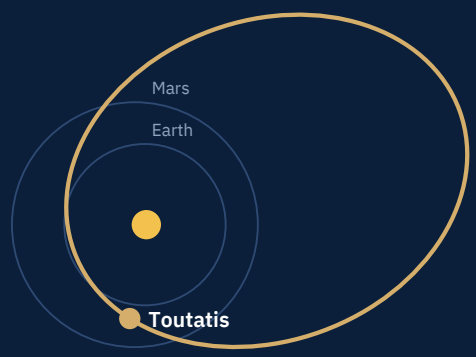
SINGLE-BODY REPORT

4179 Toutatis

Rock, regolith and access: what is known, what is not, and where the opportunity really sits



DIAMETER · IDEAL Δv FROM LOW EARTH ORBIT (SRI CALC)

2.5 km · 9.3 km/s from LEO

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

Orbit of Toutatis: a = 2.54 au, e = 0.62, i = 0.4° (JPL). Planet orbits for scale; orientation schematic.

REPORT + VALUATION MODEL (XLSX)

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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 / ASSUMED.

CONTENTS

Contents

#	SECTION	PAGE
1.	Executive summary	4
2.	Key figures at a glance	5
3.	Physical and compositional profile	6
4.	Exploration record	7
5.	Access: orbit, delta-v and transfer time	9
6.	Resource assessment	10
7.	Peer comparison	11
8.	Company landscape	13
9.	Legal and regulatory	14
10.	Risks, unknowns and data gaps	15
11.	Ranked opportunity matrix	16
12.	Valuation model	18
	Appendix A: Sources	20
	Appendix B: Methodology and assumptions	21

How to read this report

- MEASURED = a published measurement in the sources cited on toutatis.space. INFERRED = derived by SRI arithmetic from measured inputs, or estimated by the source (for example, size from brightness). ASSUMED = an SRI assumption, stated with its basis.
- All delta-v, transfer-time, gravity and temperature figures are SRI model estimates from published orbital and physical data; real trajectories and conditions differ.
- Scores, contained-resource tiers and valuation scenarios are rule-based SRI models (Appendix B). They are illustrative, not forecasts and not facts.
- The companion workbook (SRI_4179Toutatis_Valuation_Model_SAMPLE.xlsx) contains every valuation formula; the scenario figures in Section 12 are computed from the same inputs.

PART I

The body and the evidence

2.5 km

mean diameter (inferred). Sections 1–4: summary, key figures, physical profile, exploration record.

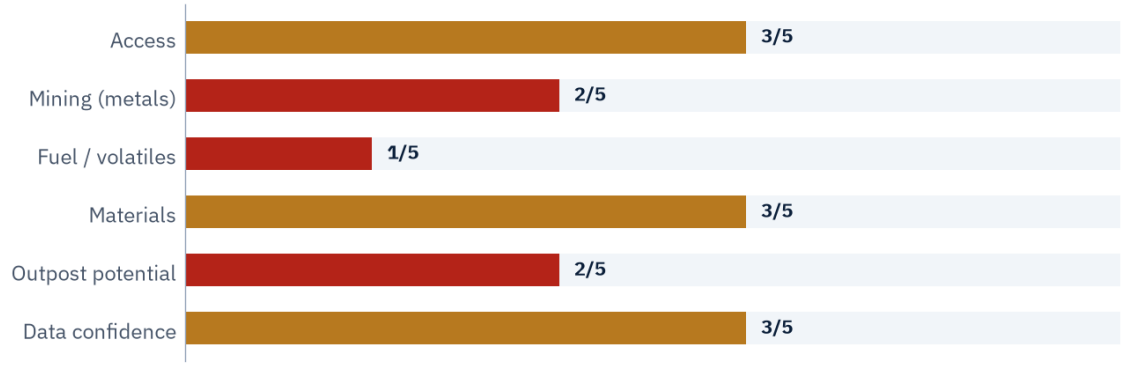
Every figure is graded MEASURED, INFERRED or ASSUMED and traced to a numbered source.

SECTION 1

Executive summary

4179 Toutatis is a near-Earth asteroid (Apollo, Sk-type). In SRI's framing it belongs to the **stony (S-complex)** class, so the most relevant product is **bulk regolith for radiation shielding and construction feedstock**. Access is **moderate**: about 9.3 km/s of ideal delta-v from low Earth orbit and an ideal transfer of about 1.2 years (SRI calc). Data quality is **moderate**.

Toutatis: SRI rule-based scores (1 weak · 5 strong)



Source: SRI rule-based scoring (Appendix B). Teal = strong (4–5), gold = moderate (3), red = weak (1–2).

What the sources show

- Diameter about 2.45 km INFERRED [2]; volume-equivalent of the 4.26 × 2.03 × 1.70 km Chang'e 2 extent (SRI calc).
- Bulk density 2.70 g/cm³ ASSUMED [8] (assumed; a round value typical of S-complex asteroids (Carry 2012)).
- The YORP effect — the tiny torque from sunlight being absorbed and re-emitted — may have drained its spin and pushed it into this tumbling state. [2][5]

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

THESIS

Toutatis is today mainly an information asset. Its data help calibrate how we read more accessible bodies of the same class; any commercial use of its regolith is a 20-year-plus question.

