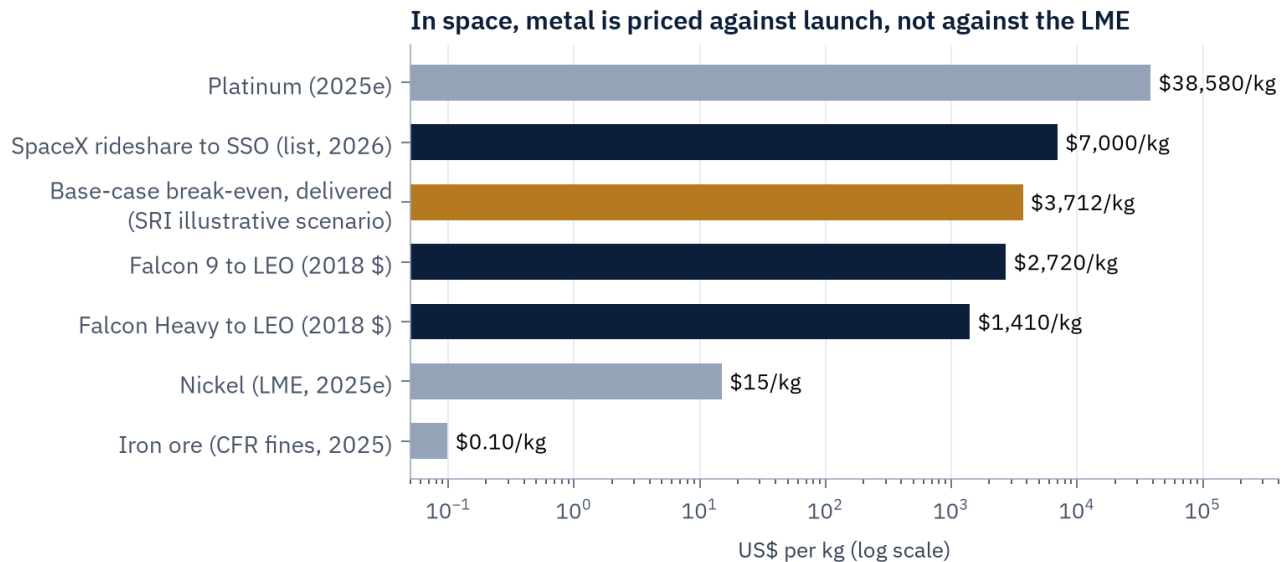
INFERRED/SPECULATIVE arithmetic by SRI. Mass: Farnocchia 2024. 29 wt% $\approx$ lower bound derived from Cambioni 2026 (≥ 16 vol%).

Ni/Pt grades: iron-meteorite analogues (Sanchez 2021 citing Buchwald and Kargel). Output: worldsteel 2025, USGS MCS 2026.

Figure 6.1 — Psyche's contained metal relative to annual world output. **INFERRED** for steel; **SPECULATIVE** for Ni and Pt, which use average iron-meteorite grades (Ni 7.9 wt% [16] citing Buchwald; Pt 28.8 ppm, a 90th-percentile value [16] citing Kargel).

Where asteroid metal has value: in space

Terrestrial prices are the wrong benchmark. A tonne of structural metal already in orbit is worth roughly what it would cost to launch that tonne from Earth to the point of use, less discounts for quality, schedule and certification. Published references put Falcon 9 at ~\$2.7k/kg and Falcon Heavy at ~\$1.4k/kg to LEO in 2018 dollars (list price ÷ capacity) [22]. SpaceX's published rideshare rate to SSO is \$350k for the first 50 kg plus \$7k/kg [23] **MEASURED**. Delivery beyond LEO, to GEO, cislunar space or deep space, costs a multiple of the LEO figure. All of these sit roughly two to four orders of magnitude above terrestrial nickel and iron-ore prices [25].



