

What the Mars Plan Overlooks

Closure, Seams and the State of the Net: a Simpler and Cheaper Road to a Self-Sustaining City on Mars

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Abstract

SpaceX has stated its goal precisely. A city on Mars must survive "if the resupply ships stop coming from Earth for any reason whatsoever". Its rough size is "not less than a million tons". The current plan reaches it by transport: about 1,000 ships of about 100 t per launch window, for about 20 years.

This article reads that plan with one theory, the Vacuum.Net Theory. The theory has one selection rule: what closes in phase stays; what does not close passes on as tension. The article states the theory from its axioms, with the proofs it uses. No earlier text is needed to follow it.

The theory makes seven things visible that the plan does not weigh:

1. The goal is a closure criterion. The plan optimises transport.
2. A closed loop can be built and measured on Earth first.
3. What must travel is the description and the seed. Most of the mass is already on Mars.
4. Every seam between two differently closed systems carries at least one open window. Seams can be counted, and the plan has many.
5. What does not close at one scale is material for the next. A ship that lands one way is 100 t of steel on Mars.
6. Read with the theory, weight can be a state of the net, not only a property of mass. One route to change it is closed. A second route is open, and a cheap weighing test can decide one branch of it.
7. The theory holds where it counts closures and is not yet beyond chance where it fixes sizes. The history of the Mars plan shows the same split. On this reading, a plan steered by counts is more robust than a plan steered by tonnage and dollars.

The article computes, for a combined route, how much mass must still come from Earth. It gives every number with its derivation and its status. It names the executor of every computation and every test. All computations were done by Claude Code. An independent judge, also run by Claude Code with its own code, recomputed every number.

How to read the statuses

Every statement in this article carries exactly one status. The convention is that of the theory itself, with one addition: assumption.

Status	Meaning
proven	follows from the axioms and definitions by the proof given
computed	obtained by a stated procedure or algorithm
measured	a published measurement
input	taken from a named source and used as given
corresponded	set beside a published measurement, with the numbers
reading	a pairing of a theoretical quantity with a measured one, without a test
hypothesis	a claim with a test fixed in advance, not yet decided
assumption	a number chosen to compute with, with the reason stated
open	not yet settled

A reading is never a result. Where the article applies the theory to a ship, a greenhouse or a settlement, the status is reading, unless a test is given.

1. The goal and its measure

1.1 The criterion

The goal is fixed in SpaceX's own words. A city on Mars must survive "if the resupply ships stop coming from Earth for any reason whatsoever". "You can't be missing anything." The order of magnitude is "probably not less than a million tons" (CNBC, 9 March 2020) [input].

This is a criterion of closure. A city meets it when every loop it depends on returns on itself without imports. The criterion has no time limit. One missed launch window is therefore a lower bound on the test, not the test [reading].

1.2 The plan in numbers

The plan is internally consistent. In January 2020: "1000 ships depart over ~30 days every 26 months" [input]. In November 2019, as reported by Ubergizmo: about 20 years to transfer a million tons [input].

Step by step [computed]:

1. Synodic period Earth–Mars: 779.94 days = 25.62 months.
2. Windows in 20 years: $20 \times 365.25 / 779.94 = 9.37$.
3. Mass: 1,000 ships $\times$ 100 t $\times$ 9.37 = 0.94 Mt. With about ten windows: 1.0 Mt.
4. Landings: 10,000.

What the transport costs depends on the propellant per landed ton. Two bases bracket it [computed; assumptions labelled]:

Basis	Mass to low Earth orbit	Launches	Per day over 20 years	Energy
minimum Δv : 5.775 t in LEO per t landed	5.78 Mt	38,000–58,000	5.3–7.9	610–915 TWh

design case: full tank of 1,600 t	17 Mt	117,000– 170,000	16–23	1,849–2,695 TWh
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Basis [assumptions labelled]: in the minimum case, Δv is 4.3 km/s from LEO to the surface with aerocapture, the ship is 120 t dry and the exhaust gives Isp 380 s. The mass ratio is 3.17, so $2.17 \times 220 \text{ t} = 477 \text{ t}$ of propellant plus 100 t of payload: 5.775 t in LEO per t landed. In the design case a full tank of 1,600 t plus 100 t of payload gives 17 t in LEO per t landed. Tankers carry 100–150 t. One launch burns 5,250 t of propellant (3,650 t booster + 1,600 t ship) at an oxidiser ratio of 3.6: 1,141 t CH₄ at 50 MJ/kg, 15.85 GWh and 3,139 t CO₂.

The design case needs 11–16 tanker flights per full tank. The 2017 plan named 3–5 [input; the difference is open].

Further numbers for the design case [computed]:

- Propellant alone at \$168 per ton: \$103–150 billion.
- Propellant per landed ton: \$103,000–150,000. The 2017 estimate was about \$140,000 per ton in total.
- CO₂ from combustion: $3.7\text{--}5.3 \times 10^8 \text{ t}$.