Most relevant product: **bulk regolith for radiation shielding and construction feedstock**. Access 3/5, data confidence 3/5 (SRI rule-based scores, Appendix B).

WHAT WOULD MAKE US WRONG

Bulk density is not measured; we assume 2.70 g/cm³ (assumed; a round value typical of S-complex asteroids (Carry 2012)). Mass, gravity and every tonnage figure scale directly with it.

Size is estimated (volume-equivalent of the 4.26 × 2.03 × 1.70 km Chang'e 2 extent (SRI calc)). Volume, and so mass, scale with the cube of diameter: a 20% size error is roughly a 70% mass error.

Resource content of regolith has not been measured in place for this body; the tiers in Section 6 are assumptions.

Extraction technology has not been demonstrated at any meaningful scale on any small body.

SECTION 2

Key figures at a glance

Every figure carries a confidence grade. Source numbers refer to Appendix A. Spheres are assumed for gravity and volume, which overstates precision for elongated or contact-binary shapes.

QUANTITY	VALUE	GRADE	SOURCE / BASIS
Object type	Near-Earth asteroid (Apollo, Sk-type)	MEASURED	[1]
Orbit (a / e / i)	2.543 au / 0.625 / 0.45°	MEASURED	[9]
Perihelion / aphelion	0.95 / 4.13 au	MEASURED	[9]
Orbital period	4.06 yr	MEASURED	[9]
Earth MOID	0.006506 au	MEASURED	[9]
Mean diameter	2.45 km (volume-equivalent of the 4.26 × 2.03 × 1.70 km Chang'e 2 extent (SRI calc))	INFERRED	[2]
Mass	2.08×10^{13} kg (model estimate: assumed density × sphere-equivalent volume)	ASSUMED	(SRI calc)
Bulk density	2.70 g/cm³ (assumed; a round value typical of S-complex asteroids (Carry 2012))	ASSUMED	[8] [8]
Geometric albedo	0.41	MEASURED	[2]
Rotation period	176 h	MEASURED	[9]
Spectral class / colour	Sk	MEASURED	[2]
Equilibrium temperature (mean distance)	≈167 K	INFERRED	SRI calc (albedo 0.41)
Surface gravity (sphere-equivalent)	9.2×10^{-4} m/s² (≈1/11,000 of Earth's)	ASSUMED	SRI calc from mass and diameter
Escape speed	1.5 m/s	ASSUMED	SRI calc
Sunlight vs Earth (mean)	15.5%	INFERRED	SRI calc ($1/r^2$)
One-way light-time from Earth	0.0541–42.8 min	INFERRED	SRI calc
Ideal Δv LEO → rendezvous	9.3 km/s (departure 4.7 + arrival 4.6)	INFERRED	SRI calc (Appendix B)
Ideal transfer time	1.18 yr	INFERRED	SRI calc (Hohmann)
Launch-window spacing (synodic period)	1.33 yr	INFERRED	SRI calc

SECTION 3

Physical and compositional profile

What the sources cited on toutatis.space say about structure and composition:

- The YORP effect — the tiny torque from sunlight being absorbed and re-emitted — may have drained its spin and pushed it into this tumbling state. [2][5]

Analyst interpretation

SRI interpretation (density). A assumed bulk density of 2.70 g/cm³ is consistent with rocky (silicate) material with some porosity. Because the value is assumed, this is a statement about our model, not about the body.

SRI interpretation (albedo). A geometric albedo of 0.41 is highly reflective, typical of fresh ice or frost. Albedo describes only the top surface layer.

Measured vs inferred. In this report, figures graded MEASURED come straight from the cited sources. Composition statements above are the sources' own. The class label *stony (S-complex)* is an SRI grouping used to pick a product and an assumption set; it is not a new measurement.

SECTION 4

Exploration record

ITEM	DETAIL	SRC
Object type	Apollo near-Earth asteroid; potentially hazardous; Sk-type (stony)	[1]
First seen	Feb. 10, 1934 (as 1934 CT) — then lost	[2]
Rediscovered	Jan. 4, 1989 by Christian Pollas, Caussols, France	[2]
Named for	Teutates/Toutatis, a Celtic tribal god	[3]
Dimensions	≈ 4.26 × 2.03 × 1.70 km	[1]
Rotation	Tumbling: 5.38-day roll plus 7.38-day precession	[2]
Geometric albedo	≈ 0.41	[1]
Distance from Sun	0.955–4.13 AU	[1]
Orbital period	≈ 4.0 years	[1]
Inclination	≈ 0.45° — almost in Earth's orbital plane	[1]
Earth MOID	≈ 0.0065 AU (≈ 2.5 lunar distances)	[1]
Spacecraft	Chang'e 2 flyby, Dec. 13, 2012 — 3.2 km at 10.73 km/s	[4]

How it has been observed

- Radar imaging showed a highly irregular body with two lobes, which may have formed when two separate bodies merged. [2]
- Images from China's Chang'e 2 confirmed that Toutatis is not a monolith but most likely a coalescence of shattered fragments, with a small "head" and a larger "body". [2]

Implication: without close-up data, every resource statement about this body rests on remote observation and assumption. Characterisation is the first investable step.