Sources: USGS MCS 2026 (Fe ore, Ni, Pt); Jones 2018 NASA NTRS (Falcon); New Space Economy Feb 2026 citing SpaceX (rideshare). Gold bar = model scenario, not a

The central tension. Falling launch costs are what make space resources thinkable, and they also lower the ceiling price of space-sourced material. A venture that needs launch to stay expensive to justify its metal price, yet cheap enough to deploy its plant, is internally inconsistent unless the metal is used far from Earth. The companion model makes this explicit: launch cost enters both as a cost and as an anchor for value.

Plausible near-term uses (what a buyer might actually pay for)

USE	WHY IT COULD WORK	READINESS / EVIDENCE	GRADE
Structural feedstock for in-space construction (trusses, shielding, ballast)	Bulk mass dominates launch cost; low-spec Fe-Ni is acceptable for shielding and ballast	No in-space metal refining demonstrated at scale; no anchor customer found in sources reviewed	SPECULATIVE
Radiation / micrometeoroid shielding mass	Raw or lightly processed material may suffice	Concept stage	SPECULATIVE
Additive-manufacturing feedstock	High value per kg in orbit; small volumes	Mature on Earth; space-sourced feedstock unproven	SPECULATIVE
Propellant from NEA volatiles (not Psyche)	The most-cited first market; Karman+ targets refuelling	Karman+ demo mission planned for 2027 [33]	SPECULATIVE
PGM return to Earth (NEAs, not Psyche)	Highest \$/kg on Earth	Capped by price collapse; small markets (Pt ~170 t/yr [25])	SPECULATIVE

Psyche itself is unlikely to supply any of these uses within 20 years, given the access penalty in Section 5. What it contributes is evidence on how metal is distributed in a large metal-rich body, and that evidence transfers to smaller, nearer targets.

SECTION 7

Comparison with other metal-rich and accessible targets

TARGET	LOCATION	SIZE	METAL EVIDENCE	ACCESSIBILITY	COMMERCIAL RELEVANCE
16 Psyche	Main belt, $a \approx 2.92$ au [4]	~ 222 km [5] MEASURED	Density 4.17 g/cm^3 [6]; radar albedo 0.34 [5]; ≥ 16 vol% metal [10] INFERRED	≈ 10 km/s ideal one-way (SRI calc) INFERRED ; ~ 5.8 yr NASA cruise [1]	Information asset; mining > 20 yr
216 Kleopatra	Main belt, $a \approx 2.8$ au [4]	~ 119 km volume-equivalent [15] MEASURED	M-type; radar albedo 0.43 [7]; low density $3.38 \pm 0.50 \text{ g/cm}^3$ [15]	Main belt; access penalty similar to Psyche INFERRED	Comparator for porous metal-rich bodies
6178 (1986 DA)	NEA; $a \approx 2.81$ au, $e \approx 0.58$ [4][16]	~ 2.8 km [16] MEASURED	Only NEA confirmed metal-rich by radar [17]; spectral $\sim 85\%$ metal / 15% pyroxene [16] INFERRED	Not in NASA NHATS accessible list; Earth MOID 0.18 au [4]	Proof-of-concept candidate if access improves
2016 ED85	NEA; $a \approx 2.98$ au, $e \approx 0.69$ [4][16]	$\sim 0.72\text{--}1.25$ km (albedo-dependent) [16] INFERRED	Spectrum near-identical to 1986 DA; no radar confirmation [16] INFERRED	Not in NHATS list	Candidate; needs radar
2022 OB5	NEA; $a \approx 1.03$ au, $e \approx 0.055$ [4]	$\sim 2.8\text{--}12$ m (NHATS est.) [18] INFERRED	Targeted by AstroForge as metallic; composition unconfirmed [30][31] SPECULATIVE	Min. round-trip $\Delta v \approx 3.5$ km/s from LEO (NHATS) [18] MEASURED	Very accessible but tiny

Pattern. Among known metal-rich targets, accessibility and size trade off against each other. The large metal-rich bodies, Psyche and Kleopatra, sit in the main belt. The one confirmed metal-rich NEA, 1986 DA, is kilometre-scale on a high-eccentricity orbit. The most accessible commercial target named in our sources, 2022 OB5, is metres across and unconfirmed as metallic. Sanchez et al. trace 1986 DA and 2016 ED85 most likely to the outer belt via the 5:2 Jupiter resonance near 2.8 au, a region that also hosts several large M-types [16]. Psyche's data therefore bear directly on how we read the NEA population that is actually reachable.