Ship-to-ship propellant transfer has not been demonstrated. Starship reached orbit for the first time on 28 September 2026, on flight 14 [input; AIAA news, 28 September 2026].

1.3 Where the million tons goes

How much one person needs from Earth over 20 years depends on what closes locally. The table builds up the closure loop by loop [computed from stated assumptions; sources in the reference list]:

What closes locally	t per person (20 years)	Persons per Mt
nothing	48.0	20,835
+ oxygen and water	31.9	31,383
+ a shell of regolith	28.7	34,826
+ food at the level of Lunar Palace 365	26.5	37,712
+ all food	25.3	39,473
+ 90 % of machines, life support, growing systems	3.7	267,809
+ 90 % of energy	2.8	351,074
food, O ₂ , water 100 %; rest 1 %	0.28	3,510,743

The components per person [assumptions]: habitat 3.5 t, fission power 0.98 t (6.56 kW at 150 kg/kWe), life support 1.0 t, growing systems 1.0 t and tools 10 t. Spares run at 5 % per year of 12 t of equipment: 12 t over 20 years. Per year: O₂ 0.307 t (0.84 kg/day), water make-up 0.5 t, food 0.219 t (0.6 kg/day dry).

The largest single step is machines: a factor 6.8 [computed]. It rests on two assumptions without a source: tools of 10 t per person and spare parts of 12 t over 20 years [assumption; open]. The direction holds whatever their size. The mass sits in the kind of machine.

A habitat shell alone weighs 11.25 t per person. That is a 90 t control mass for 8 crew (Howard et al., ASCEND 2023) [computed from input]. A million people with habitats from Earth would need 11–13 Mt: 11–13 times the whole plan [computed]. The plan works only if the habitats arise on Mars [reading].

2. The theory, stated from its axioms

This section gives everything the rest of the article uses. The source is "The Vacuum.Net Theory: Definition, Theorems and Tests", version 4 (Konstapel 2026). Proofs are given in full.

2.1 The picture

The theory describes everything that stays as one strand that crosses itself. Where the strand meets itself, it forms a knot. Between strands lies an opening: a mesh. Every crossing carries a value in the balanced ternary register: +1, 0 or −1. One rule selects: a group of three crossings closes when its values sum to zero modulo 3. What closes stays. What does not close passes on as tension.

A fishing net is a fair image. The knots are matter. The meshes are what we call empty space. Pull one knot and the whole net feels it. A tight net is stiff. A slack net is soft.

2.2 Signature

- An ordered index set I : the course of the strand.
- A set P of places.
- The strand: a map $\sigma: I \rightarrow P$.
- A **touching** is a pair $i < j$ in I with $\sigma(i) = \sigma(j)$.
- A **knot** is a place x with at least two indices in $\sigma^{-1}(x)$.
- A **trit** $\tau(i, j) \in \mathbb{Z}_3$ is assigned to each touching.
- A **window** is three touchings that follow each other in the order of I .
- A window **closes** when the sum of its three trits is 0 in $\mathbb{Z}_3$.

2.3 Axioms

N1 (Strand). There is exactly one strand σ . Every distinction is a touching.

N2 (Closure). A touching persists if and only if it lies in a closed window. What does not close passes on as tension.

N3 (Memory). At every knot the passages are ordered by I . The first passage fixes the orientation. The trits of later passages are taken relative to it.

N4 (Context). Every constant of the theory is a function of σ , not a fixed number.

N5 (Scale). Let κ_λ merge places into blocks of λ^3 . The coarse strand $\kappa_\lambda \circ \sigma$ satisfies N1 to N4 again. What does not close at one scale is the material of the next.

2.4 Definitions used here

- **Winding.** A part of the strand that returns on itself in phase.
- **Mesh.** An opening between strands, with an extent in space or in time.

- **Natural units.** The theory takes four inputs from CODATA 2018: the Rydberg constant, the proton-to-electron mass ratio, c and h . From them, with $R_H = R_\infty/(1 + m_e/m_p)$ [computed]:
 - length $S_0 = 1/(2R_H) = 4.5588167 \times 10^{-8} \text{ m}$ (45.588 nm);
 - time $T_0 = S_0/c = 1.5206576 \times 10^{-16} \text{ s}$;
 - energy $E_0 = h/T_0 = 27.196575 \text{ eV}$, the Hartree energy of hydrogen with its reduced mass.

2.5 The theorems this article uses

Theorem 1 (Passage). Energy per unit time has dimension $1/S$. *Proven.*

Proof. In the dimensional ladder every magnitude is written as $S^x T^y$, and motion is S/T . Energy has dimension T/S . Divided by T it gives $1/S$. ■

So passage through a mesh scales with one over its open size. A small mesh passes much. Read for engineering, this matches a familiar fact: what closes locally does not need to be carried through the long chain from Earth [reading].