PART II

Getting there, and what it holds

9.3 km/s

ideal delta-v from low Earth orbit to rendezvous, with an ideal transfer of about 1.2 years (SRI calc). Sections 5–7: access, resources, peers.

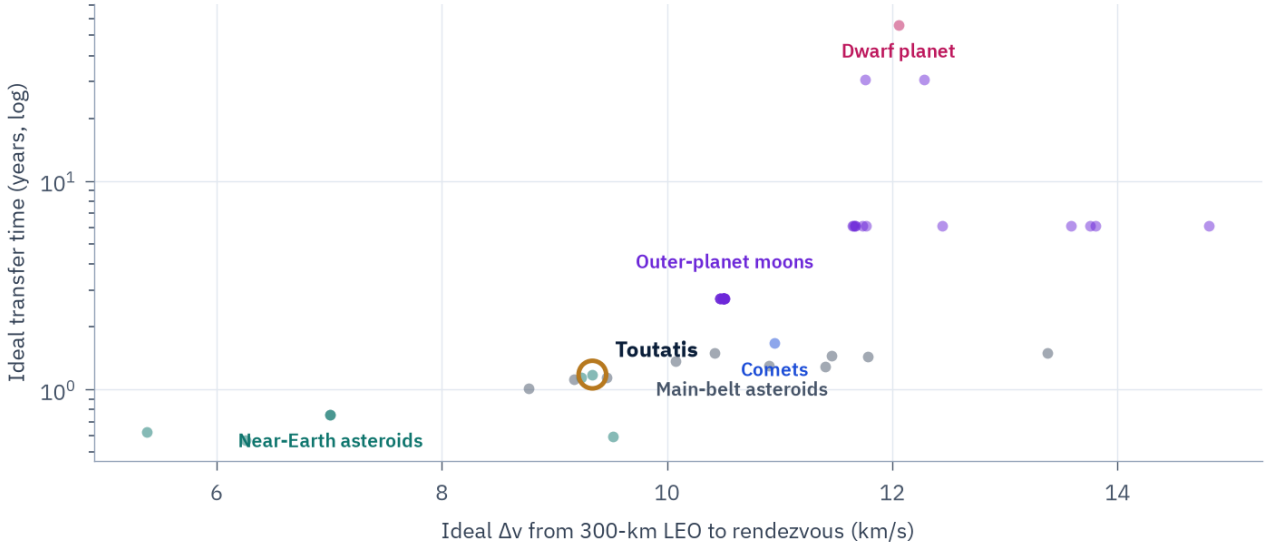
Real trajectories differ; the comparison across bodies is what matters.

SECTION 5

Access: orbit, delta-v and transfer time

LEG (IDEAL, IMPULSIVE)	ΔV (KM/S)	GRADE	BASIS
Departure from 300-km LEO	4.69	INFERRED	Hohmann transfer incl. plane change
Arrival / rendezvous	4.65	INFERRED	Orbit matching
Total	**9.34**	INFERRED	SRI calc
Transfer time	1.18 yr	INFERRED	Half-ellipse transfer time
Synodic period (window spacing)	1.33 yr	INFERRED	Earth vs body
Distance from Earth	9.73e+05–7.7e+08 km	INFERRED	SRI calc
One-way light-time	0.0541–42.8 min	INFERRED	SRI calc

Access versus the 49 bodies in the SRI coverage set



Source: SRI calc from JPL orbital elements (Hohmann transfers, Appendix B). Model estimates, not mission designs.

Reading. With an access score of 3/5 (moderate), Toutatis needs more delta-v or time than the near-Earth bodies in the set. One-way radio delay of up to 43 minutes rules out real-time teleoperation; operations must be autonomous. Ideal impulsive figures understate real missions, which use low-thrust spirals and gravity assists that trade time for propellant.