Implication: the first commercially meaningful metal-rich target is likely to be a near-Earth body found by surveys and confirmed by radar. Psyche will be the calibration standard for judging it.

On 1986 DA valuations: Sanchez et al. estimate its precious-metal value at $\sim \$11.65$ trillion, after applying Kargel's price-deflation model and assuming the metal is marketed over 50 years [16]. We cite this to illustrate method, not to endorse a value. The same objections to “mass $\times$ price” apply, though more weakly.

PART III

Markets, law and risk

4

national laws (US, Luxembourg, UAE, Japan) recognise private ownership of extracted resources, while the body itself cannot be appropriated. Sections 8–11.

Company landscape, legal regime, risks and data gaps, and the ranked opportunity matrix.

SECTION 8

Company landscape

Stage and funding appear only where a public source supports them. No company in our sources is commercially targeting 16 Psyche; all target near-Earth objects, in-orbit services or adjacent capabilities. Inclusion is not endorsement.

COMPANY (HQ)	FOCUS	STAGE / FUNDING (SOURCED)	RECENT MILESTONES (SOURCED)
AstroForge (California, US)	Prospecting and ultimately mining metal-rich NEAs; PGMs	\$40M Series A (Aug 2024) led by Nova Threshold, taking total raised to \$55M at the time [29]; TechCrunch (Sep 2026) reports \$56M in venture funding [32] MEASURED	Odin launched 26 Feb 2025 on the IM-2 rideshare; built for ~\$3.5M; contact lost, so the flyby of 2022 OB5 was not achieved [30][31]. The next vehicle is named DeepSpace-2 [31]; an onboard-AI autonomy focus was reported in Sep 2026 [32]
Karman+ (Colorado, US)	NEA regolith excavation; water for in-orbit refuelling; later metals	\$20M seed (Feb 2025) co-led by Plural and Hummingbird [33] MEASURED	High Frontier demonstration targeting a 2027 launch; aims to mine ~1 kg; mission budget goal under \$10M [33]
TransAstra (California, US)	Optical mining, Capture Bag, space logistics, asteroid detection	\$2.5M NASA CCRPP contract matched by \$2.5M private investment (Sep 2025) [34] MEASURED	1-m Capture Bag delivered to the ISS for testing (Sep 2025); scaling to 10 m [34]
Origin Space (China)	Space resources, debris-capture demonstrations, NEO observation	Private funding not sourced here	NEO-01 test spacecraft launched Apr 2021 on a Long March 6 rideshare [36]
Planetary Resources (US), historical	Asteroid prospecting	Acquired by blockchain firm ConsenSys in 2018 [35]	Assets later dispersed; a cautionary precedent
Deep Space Industries (US), historical	Asteroid mining; small-satellite propulsion	Acquired by Bradford Space in 2019 [35]	Pivoted to propulsion; a cautionary precedent

Ecosystem players that matter but are not asteroid miners

- **Launch providers.** Launch cost sets both the cost base and the ceiling price (Section 6). SpaceX launched NASA's Psyche spacecraft [1].
- **Electric-propulsion suppliers.** Psyche is the first mission to use Hall-effect thrusters for interplanetary travel. Its SPT-140 units show the propulsion class a commercial deep-space bus would use [19].
- **Lunar landers and rideshare hosts.** Small asteroid missions have flown as secondary payloads on lunar missions (e.g., Odin on IM-2 [30]). How often those hosts fly sets the launch opportunities open to start-ups.

Read-across: the 2012–2019 cohort, Planetary Resources and Deep Space Industries, ended in acquisitions and pivots [35]. Today's cohort runs on much smaller budgets: a mission budget goal under \$10M (Karman+) and a ~\$3.5M spacecraft (AstroForge Odin) [31][33]. Its first deep-space attempt, Odin, did not achieve its objective. Diligence should weight demonstrated flight heritage, cost per attempt and non-mining revenue lines.