Theorem 2 (Mass to energy). Mass times the square of motion has the dimension of energy. *Proven.*

Proof. $(T^3/S^3) \cdot (S/T)^2 = T/S$. ■

Mass is a knot: a closure of dimension T^3/S^3 . To open a knot costs its full closure, mc^2 [reading of Theorem 2 with the rung of mass].

Theorem 4 (Nine of twenty-seven). Exactly 9 of the 27 windows close. They form a subgroup of $\mathbb{Z}_3^3$ of index 3. *Proven; checked by enumeration.*

Proof. The sum map $\mathbb{Z}_3^3 \rightarrow \mathbb{Z}_3$ is a surjective homomorphism. The closing windows are its kernel, of order $27/3 = 9$. ■

Theorem 5 (Two kinds of closure). A window closes if and only if its trits are all equal or all different. *Proven; enumeration gives 3 and 6.*

Proof. All equal gives $3a \equiv 0$. All different gives $0 + 1 + 2 \equiv 0$. Two equal and one different gives $2a + b \equiv 0$. Since $2 \equiv -1$, that means $b \equiv a$, a contradiction. ■

There are therefore exactly two kinds of closure: uniform (all equal, 3 cases) and complementary (all different, 6 cases).

Seam lemma. At a seam between two closed triples, two windows straddle the boundary. Both close only if the two triples are equal. *Proven.*

Proof. Let (a, b, c) and (d, e, f) close. If $b + c + d \equiv 0$ and $c + d + e \equiv 0$, then $d \equiv -(b + c) \equiv a$, $e \equiv b$, and $f \equiv c$. ■

So a seam between two differently closed structures always carries at least one open window [proven for trits].

The judges of this study checked the lemma by enumeration [computed]:

- a uniform block beside a complementary block: in 0 of 18 cases do both straddling windows close; 12 of the 36 single windows do;
- 72 ordered pairs of distinct closed triples: in 0 cases do both straddling windows close; 36 of the 144 single windows do;
- two uniform blocks of different value: every straddling window is open.

Carrying this to engineering is a reading. A seam between steel and ceramic, or between a greenhouse and a concrete wall, is not a trit window. What the reading gives is a count: the number of seams between differently closed subsystems. That count can be fixed before the data are read, and then tested.

Lemma 1 (Closure probability). For independent trits with law (p_0, p_1, p_2) , a window closes with probability $(1/3) \cdot [1 + \hat{p}(\omega)^3 + \hat{p}(\omega^2)^3]$, where $\hat{p}(z) = p_0 + p_1 z + p_2 z^2$ and $\omega = e^{(2\pi i/3)}$. *Proven.* The uniform law gives $1/3$. The law $(2/3, 1/6, 1/6)$ gives $5/12$. *Computed.*

Proof. The indicator of $s \equiv 0 \pmod{3}$ is $(1/3) \cdot \sum_k \omega^{ks}$. Take expectations over independent entries. ■

Check of 5/12 [computed]: $\hat{p}(\omega) = 2/3 + (\omega + \omega^2)/6 = 2/3 - 1/6 = 1/2$. Likewise $\hat{p}(\omega^2) = 1/2$. So $(1/3)(1 + 1/8 + 1/8) = 5/12$.

Theorem 9 (Coupling law). Let $e(n)$ be a smooth closing energy as a function of a density n . Write $\bar{g} = e''(\bar{n})$, $\gamma = \bar{n} \cdot e'''(\bar{n})/e''(\bar{n})$ and $\delta = (n - \bar{n})/\bar{n}$. The local coupling is $e''(n) = \bar{g} \cdot (1 + \gamma\delta) + O(\delta^2)$. For a cubic $e(n)$ it is exact. *Proven.*

Proof. Expand $e''(\bar{n} + \bar{n}\delta) = e''(\bar{n}) + e'''(\bar{n}) \cdot \bar{n}\delta + O(\delta^2)$. ■

This is the formal content of N4. A coupling is not a fixed number. It moves with the local state δ , with lever γ .

Theorem 10 (Estimator). If a density fluctuates with weight proportional to $\exp(-N \cdot f(x))$, where $f(x) = (a/2)x^2 + (b/6)x^3 + \dots$, then $-\bar{n} \cdot \kappa_3/\kappa_2^2 = \bar{n} \cdot b/a + O(1/N)$. With $f = e$ this is γ . *Proven in v4.*

Theorem 11 (Lever in the path realisation). Let σ be a free lattice path in $d \geq 3$ dimensions. Its returns to a visited place are independent, with probability P_d . Then $\gamma = -(1 + P_d)/P_d$. *Proven.*

Proof. The number of passages X at a place is geometric with ratio P_d . With $q = 1 - P_d$: mean $1/q$, $\kappa_2 = (1 - q)/q^2$, $\kappa_3 = (1 - q)(2 - q)/q^3$. Theorem 10 gives the lever as $-\bar{n} \cdot \kappa_3/\kappa_2^2$. This equals $-(2 - q)/(1 - q) = -(1 + P_d)/P_d$. ■

For $d = 3$, $P_3 = 0.340537$ (Watson 1939). So $\gamma = -3.9365$ [computed]. A note on the wording: v4 says the observer "counts the passages it sees minus one". The proof uses the full count X . With $X - 1$ the lever would be -1.34 . The formula holds as proved; the words "minus one" should go [computed; a gap in the wording of v4].