SECTION 6

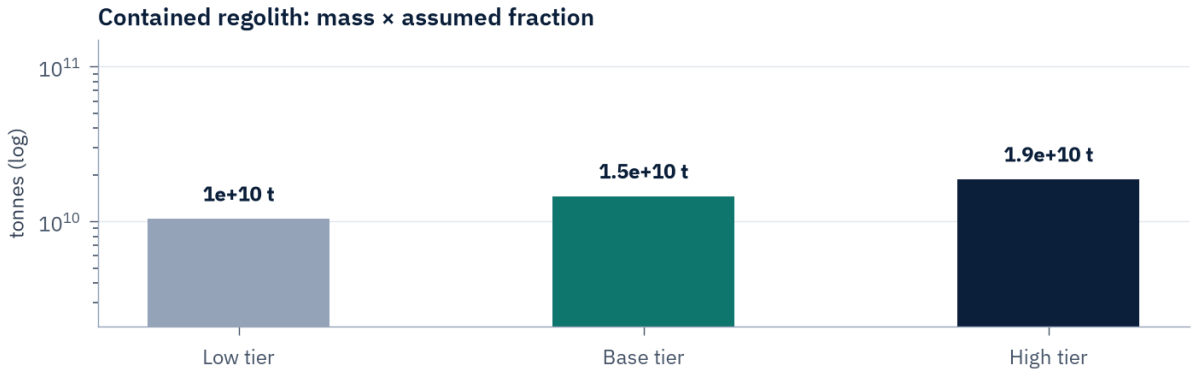
Resource assessment

Four lenses, each scored 1–5 by the SRI rules in Appendix B. Scores compare bodies within our coverage set; they are not probabilities.

LENS	SCORE	RATIONALE (SRI)
Mining (metals)	2	Ordinary-chondrite-like stony material can contain some free iron–nickel metal, but the amount on this body is not measured. Metals are a by-product case, not the lead case.
Fuel / volatiles	1	Stony and metal-rich bodies are generally dry; volatiles are not the lead case.
Materials	3	Every body offers loose surface material that could, in principle, be used for radiation shielding or as construction feedstock with little processing.
Outpost potential	2	Surface gravity of about 9.2×10^{-4} m/s² means equipment must be anchored; escape speed is only about 1.5 m/s; sunlight is about 15.5% of earth's, marginal for solar power; radio delay up to 43 min one way.
Data confidence	3	Moderate.

Contained regolith: model estimate

Contained regolith = total mass (2.08×10^{13} kg, ASSUMED) × an assumed fraction of 50% / 70% / 90% (low / base / high, ASSUMED). This gives about 1.0×10^{10} / 1.5×10^{10} / 1.9×10^{10} tonnes. In-place content is not a reserve: only a tiny share could be extracted with any foreseeable technology, and Section 12 shows why price, not tonnage, decides value.



Source: SRI calc; content fractions are ASSUMED tiers (Appendix B), not measurements.

SECTION 7

Peer comparison

Peers are drawn from the 49 bodies in the SRI coverage set, matched on class (or, where few share the class, on type) and sorted by closeness in delta-v. Each peer's figures come from its own edition's sources; Δv and transfer time are SRI calc (INFERRED).

BODY	CLASS	DIAMETER (KM)	DENSITY (G/CM³)	ΔV (KM/S)	TRANSFER (YR)	DATA
4179 Toutatis	stony (S-complex)	2.45 INFERRED	2.70 ASSUMED	9.3	1.2	moderate
6489 Golevka	stony (S-complex)	0.530 MEASURED	2.70 INFERRED	9.2	1.1	moderate
17 Thetis	stony (S-complex)	84.9 MEASURED	3.21 INFERRED	9.5	1.1	moderate
1620 Geographos	stony (S-complex)	2.56 MEASURED	2.70 ASSUMED	9.5	0.6	moderate
951 Gaspra	stony (S-complex)	12.2 MEASURED	2.70 ASSUMED	8.8	1.0	moderate
532 Herculina	stony (S-complex)	168 MEASURED	2.70 ASSUMED	11.4	1.3	thin
65803 Didymos	stony (S-complex)	0.780 MEASURED	2.17 MEASURED	7.0	0.8	rich

Pattern. Toutatis ranks 4 of 7 on delta-v within this peer group. Better-measured peers can serve as analogues for what remains unknown here.

Implication: for a resource venture, the best target in any class is the one that combines low delta-v with measured composition. Bodies with assumed densities should be treated as candidates for characterisation, not as resource cases.

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. None of the companies below has announced Toutatis as a target in our sources; they 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), total raised $55M at the time [11]; TechCrunch (Sep 2026) reports $56M in venture funding [12] MEASURED	Odin launched 26 Feb 2025 on the IM-2 rideshare; contact lost, flyby of 2022 OB5 not achieved [13][14]. Next vehicle named DeepSpace-2 [14]
Karman+ (Colorado, US)	NEA regolith excavation; water for in-orbit refuelling; later metals	$20M seed (Feb 2025) co-led by Plural and Hummingbird [15] MEASURED	High Frontier demonstration targeting a 2027 launch; aims to mine ~1 kg; budget goal under $10M [15]
TransAstra (California, US)	Optical mining, Capture Bag, space logistics, asteroid detection	$2.5M NASA CCRPP contract matched by $2.5M private investment (Sep 2025) [16] MEASURED	1-m Capture Bag delivered to the ISS for testing (Sep 2025); scaling to 10 m [16]
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 [17]
Planetary Resources (US), historical	Asteroid prospecting	Acquired by ConsenSys in 2018 [18]	Assets later dispersed; a cautionary precedent
Deep Space Industries (US), historical	Asteroid mining; small-satellite propulsion	Acquired by Bradford Space in 2019 [18]	Pivoted to propulsion; a cautionary precedent