SECTION 9

Legal & regulatory

INSTRUMENT	KEY PROVISION FOR RESOURCE ACTIVITY	STATUS / RELEVANCE	SOURCE
Outer Space Treaty (1967)	Art. II: outer space, including celestial bodies, is not subject to national appropriation. Art. VI: States bear responsibility for national activities, including those of non-governmental entities, which need authorisation and continuing supervision	Foundation for every regime below; says nothing explicit on ownership of extracted resources	UNOOSA [37]
US Commercial Space Launch Competitiveness Act (2015), Title IV	51 U.S.C. §51303: a US citizen engaged in commercial recovery of an asteroid or space resource “shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell” it, consistent with US international obligations	In force; covers extracted resources, not the body itself	Public Law 114-90 [38]
Luxembourg: Law of 20 July 2017 on the exploration and use of space resources	Space resources are capable of being appropriated; activities require national authorisation	In force	Legilux [39]
UAE: Federal Law No. 12 of 2019 (space sector)	Regulates authorised space-resource activities, including extraction, use and trade	In force	UAE Ministry of Justice [40]
Japan: Act No. 83 of 2021 on space resources	Permit holders acquire ownership of resources extracted under an approved plan	In force	Cabinet Office [41]; Library of Congress [24]
Artemis Accords (2020–)	Resource extraction and use to comply with the OST; deconfliction through notified, temporary “safety zones”	77 signatories as of 19 Oct 2026; Uzbekistan was the 77th [42] MEASURED	NASA [42] [43]
UN COPUOS Working Group on Legal Aspects of Space Resource Activities	Drafting non-binding recommended principles: compliance with international law, freedom of use, access for all, non-appropriation	Draft principles updated during 2026; under negotiation; not binding	UNOOSA [45]

Analysis. A growing minority of states recognise private ownership of *extracted* resources while holding that the celestial body itself cannot be appropriated; the US, Luxembourg, UAE and Japanese statutes above are consistent on this. Legal risk for a Psyche-specific venture is low in the near term, simply because no near-term activity there is plausible. NEA ventures face three practical risks: (i) choosing which national licensing regime to operate under, (ii) the content of the final COPUOS principles, and (iii) disputes over operating areas, which the Accords' safety-zone concept addresses only among signatories. Investors should make a licensing plan with the relevant national authority a pre-condition for any extraction-stage financing.

Legal verdict: clear enough to finance prospecting and demonstration missions under US, Luxembourg, UAE or Japanese licensing. International consensus on commercial-scale extraction is not yet in place; that is a 10-year issue, not a 2-year one.

SECTION 10

Risks, unknowns & what data would change our view

Each row gives the unknown, why it matters to value, the observation that would resolve it, and when that observation could plausibly arrive.

UNKNOWN / RISK	WHY IT MATTERS	WHAT DATA WOULD CHANGE THIS	EXPECTED TIMING
Bulk metal fraction (INFERRED)	Sets tonnage and grade for any metal-rich-body thesis	Psyche GRNS Fe/Ni maps, plus gravity field and shape (bulk density to better than 1%) [7]	2029–2031 (prime mission) PLANNED
Ni content / core origin (INFERRED)	Ni above ~4 wt% suggests a core [7], which implies continuous metal at depth	GRNS Ni abundance; magnetometer detection of a remanent field [7][10]	2029–2031 PLANNED
Internal structure and porosity (INFERRED)	Rubble pile vs coherent body changes excavation, anchoring and grade continuity	Degree ~18 gravity field compared with topography [7]	2030–2031 PLANNED
Surface regolith properties (INFERRED)	Drives landing, anchoring and tool design; thermal inertia estimates conflict [7]	High-resolution imaging (≤ 20 m/px, some areas < 5 m/px); crater morphology [7]	2029–2030 PLANNED
PGM grade (SPECULATIVE)	The only plausible driver of Earth-return value	Not measured by the Psyche payload [7]; needs sample analysis or new instruments on NEAs	After 2031; possibly via NEA missions
Mission execution risk	Delays the catalyst	Continued nominal cruise reports from NASA [3]	Ongoing to Aug 2029
Launch-cost trajectory	Cuts the cost of deployment but also the value of in-space metal (Section 6)	Published \$/kg for fully reusable heavy lift; rideshare price changes [22][23]	2026–2031
In-space demand for metal	No anchor customer for space-sourced structural metal found in our sources	Binding offtake contracts; large in-space construction programmes	2028–2036
Extraction technology	No asteroid extraction demonstrated at any meaningful scale	Karman+ High Frontier (~1 kg target, 2027) [33]; follow-on demonstrations	2027–2030
Start-up execution / capital	The previous cohort ended in acquisitions [35]; Odin anomaly [30]	A successful rendezvous and landing by a private spacecraft	2027–2030
Legal / international acceptance	Affects market access, insurance and sovereign participation	Final COPUOS principles [45]; new national laws; growth of the Accords [42]	2026–2030