2.6 What the theory has shown so far

The library of the theory fixed tests in advance and ran them. The result has a clear pattern (v4 §8.2) [computed in the library]:

Where the theory counts closures, it holds:

- colour confinement: all six measured kinds of hadron inside;
- calendar cycles as convergents of year over month;

- bonding within the derived potential: 91 of 93 compounds;
- alkanes as trees of degree at most four: all up to C_{12} ;
- layers of self-maintained hierarchies with step 2–4.5: two blind rounds, all decided cases fit.

Where the theory fixes a size, nothing is yet beyond chance:

- the Lamb shift from the net's rule: a factor 83 off;
- the step between brain rhythms: failed;
- a critical exponent: 1 predicted, 1.26 measured;
- tension thresholds as alarms: failed three times.

Several counts are also standard results: $SU(3)$ triality, valence. There the theory reproduces; it does not yet discriminate. The sizes each needed a value the axioms do not supply.

This split is the most useful thing the theory gives an engineer. It says what to trust: counts of closures and seams. It says what not to take from it: a coefficient, a threshold, a size.

2.7 How the theory is applied in this article

Six translations carry the theory to the plan. Each is a reading.

Theory	Engineering
closure (N2)	a loop that returns on itself without import: air, water, food, parts
tension (N2)	what does not close: an import stream
seam (Theorem 5)	an interface between two differently closed subsystems
first passage fixes orientation (N3)	the description and the seed travel; the bulk does not
next scale (N5)	what one loop leaves over is feedstock for the next
constants as state (N4, Theorem 9)	a coupling, including weight, can depend on the local state

The article uses only these. It does not tell a story of what causes what. It counts what closes, what stays open, and what it costs.

3. What the plan overlooks

Each finding has the same order: the step from the theory, the numbers, the decision it offers, and the first test with its executor.

3.1 The goal is closure; the plan is passage

Step from the theory. By N2, what closes stays and what does not close passes on as tension. A city that survives without ships is a set of windings that return in phase without the passage from Earth [reading]. An import stream is the form tension takes for a settlement [reading].

Numbers. The plan measures progress in tons landed: 1 Mt, 10,000 landings, 38,000–170,000 launches (§1.2) [computed]. None of these numbers says whether the city closes. Table 1.3 shows what does: the mass needed per person falls from 48 t to 0.28 t as loops close [computed from

assumptions]. The same million tons supports 20,835 people with nothing closed, or 3.5 million with food, air and water closed and 99 % of the rest local.

Decision. Measure the plan by closure fractions per loop, not by tons. The tons can be read off the closure fractions. The closure cannot be read off the tons.

First test. Claude Code writes the closure ledger of the city: one row per loop (O_2 , water, food, solid waste, nitrogen, metals, polymers, electronics, energy). Each row gets the measured closure where one exists, and "open" where none exists. The ledger is fixed before any architecture is chosen.

3.2 Close on Earth first

Step from the theory. A settlement off Earth adds seams to what a closed test on Earth leaves open. It cannot close better than that test [reading]. By N5, what a greenhouse leaves open is material for the next scale, the transport line [reading].

Numbers [measured unless marked]:

- Lunar Palace 365 (Fu et al. 2021): 370 days, crew of 4 at a time in two shifts, 160 m², 500 m³, 120 m² of crops.
- O_2 and water closed 100 %. Urine 99.7 %. Solid waste 67 %. Food 73 % dry. Overall closure 98.2 %.
- Cabin gas leakage 0.043 % per day.
- The open part is food and solid waste, not air and water.
- From 98.2 % to 99 % closure: imports 1.8 × lower. To 99.9 %: 18 × lower [computed].
- For 99.9 %, food closure must rise from 73 % to about 98.5 % [computed; assumption: the open share scales with food].
- Full food closure at the same yield: 41 m² per person [computed, linear]. NASA: 40–50 m² or more (Johnson et al. 2021) [input].
- Biosphere 2: O_2 fell from 20.9 to 14.5 % in 16 months through soil microbes and CO_2 bound in concrete. The group split into two factions.
- BIOS-3: about 20 % of minerals and 40 % of nitrogen retained.