Ecosystem players that matter but are not miners

- **Launch providers.** Launch cost sets both the cost base of any venture and the ceiling price of any in-space product (Section 12).
- **Electric-propulsion suppliers.** NASA's Psyche was the first interplanetary use of Hall-effect thrusters; its SPT-140 units show the propulsion class a commercial deep-space bus would use [19].
- **Lunar landers and rideshare hosts.** Small asteroid probes have flown as secondary payloads on lunar missions (e.g., Odin on IM-2 [13]). 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 [18]. Today's cohort runs on much smaller budgets, and its first deep-space attempt, Odin, did not achieve its objective [13]. Diligence should weight demonstrated flight heritage, cost per attempt and non-mining revenue lines.

SECTION 9

Legal and regulatory

INSTRUMENT	KEY PROVISION FOR RESOURCE ACTIVITY	STATUS / RELEVANCE	SOURCE
Outer Space Treaty (1967)	Art. II: celestial bodies are not subject to national appropriation. Art. VI: States bear responsibility for national activities, including non-governmental ones, which need authorisation and continuing supervision	Foundation for every regime below; silent on ownership of extracted resources	UNOOSA [20]
US Commercial Space Launch Competitiveness Act (2015), Title IV	51 U.S.C. §51303: a US citizen engaged in commercial recovery of a space resource "shall be entitled to any asteroid resource or space resource obtained"	In force; covers extracted resources, not the body itself	Public Law 114-90 [21]
Luxembourg: Law of 20 July 2017	Space resources are capable of being appropriated; activities require national authorisation	In force	Legilux [22]
UAE: Federal Law No. 12 of 2019	Regulates authorised space-resource activities, including extraction, use and trade	In force	UAE Ministry of Justice [23]
Japan: Act No. 83 of 2021	Permit holders acquire ownership of resources extracted under an approved plan	In force	Cabinet Office [24]; Library of Congress [25]
Artemis Accords (2020–)	Resource extraction to comply with the OST; deconfliction via notified, temporary "safety zones"	77 signatories as of 19 Oct 2026 [26] MEASURED	NASA [26] [27]
UN COPUOS Working Group on Legal Aspects of Space Resource Activities	Drafting non-binding recommended principles	Draft principles updated during 2026; not binding	UNOOSA [28]

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 specific to Toutatis is low in the near term simply because no near-term activity there is plausible; the general risks (licensing regime, final COPUOS principles, operating-area disputes) still apply.

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.

SECTION 10

Risks, unknowns and data gaps

We state unknowns plainly. Rows marked ASSUMED or INFERRED are the places where this report relies on models rather than measurements.

UNKNOWN / RISK	WHY IT MATTERS	WHAT DATA WOULD CHANGE THIS
Bulk density (ASSUMED)	Mass, gravity and every tonnage figure scale with it	A mass measurement: spacecraft flyby or rendezvous, a companion moon, or gravitational perturbations
Size (INFERRED)	Volume scales with diameter cubed	Thermal-infrared measurement, stellar occultation or radar
Resource content (ASSUMED)	Sets the tonnage of regolith	Close-up spectroscopy; gamma-ray/neutron spectrometry; sample return
Surface and interior structure	Rubble pile vs coherent body changes excavation and anchoring	Imaging, gravity-field mapping, radar
Extraction technology	No small-body extraction demonstrated at any meaningful scale	Karman+ High Frontier (~1 kg target, 2027) [15]; follow-on demonstrations
Launch-cost trajectory	Cuts deployment cost but also the value of in-space product (Section 12)	Published $/kg for reusable heavy lift; rideshare price changes [29][30]
In-space demand	No anchor customer for space-sourced regolith found in our sources	Binding offtake contracts; in-space construction or refuelling programmes
Capital and execution	The previous cohort ended in acquisitions [18]; the Odin anomaly [13]	A successful rendezvous and landing by a private spacecraft
Legal acceptance	Market access, insurance, sovereign participation	Final COPUOS principles [28]; new national laws

SECTION 11

Ranked opportunity matrix

Ranked by SRI judgement using the scores in Section 6. Timing bands are SRI assumptions, not schedules.

OPPORTUNITY	TIMING	ATTRACTIVENESS (SRI)	EXECUTION RISK (SRI)	NOTE
Information asset: characterisation data and analysis	Now	High	Low	Size, mass and composition data improve every downstream estimate; existing data can be re-used as an analogue.
Technology demonstrations at more accessible analogues	5–10 yr	Medium	High	Lessons transfer to Toutatis later.
Bulk shielding / construction feedstock	15–25 yr	Low	High	Low value per kg; only works close to point of use.
Science-led partnerships (data, instruments)	Now–10 yr	Medium	Medium	Revenue from agencies rather than resources.