Signposts to monitor (quarterly)

- NASA Psyche cruise updates and any thruster or anomaly reports [3].
- Peer-reviewed updates to Psyche's mass and density, e.g., from further Gaia-era astrometry [6][14].
- Launch dates and outcomes of private NEA missions (Karman+ in 2027 [33]; AstroForge's next vehicle [31][32]).
- Changes in published launch \$/kg [22][23].
- COPUOS working-group texts and new national space-resource laws [45].

SECTION 11

Ranked opportunity matrix (5 / 10 / 20 years)

The ranking reflects our judgement of three things: investability (can capital go in staged amounts, with exits?), evidence of demand, and technical readiness. It is **SPECULATIVE** by construction; treat it as a framework to argue with, not a fact.

	5-year (to 2031)	10-year (to 2036)	20-year (to 2046)
1. Characterisation data & analytics	4 · High	5 · Very high	4 · High
2. Deep-space SEP propulsion & low-cost buses	4 · High	4 · High	4 · High
3. Small NEA prospecting / rendezvous missions	3 · Medium	3 · Medium	4 · High
4. In-space metal processing & manufacturing	2 · Low	3 · Medium	4 · High
5. NEA water / volatiles for propellant	1 · Very low	3 · Medium	4 · High
6. NEA-sourced metal for in-space construction	1 · Very low	2 · Low	3 · Medium
7. PGM return to Earth from NEAs	1 · Very low	1 · Very low	2 · Low
8. 16 Psyche itself as a mining asset	0 · Nil	0 · Nil	1 · Very low

Analyst judgement (SPECULATIVE): attractiveness = investability x evidence of demand x technical readiness. Not investment advice.

#	OPPORTUNITY	RATIONALE	PRIMARY DEPENDENCY
1	Characterisation data & analytics	Psyche data (2029–31) and NEA surveys create demand for target ranking, risk models and due-diligence services	Open NASA data release; survey cadence
2	Deep-space SEP propulsion & low-cost buses	Every deep-space resource architecture needs efficient propulsion; Psyche is demonstrating the Hall-thruster class [19]	Number of commercial deep-space missions
3	Small NEA prospecting / rendezvous	Missions costing ~\$3.5M to under \$10M [31][33] create option value on target discovery	First successful private rendezvous
4	In-space metal processing & manufacturing	Feedstock-agnostic: can begin with scrap or lunar regolith and later take asteroid metal	An anchor in-space construction customer
5	NEA water / volatiles for propellant	The most-cited first market; does not depend on metal prices	Demand for in-orbit refuelling
6	NEA-sourced metal for in-space construction	Value anchored to avoided launch cost; needs proven processing	Launch-cost path; processing at scale
7	PGM return to Earth from NEAs	High \$/kg, but small markets and price-collapse risk	Measured PGM grades; demand elasticity
8	16 Psyche as a mining asset	~10 km/s each way, multi-year transits, little near-term demand	A mature deep-space industry

PART IV

What it could be worth

\$3.7k/kg

break-even price of delivered metal in the base scenario of a Psyche-distance venture, about 2.6× the assumed launch cost. Section 12 and appendices.