Decision. Close the food and solid-waste seam in a sealed greenhouse on Earth, with a crew of human size, before the first settlement ship leaves. This costs a building and volunteers, not rockets. Every percent gained divides the import stream of the whole plan.

First test. Claude Code counts, in the Lunar Palace tables, the number of crop species against food closure, and fixes the target closure per loop. The physical run belongs to a group with the method: the Lunar Palace team (Beihang University) or Biosphere 2 (University of Arizona). There is no agreement.

Added by the theory [reading on a proven count]. Lemma 1 gives $P = 1/3 + (2/3) \cdot \text{Re}[\hat{p}(\omega)^3]$. For a law with one dominant value and two equal others, $(p, (1-p)/2, (1-p)/2)$ with $p > 1/3$, $\hat{p}(\omega) = (3p - 1)/2 > 0$. Such a law closes more often than the uniform law: 5/12 against 1/3 at $p = 2/3$. Other skews close less: $(1/2, 1/2, 0)$ gives 1/4. A loop in which one rest state dominates and the other two are balanced would close more often. This is a direction to try, not a size.

3.3 Send the address, not the mass

Step from the theory. By N3, the first passage fixes the orientation; later passages are taken relative to it. What must travel is the orientation: the description, the seed, the genome. The bulk is

found where the winding closes [reading]. In the theory's own terms an element is an address plus a state. Rearranging what is already there is cheap; opening a knot is not.

The energy order of making [computed from input]:

Operation	Energy
rearrange (chemistry)	$\sim 10^5$ J/mol
shift an address (e.g. ^{163}Dy)	4.85×10^9 J/mol
open a closure	9.0×10^{13} J/mol

Mars material is oxidised, so rearranging starts with reduction [computed from standard enthalpies of formation]:

Product	MJ/kg	× lift to LEO (33.1 MJ/kg)
Fe from Fe_2O_3	7.4	0.22
O_2 from H_2O	17.9	0.54
Ti from TiO_2	19.7	0.60
Al from Al_2O_3	31.1	0.94
Si from SiO_2	32.4	0.98

The lift to LEO is 29.4 MJ/kg kinetic plus 3.7 MJ/kg potential = 33.1 MJ/kg [computed]. A real rocket delivers about 7 % of its propellant energy to the payload, so the real lift costs about 473 MJ/kg [computed; assumption $\sim 5,000$ t propellant at ~ 10 MJ/kg for 100–150 t]. Real reduction processes cost 2–5 × their minimum. Making on Mars stays cheaper than lifting from Earth by a real margin.

The seed [input]:

- Metzger et al. 2016: a first set of 7.7 t, 64 kW, three robots; 20 kg of regolith per hour in, 4 kg of parts per hour out.
- 12 t landed grows to 156 t in about 20 years. 41 t launched reaches 40,000 t "at the end of bootstrapping"; the paper gives no year for that case. Electronics made locally: 90 % in generation 3.0, 95 % in 4.0, 99 % in 5.0, 100 % in 6.0, with generations about 2 years apart.
- Chirikjian et al. 2002: robots without microprocessors, with relays and simple tubes, casting in moulds of sintered regolith.
- Sulphur concrete with Mars simulant: > 50 MPa, fully reusable by remelting [measured].
- Plants grew 50 days on Mars simulant without additions (Wamelink et al. 2014) [measured]. Perchlorate at 0.3–0.5 wt % is the open seam [input].
- Cyanobacteria grow on Mars gas at 100 hPa (Verseux et al. 2021) [measured].
- Biomining of rare-earth elements from basalt works at simulated Mars gravity (Cockell et al. 2020) [measured].

The number that steers the route [reading]. Not the number of ships, but f: the share of each new machine that cannot be made on Mars. The import is f times the growth of the installations.

The combined route, computed. Claude Code computed the Earth mass for one combined route. It closes on Earth first and lands a seed of 41 t. It makes O₂, water and building material locally, sends a founding crew, and carries genetic breadth as frozen gametes. An independent judge recomputed it with its own code, re-opened Metzger, Kleinhenz & Paz and Lunar Palace, and corrected four inputs. The numbers below are the judge's.

The model [computed]:

$$M_{\text{Earth}} = \text{seed} + f \cdot (P \cdot m_{\text{grown}} - \text{seed}) + P \cdot \text{liner} + P \cdot c \cdot t_{\text{b}} + P \cdot m_{\text{person}}$$

with these inputs, each derived from table 1.3 and its sources:

- seed = 41 t landed [input, Metzger].
- m_{grown} = installed mass per person grown on Mars: 24.96 t (low) to 28.46 t (high), plus the power for manufacturing [computed]. Of the 24.96 t, 23.98 t is machines, tools, life support and growing systems; 0.98 t is a fission plant for 6.56 kW per person at 150 kg/kWe. Manufacturing takes 15–162 MJ per kg grown.
- liner = 0.35 t per person: 10 % of a 3.5 t habitat, the pressure liner of a habitat whose shell is regolith [computed]. The high case carries the full 3.5 t habitat inside m_{grown} instead.
- c = 0.307 + 0.5 + 0.219 = 1.026 t per person per year of O₂, water and food until the local loops close [computed].
- t_b = 2.0–4.3 years of bridge: one to two synodic periods [assumption; valid only if people arrive in step with capacity].
- m_{person} = 0.5–1.0 t per traveller: body, suit, personal items [assumption, no source].
- Growth at Metzger's rate, 41 → 40,000 t, doubling every 2.0 years [reading: a Moon model used on Mars].