Bottom line: Toutatis is today mainly an information asset. Its data help calibrate how we read more accessible bodies of the same class; any commercial use of its regolith is a 20-year-plus question.

PART IV

What it could be worth

0.8×

base-case break-even delivered value as a multiple of launch cost (SRI model, illustrative, not a forecast). Section 12 and appendices.

Every input is an assumption you can change in the companion workbook.

SECTION 12

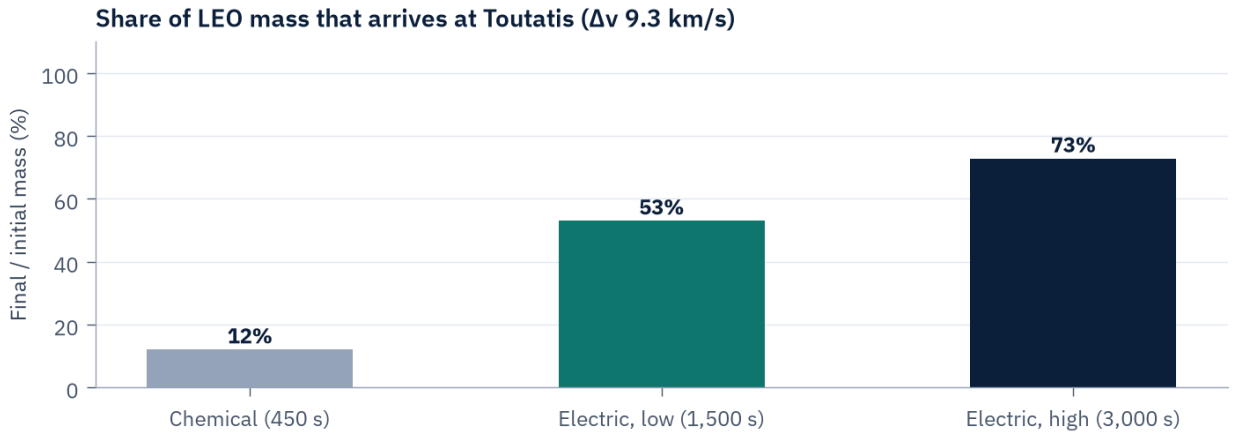
Valuation model

A transparent cash-flow model for a hypothetical venture supplying **bulk regolith for radiation shielding and construction feedstock** from Toutatis. Every default below is an SRI assumption unless a basis is given; the companion workbook contains the formulas and lets users change any input. Outputs are scenarios, not forecasts or a valuation of any company.

INPUT	UNIT	BEAR	BASE	BULL	BASIS
Launch cost to LEO	$/kg	2,720	1,410	500	Assumption
In-space regolith value (delivered)	$/kg	100	300	600	Assumption
Plant + spacecraft dry mass at the body	kg	20,000	10,000	5,000	Assumption
Propulsion specific impulse	s	450	1,500	3,000	Assumption
Delta-v, LEO to rendezvous (ideal impulsive)	km/s	9.34	9.34	9.34	Inferred
Programme capex excl. launch	$M	3,000	1,500	750	Assumption
Development period	years	8	6	5	Assumption
Outbound transit	years	2	1	1	Inferred / Assumption
Return transit (laden)	years	2	1	1	Assumption
Extraction rate	t/yr	100	1,000	5,000	Assumption
Usable regolith fraction of extracted material	fraction	0.50	0.70	0.90	Assumption
Transport efficiency (delivered / shipped)	fraction	0.50	0.70	0.85	Assumption
Operating years at body	years	10	10	10	Assumption
Annual operating cost	$M/yr	150	100	50	Assumption
Discount rate	%	15%	12%	10%	Assumption
Probability of technical success	fraction	0.20	0.35	0.50	Assumption

Scenario outputs

OUTPUT (SRI MODEL)	BEAR	BASE	BULL
Launch cost incl. propellant ($M)	452	27	3
NPV ($M)	-2,014	-961	6,492
Risk-adjusted NPV ($M)	-1,867	-1,013	2,961
Total regolith delivered (t)	250	4,900	38,250
First delivery year	13	9	8
Break-even delivered value ($/kg)	85,986	1,160	62
Break-even ÷ launch cost (×)	31.6	0.8	0.1



Source: SRI calc, rocket equation $m_1/m_0 = \exp(-\Delta v / g_0 Isp)$.

Model logic. Capex is spread evenly over development; launch cost (dry mass × rocket-equation mass ratio for the body's Δv at the chosen specific impulse × launch $/kg) is booked in the last development year. Operations start after the outbound transit; product delivered each operating year = extraction rate × usable fraction × transport efficiency, paid for after the return transit. Risk-adjusted NPV = −PV(capex + launch) + P(success) × PV(revenue − opex).

Key tension: launch cost appears twice, as a cost (launching the plant) and as the ceiling on what in-space product is worth (a buyer will not pay much more than the cost of launching the same mass from Earth). Scenarios that pair very cheap launch with a very high in-space value are internally inconsistent unless the product is used far beyond low Earth orbit.