Scenario output, not a forecast. Every input is an assumption you can change in the companion workbook.

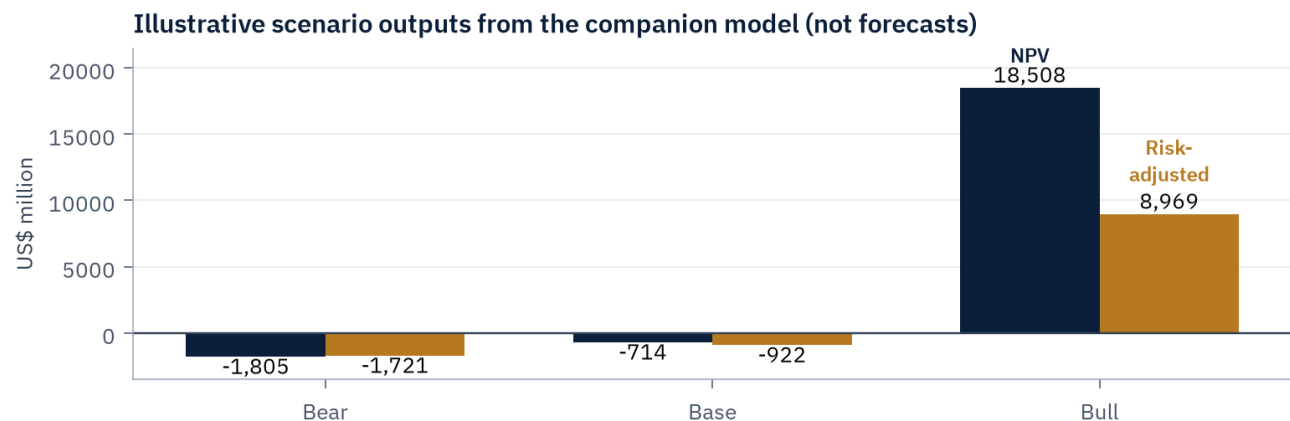
SECTION 12

Valuation model: structure and illustrative scenarios

Everything in this section is an illustrative scenario computed from editable assumptions. None of it is a forecast, a valuation of any company, or a fact. The defaults are Space Resource Intelligence assumptions, graded **SPECULATIVE**, chosen to bracket a wide range. Change them in the workbook.

Structure. The workbook *SRI_16Psyche_Valuation_Model_SAMPLE.xlsx* models a hypothetical venture that develops a mining and processing plant, launches it, travels to a metal-rich body, extracts and processes metal, and ships it back for sale in space. All logic is in visible formulas. Sheets: *README*; *Inputs* (Bear/Base/Bull columns, yellow cells editable); *Bear*, *Base* and *Bull* (40-year annual cash flows); *Summary*; *Sensitivity* (NPV against metal value × extraction rate); *Earth_Return_Check* (price-collapse calculator); *Psyche_Inventory* (contained-metal arithmetic); *Reference_Data* (sourced, graded constants).

ASSUMPTION (DEFAULT)	BEAR	BASE	BULL	ANCHOR
Launch cost to LEO (\$/kg)	2,720	1,410	500	Jones 2018 [22] for Bear/Base; Bull is an assumption
In-orbit metal value (\$/kg)	500	1,500	3,000	Assumption; compare with launch \$/kg
Launched plant mass (kg)	20,000	10,000	5,000	Assumption
Mission capex excl. launch (\$M)	3,000	1,500	750	Assumption (NASA Psyche life-cycle cost \$985M [20])
Development period (yr)	8	6	5	Assumption
Outbound / return transit (yr)	6 / 6	5 / 5	3 / 3	NASA Psyche cruise ≈5.8 yr [1]
Extraction rate (t/yr)	100	1,000	5,000	Assumption (no demonstrated rate exists)
Processing yield · transport efficiency	0.30 · 0.50	0.50 · 0.70	0.70 · 0.85	Assumption; bounded by metal fraction [10][11]
Operating years · opex (\$M/yr)	10 · 150	10 · 100	10 · 50	Assumption
Discount rate · P(technical success)	15% · 0.20	12% · 0.35	10% · 0.50	Assumption



SCENARIO OUTPUT driven by SRI default assumptions in *SRI_16Psyche_Valuation_Model_SAMPLE.xlsx*. Change the inputs and these numbers change.