People P	f	Earth mass, t	Share of 1 Mt	Landings	Windows	Years of growth	Import per window after closure, t
110	0	360–636	0.04–0.06 %	4–7	7	12.2–12.8	0
110	5%	496–801	0.05–0.08 %	5–9	7	12.2–12.8	7
110	20%	904–1,294	0.09–0.13 %	10–13	7	12.2–12.8	28
1,000	0	2,943–5,152	0.29–0.55 %	30–55	10	18.6–19.1	0
1,000	5%	4,194–6,832	0.42–0.69 %	42–70	10	18.6–19.1	64
1,000	20%	7,946–11,275	0.79–1.14 %	80–114	10	18.6–19.1	256
10,000	0	29,060–51,157	2.9–5.4 %	291–512	13–14	25.3–25.8	0
10,000	5%	41,573–68,832	4.2–6.9 %	416–688	13–14	25.3–25.8	640
10,000	20%	79,111–112,821	7.9–11.3 %	792–1,129	13–14	25.3–25.8	2,558
current plan	—	1,000,000	100%	10,000	~10	~20	not stated

What the table says [computed]:

- A city of 1,000 people needs 0.3–1.1 % of the planned mass from Earth: 30–114 landings instead of 10,000.
- At $f \leq 5$ % the largest term is not the import of parts but the consumables of the bridge years. For 1,000 people at 5 %: 2,052 t of 4,194 t. Closing water, oxygen and food early, on Earth first (§3.2), is therefore worth more than any lift improvement.

- The rows for 10,000 people need $6-7 \times$ Metzger's end point. They are extrapolation.

The criterion itself [computed]. With $f > 0$ the import never stops. Spare parts wear at $0.05 \times (10 + 0.98 + 1.0) t = 0.6 t$ per person per year, and f of that must come from Earth for ever. "Any reason whatsoever" admits no stockpile that lasts. So the plan meets the criterion only at $f = 0$ for every class of part. In Metzger's schedule that is generation 6.0, about year 10 [input, model; never run]. If f falls to 0 by then, the total import is bounded by $f \times 1,240 t$: at most 248 t, whatever the population.

Not in the table [computed]. A return flight needs a propellant plant on Mars: about 236 t per return ship per window for a 1,200 t return load: 25 plants of 1.7 t and 1.29 MW of fission power at 150 kg/kWe. It is not needed for closure. Ships kept as scrap steel would add 17–22 % to the grown target, on an assumed dry mass of 100–120 t.

Decision. Ship a seed and its description, then the people who tend it. Spend engineering on lowering f , class by class: electronics, bearings, seals, catalysts, sensors.

First test. Claude Code runs Metzger's model with Mars inputs and counts, per generation, which part classes must still be imported. Physical work: Metzger (University of Central Florida) and NASA KSC Swamp Works. There is no agreement.

3.4 Count the seams

Step from the theory. By Theorem 5 and the seam lemma of §2.5, every boundary between two differently closed structures carries at least one open window. Every interface between two differently closed subsystems is therefore a candidate seam [proven for trits; the count in machines is a reading].

The heat shield. The steel hull is closed for cryogenic cold; the ceramic tile is closed for heat. Their attachment and the tile gaps form the seam. Recovered ships show scuffed and missing tiles. The theory says a seam does not close; it only moves. Standard engineering says the same from the mismatch in thermal expansion. Here the theory reproduces; it does not yet discriminate.

Hypothesis H-S1 [hypothesis, plan fixed in advance]. On the inspection photographs of recovered upper stages, tile loss lies on seams (tile edges, flap transitions, hinges) more often than the seam share of the surface.

- *Plan.* Claude Code marks, before counting, which share of the visible surface is seam. Then it counts missing or scuffed tiles per category.
- *Fails if* the loss share on seams is not larger than the seam share of the surface at the 5 % level.
- *Limit.* The public photographs may be too few.
- *If it holds:* the gain lies in fewer seams, not in better tiles.

The transport chain, normalised to the transfer to Mars [reading]. Counting rule: one seam for ground–booster, one for booster–ship, one per docking or propellant transfer.

Chain	Seams
Starship, design case	13–18
Starship, minimum case (3–5 tankers)	5–7
electromagnetic launch tunnel (StarTram) + transfer stage	5–6

Each propellant transfer is a seam. It has never been demonstrated.