Launch-cost anchors: Falcon 9 ≈ $2.7k/kg and Falcon Heavy ≈ $1.4k/kg to LEO in 2018 dollars (list price ÷ capacity) [29]; SpaceX's published rideshare rate is $350k for the first 50 kg plus $7k/kg [30]. Capex benchmarks: NASA Psyche life-cycle cost $985M including launch [31]; AstroForge Odin [13].

APPENDIX A

Appendix A: Sources

Sources 1–10 are those cited on toutatis.space for this body. Later sources are shared industry, legal and cost references reused across Space Resource Intelligence editions. Figures marked SRI calc are our own arithmetic (Appendix B).

[1] Small-Body Database Lookup: 4179 Toutatis. NASA JPL Solar System Dynamics. https://ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/?sstr=4179

[2] 4179 Toutatis. Wikipedia. https://en.wikipedia.org/wiki/4179_Toutatis

[3] Teutates. Wikipedia. https://en.wikipedia.org/wiki/Teutates

[4] Chang'e 2. Wikipedia. https://en.wikipedia.org/wiki/Chang%27e_2

[5] YORP effect. Wikipedia. https://en.wikipedia.org/wiki/YORP_effect

[6] Potentially hazardous object. Wikipedia. https://en.wikipedia.org/wiki/Potentially_hazardous_object

[7] Planetary Fact Sheet (orbit comparison). NASA NSSDCA. https://nssdc.gsfc.nasa.gov/planetary/factsheet/

[8] Carry, B. (2012). Density of asteroids. Planetary and Space Science 73, 98–118. Elsevier. https://doi.org/10.1016/j.pss.2012.03.009

[9] JPL Small-Body Database (SBDB) API record. NASA/JPL Solar System Dynamics. https://ssd-api.jpl.nasa.gov/sbdb.api?sstr=4179&phys-par=1

[10] Moon Facts (surface gravity about one-sixth of Earth's). NASA Science. https://science.nasa.gov/moon/facts/

[11] SpaceNews (Aug 2024). AstroForge raises $40 million. https://spacenews.com/astroforge-raises-40-million/

[12] TechCrunch (22 Sep 2026). AstroForge is putting AI in command of its next spacecraft. https://techcrunch.com/2026/09/22/astroforge-is-putting-ai-in-command-of-its-next-spacecraft/

[13] Space.com (Mar 2025). Hope is all but lost for private Odin asteroid probe in deep space. https://www.space.com/space-exploration/private-spaceflight/hope-is-all-but-lost-for-private-asteroid-probe-in-deep-space-the-chance-of-talking-with-odin-is-minimal

[14] AstroForge, Odin page. https://www.astroforge.com/odin-mission

[15] Karman+ press release (19 Feb 2025), "Karman+ raises $20 million to mine asteroids to supply the space economy"; Payload (21 Feb 2025), "Karman+ Raises $20M For Asteroid Mining Demo." https://www.karmanplus.com/karman-raises-20-million-to-mine-asteroids-to-supply-the-space-economy-2/ ; https://payloadspace.com/karman-raises-20m-for-asteroid-mining-demo/

[16] ACCESS Newswire (23 Sep 2025). TransAstra Secures $5M to Scale Asteroid Capture Technology With NASA and Private Investment. https://www.accessnewswire.com/newsroom/en/aerospace-and-defense/transastra-secures-5m-to-scale-asteroid-capture-technology-with-nasa-and-priv-1077114

[17] SpaceNews (2021). China launches space mining test spacecraft on commercial rideshare mission. https://spacenews.com/china-launches-space-mining-test-spacecraft-on-commercial-rideshare-mission/

[18] SpaceNews: "Asteroid mining company Planetary Resources acquired by blockchain firm" (2018); "Deep Space Industries acquired by Bradford Space" (2019). https://spacenews.com/asteroid-mining-company-planetary-resources-acquired-by-blockchain-firm/ ; https://spacenews.com/deep-space-industries-acquired-by-bradford-space/

[19] IEPC-2024-126, "Psyche Launch and Initial Checkout Overview," International Electric Propulsion Conference 2024 (SPT-140 Hall-effect thrusters). https://electricrocket.org/IEPC_2024/126.pdf

[20] UNOOSA. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (1967). https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html

[21] U.S. Commercial Space Launch Competitiveness Act, Public Law 114-90 (H.R. 2262, 2015), Title IV; 51 U.S.C. §51303. https://www.congress.gov/bill/114th-congress/house-bill/2262 ; https://www.law.cornell.edu/uscode/text/51/51303

[22] Luxembourg. Law of 20 July 2017 on the exploration and use of space resources. https://legilux.public.lu/eli/etat/leg/loi/2017/07/20/a674/jo/en

[23] United Arab Emirates. Federal Law No. (12) of 2019 on the Regulation of the Space Sector. https://www.moj.gov.ae/assets/2020/Federal%20Law%20No%2012%20of%202019%20on%20THE%20REGULATION%20OF%20THE%20SPACE%20SECTOR.pdf.aspx