ILLUSTRATIVE OUTPUT (SCENARIO)	BEAR	BASE	BULL
NPV (\$M)	-1,805	-714	+18,508
Risk-adjusted NPV (\$M)	-1,721	-922	+8,969
Total metal delivered (t)	150	3,500	29,750
First delivery (year from programme start)	21	17	12
Break-even in-orbit metal value (\$/kg)	≈392,800	≈3,710	≈110
Break-even ÷ assumed launch cost	≈144×	≈2.6×	≈0.2×

How to interpret. The outcomes depend almost entirely on extraction rate, transit time and in-orbit value, none of which has an empirical basis today. Base is negative because value arrives 17 years out and is heavily discounted. Bull is positive only because it combines 5,000 t/yr extraction, 3-year transits and a \$3,000/kg metal price with \$500/kg launch. As Section 6 notes, cheap launch and expensive in-space metal are inconsistent unless the metal is used far beyond LEO. The most useful output is the **break-even in-orbit value**: it turns any set of engineering assumptions into a single \$/kg hurdle that can be compared with launch prices.

Earth-return check (workbook tab). Using USGS 2025 reference values [25]: adding 1 Mt/yr of nickel at elasticity -1 lowers the illustrative price by ~20%, while total market revenue stays the same. Adding a further year of world platinum output at elasticity -0.8 lowers the illustrative price by ~58% and reduces total market revenue. Both are scenario outputs **SPECULATIVE**.

APPENDIX A

Sources

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APPENDIX B

Methodology, grading & disclaimers

Grading rules. **MEASURED** : a direct observation, a dated event, an official statistic, or a published measurement with stated uncertainty. **INFERRED** : derived from measurements through a published model, or through SRI arithmetic shown in the text. **SPECULATIVE** : assumptions, analogues (e.g., iron-meteorite grades applied to Psyche) and all model defaults. **PLANNED** : scheduled events that have not yet happened.

SRI calculations. (1) Δv : two-body Hohmann transfer between circular, co-planar heliocentric orbits at 1 au and at Psyche's distance ($\mu_{\text{Sun}} = 1.327 \times 10^{11} \text{ km}^3/\text{s}^2$). Departure from a 300-km circular LEO uses $\Delta v = \sqrt{v_{\infty}^2 + v_{\text{esc}}^2} - v_{\text{circ}}$; arrival combines a 3.1° plane change with circularisation. (2) Surface gravity and escape speed: GM/r^2 and $\sqrt{2GM/r}$, with $GM = 1.601 \text{ km}^3/\text{s}^2$ and $r = 111 \text{ km}$. (3) Synodic period: $1/(1 - 1/P)$, with $P = 4.998 \text{ yr}$. (4) Lower bound on metal mass fraction: $16 \text{ vol\%} \times 7,650 \text{ kg/m}^3 \div 4,172 \text{ kg/m}^3 \approx 29 \text{ wt\%}$, using the iron density assumed by Cambioni et al. [10]. (5) Years of output: contained mass $\div$ 2025 annual production. (6) Mass of Siltala & Granvik (2021) converted from 1.117×10^{-11} solar masses.

Figures we could not source, and therefore omitted or flagged: Psyche's platinum-group metal content (unmeasured; analogues only); verified total private funding for TransAstra and Origin Space; a NASA-published Δv for 1986 DA and 2016 ED85 (neither appears in NHATS); a current SpaceX dedicated-launch list price verified on the primary page (the rideshare rate is cited via a secondary report); a size for 2022 OB5 beyond NHATS's range; Psyche's launch wet mass from a primary page we could load; any market price for metal delivered in orbit (none exists).

Independence and conflicts. Space Resource Intelligence holds no positions in the companies named and received no compensation from them for this sample. (Template statement; confirm before commercial distribution.)

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