Ways to remove seams [input and computed]:

- **One-way ships.** No return propellant to carry. The ship stays as material (§3.5).
- **Return propellant made on Mars.** NASA (Kleinhenz & Paz): 6,978 kg CH₄ + 22,728 kg O₂ in 480 days, 52 kW, plant mass 1.7 t; 15.7 t of water from 785 t of regolith at 2 %. Energy: 72.6 MJ per kg of propellant [computed]. A full return load of 1,200 t needs 2.1 MW for 480 days [computed, linear].
- **Ice instead of regolith.** Water from ice costs $2.05 \text{ kJ/kg} \cdot \text{K} \times 60 \text{ K} + 334 \text{ kJ/kg} + 4.18 \text{ kJ/kg} \cdot \text{K} \times 20 \text{ K} = 0.54 \text{ MJ/kg}$. From regolith at 2 % water, $50 \text{ kg} \times 0.8 \text{ kJ/kg} \cdot \text{K} \times 360 \text{ K} = 14.4 \text{ MJ}$ per kg of water, sensible heat only: 27 × more [computed]. Ice lies at 1–2 m depth in layers over 100 m thick (Dundas et al. 2018) [measured].
- **Lunar water.** Escape from the Moon costs 2.8 MJ/kg against 62.6 MJ/kg from Earth: a ratio 0.045 [computed]. Refuelling with lunar water lowers the launch mass of a Mars mission "by up to 68 percent" (Ishimatsu, de Weck et al. 2016) [input, secondary source].
- **ISRU oxygen** lowers a lander from 79.5 to 54.2 t: –32 % (NASA DRA 5.0) [input].
- **Aerocapture** replaces 2–4 km/s of braking by one seam [computed from Burke et al. 2010]. It has never been flown [input].

Decision. Fix the seam count of each candidate architecture before choosing. Prefer the architecture with fewer seams when the masses are comparable.

First test. Claude Code fixes one seam rule in advance and counts each architecture with it. Then it counts again with a second rule. A ranking that changes with the rule is not used.

3.5 What does not close is material for the next scale

Step from the theory. N5: what does not close at one scale is the material of the next [axiom; the application is a reading].

Numbers.

- A Starship that lands one way is roughly 100 t of stainless steel already on Mars [assumption; SpaceX dry mass not taken from a primary source]. At 1,000 ships per window that is of order 10^5 t of metal per window.
- Crop residues become fungal building material. Waste from ice mining becomes stone. Sulphur becomes binder [reading; sulphur concrete measured, §3.3].
- Sintered regolith bricks: 23.9–40.8 MPa at 1,150 °C [measured].
- A cover of 9.0 m of regolith holds 0.5 bar [computed; assumption 1,500 kg/m³].

Decision. Design the ship for its second life: tanks as pressure volumes, hull as feedstock, engines as spare parts. A ship is then not transport overhead but the first factory stock.

First test. Claude Code finds the dry mass of the current ship in SpaceX primary sources and splits it into reusable classes: pressure vessel, structure, engines, electronics.

3.6 Weight as a state of the net

Step from the theory. N4 says every constant is a function of the strand. Theorem 9 gives the form: a coupling is $\bar{g}(1 + \gamma\delta)$. Equating the gravitational coupling with this law is a reading; v4 does not yet translate gravity [open].

There are two routes to change weight.

Route 1: open the knot. Mass is a closure of dimension T^3/S^3 (Theorem 2). To open it costs $c^2 = 8.99 \times 10^{16}$ J/kg. The lift to LEO costs 33.1 MJ/kg. The ratio is 2.7×10^9 [computed]. This route is closed.

Route 2: set the state of the net around the knot. This route is open. What it would need [computed, under the reading]:

γ	origin	δ for 10 % less weight
-3.937	Theorem 11, free path, $d = 3$	25
-3.44 to -3.85	near a wall (v4 §8.3)	+0.026 to +0.029
+2 π	Applied Vacuum Theory, via a_0	-16

The sign differs between the families [open].

What measurements already bound [measured]:

State	Measurement	Bound
spin orientation ^{87}Rb	Duan et al. 2016	$\eta = (0.2 \pm 1.2) \times 10^{-7}$
bulk spin, $\sim 10^{23}$ electrons	Heckel et al. 2008	$< \sim 10^{-21}$
internal energy state	Rosi et al. 2017	low 10^{-9}
composition Be/Ti	Schlamming et al. 2008	$(0.3 \pm 1.8) \times 10^{-13}$
composition Ti/Pt	MICROSCOPE 2022	$(-1.5 \pm 2.3 \pm 1.5) \times 10^{-15}$
extra coupling at gravitational strength	Lee et al. 2020	excluded above 38.6 μm
forces at 40–8,000 nm	Chen et al. 2016	only far above gravitational strength

What measurements do not bound [open]: a state variable set by geometry, on 10–100 nm, at gravitational strength, in bodies of equal composition.