[24] Japan. Act No. 83 of 2021 on the Promotion of Business Activities Related to the Exploration and Development of Space Resources (Cabinet Office English translation). https://www8.cao.go.jp/space/english/resource/documents/act83_2021.pdf

[25] Library of Congress, Global Legal Monitor (15 Sep 2021). Japan: Space Resources Act Enacted. https://www.loc.gov/item/global-legal-monitor/2021-09-15/japan-space-resources-act-enacted/

[26] NASA (20 Oct 2026). NASA Welcomes Uzbekistan as Newest Artemis Accords Signatory. https://www.nasa.gov/organizations/oiir/artemis-accords/nasa-welcomes-uzbekistan-as-newest-artemis-accords-signatory/

[27] NASA. Artemis Accords overview and text (2020). https://www.nasa.gov/artemis-accords/

[28] UNOOSA. Working Group on Legal Aspects of Space Resource Activities; updated initial draft set of recommended principles (2026). https://www.unoosa.org/oosa/en/ourwork/copuos/lsc/space-resources/index.html

[29] Jones, H.W. (2018). The Recent Large Reduction in Space Launch Cost. 48th International Conference on Environmental Systems, ICES-2018-81. NASA NTRS 20200001093. https://ntrs.nasa.gov/citations/20200001093

[30] New Space Economy (27 Feb 2026). SpaceX Rideshare Pricing as of February 2026 (citing spacex.com/rideshare). https://newspaceeconomy.ca/2026/02/27/spacex-rideshare-pricing-as-of-february-2026-what-it-costs-whats-included-and-how-buyers-budget-a-mission/

[31] NASA statement on Psyche launch delay and independent review, including the $985M life-cycle cost (2022), via PR Newswire. https://www.prnewswire.com/news-releases/nasa-announces-launch-delay-for-psyche-asteroid-mission-301575060.html

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APPENDIX B

Appendix B: Methodology and assumptions

Grades

MEASURED : published measurement in a cited source. INFERRED : derived by SRI arithmetic from measured inputs, or estimated by the source rather than measured directly. ASSUMED : an SRI assumption, with its basis stated. A figure computed from an assumed input is itself graded ASSUMED .

Formulas (SRI calc)

- Volume = $(\pi/6)\cdot D^3$ (sphere-equivalent); mass = density × volume when no mass is published.
- Surface gravity $g = GM/r^2$; escape speed = $\sqrt{(2GM/r)}$.
- Equilibrium temperature $T = 278.6\ K \times (1 - A)^{1/4} / \sqrt{r(au)}$, with Bond albedo A approximated from the geometric albedo.
- Sunlight fraction = $1/r(au)^2$ at mean distance; light-time = distance / c.
- Δv: two-impulse Hohmann transfer from a 300-km circular LEO (heliocentric bodies include a plane change at the far node); for moons, a Hohmann transfer to the parent planet, capture, then transfer to the moon's orbit.
- Rocket equation: mass ratio = $\exp(\Delta v / (g_0 \cdot Isp))$, $g_0 = 9.80665\ m/s^2$.

Assumptions specific to this edition

- Bulk density assumed at 2.70 g/cm³: assumed; a round value typical of S-complex asteroids (Carry 2012).
- Diameter 2.45 km: volume-equivalent of the 4.26 × 2.03 × 1.70 km Chang'e 2 extent (SRI calc).
- Contained-regolith fractions of 50 / 70 / 90% of total mass are SRI assumptions chosen to bracket plausible values for the stony (S-complex) class.
- All valuation defaults (Section 12) are SRI assumptions unless a basis is cited.

Rule-based scores

SCORE	RULE
Access	Δv from LEO: <6 km/s = 5, 6–8 = 4, 8–10 = 3, 10–12 = 2, ≥12 = 1; minus 1 if ideal transfer >5 yr, minus 2 if >15 yr.
Mining (metals)	Metal (M-type) = 4 (3 if measured density <3.5 g/cm³); stony or carbonaceous = 2; other classes = 1.
Fuel / volatiles	Comet = 5; carbonaceous = 4; TNO or icy small moon = 3; irregular or dark inner moon (composition unmeasured) = 2; stony or metal = 1.

SCORE	RULE
Materials	Metal = 4; stony or carbonaceous = 3; other = 2 (bulk regolith for shielding is assumed available on every body).
Outpost potential	Start at 3; −1 if sunlight <4% of Earth's (−2 if <0.2%); −1 if one-way light-time can exceed 30 min; −1 if surface gravity <0.001 m/s²; +1 if diameter >100 km; +1 if near-Earth object.
Data confidence	Rich data (spacecraft visit or measured mass) = 5; moderate = 3; thin (size from brightness, density assumed) = 1.

Limitations. This is a sample-edition desk study. It relies on published sources and simple physics; it does not replace mission design, geological assessment or legal advice. Nothing here is investment advice.