The gap computation [computed by Claude Code; recomputed by an independent judge with its own code].

The model is the free lattice path of Theorem 11, with the wall rule of v4 §8.3: the step towards a wall is removed and the choice falls uniformly on the other five.

Check of the model. A free path gives $\gamma = -3.936 \pm 0.004$ at infinite length; Theorem 11 gives -3.9365 . Knots per step: 0.2245 against $(1 - P_3) \cdot P_3 = 0.2246$. Near a wall: $\gamma = -3.442, -3.632, -3.848$ at heights 1, 3 and 10, which are the values of v4.

A path between two walls at distance h ($N = 20,000$ steps):

h	$\gamma(h)$	passages per place	δ
fre e	-3.9 7	1.507	0
1	-2.3 3	3.714	1.46
2	-2.5 4	2.742	0.82
4	-2.8 9	2.105	0.40
8	-3.3 0	1.776	0.18
16	-3.6 2	1.621	75
32	-3.8 1	1.558	34
64	-3.9 0	1.531	15
128	-3.9 4	1.514	5

At $h = 1$, γ tends to -2 , the limit $P \rightarrow 1$ of Theorem 11, slowly as $1/\ln N$.

The law. A gap behaves on large scales like a plane. A path keeps returning there. So δ has no final value; it grows with the path length N :

$$\delta(h, N) \approx k \cdot \ln(N/N_0) / h,$$

with $k = 0.25 \pm 0.02$ between 10^3 and 10^6 steps (fit value 0.245), rising towards $0.315 = 3/(2\pi G_3)$, the planar limit. Here $G_3 = 1/(1 - P_3) = 1.516$ is the mean number of visits to the start place. N_0 lies between h^2 and $4h^2$ [computed].

Which δ [open]. Here δ is the mean number of passages per visited place. That matches the γ of Theorem 11. v_4 does not fix it. For $h \geq 4$, five definitions give the same sign; the size differs up to a factor 3.

Size, under three assumptions:

- A1: one step per $T_0 = 1.52 \times 10^{-16}$ s, so $N = t/T_0$. A strand that leaves the gap sideways stops earlier, after about $(r/S_0)^2$ steps. A1 is an upper bound [assumption].
- A2: the gravitational coupling of a knot follows Theorem 9 with $\gamma = -3.9365$ [assumption].
- A3: one lattice unit is $S_0 = 45.6$ nm [assumption].

After 1 s [computed; basis: $k = 0.245$ to 0.315 , $N_0 = h^2$, $N = 1 \text{ s} / T_0 = 6.58 \times 10^{15}$ so $\ln N = 36.42$, $\gamma = -3.9365$]:

gap	h	δ	$\Delta g/g$, first order
4.6 μm	100	0.067–0.086	–26 to –34 %
20 μm	439	0.013–0.017	–5 to –7 %

46 μm	1,000	0.0055–0.0071	–2.2 to –2.8 %
0.46 mm	10,000	$4.4\text{--}5.7 \times 10^{-4}$	–0.17 to –0.22 %
1.99 mm	43,650	$0.85\text{--}1.1 \times 10^{-4}$	–0.033 to –0.043 %

Only knots that read the δ of the gap change. Whether that is the wall layer only, or deeper, is open. Whether holding the state costs energy is open: the path model carries no energy.

The existing record [measured]. NPL Report ENG 46 (2013) compares 1 kg stacks of steel discs with a solid cylinder. The discs stand on spacers of 1.99 mm. Per laboratory the difference between Stack 1 and the cylinder carries 0.4–1.5 μg standard uncertainty; for Stack 2 up to 4.1 μg .

- Basis: one lattice layer on each face is $2 \times 22.7 \text{ cm}^2 \times 45.6 \text{ nm} \times 7,888 \text{ kg/m}^3 = 1.63 \text{ mg}$ per gap. The low end uses the lateral exit bound, $N = (r/S_0)^2$ with $r = 2.69 \text{ cm}$ ($\ln N = 26.6$) and $k = 0.245$; the high end uses one year and $k = 0.315$.
- If only the wall layer reads the gap, the law predicts 0.19–1.5 μg per gap. That is at the uncertainty.
- If the whole stack reads it, the law predicts 115–918 mg per kg. Mass over volume differs between stack and cylinder by only about 2×10^{-5} . That argues weakly against this reading, if all parts have the same density [reading].
- The record does not decide. The gap terms drop out between air and vacuum, and each stack is adjusted to 1 kg by weighing.

Hypothesis H-G1: the weighing test [hypothesis; prediction fixed in advance]. The same discs, so the same number of knots: first on spacers of 2 mm, then on shims of 20 μm . Same comparator, same day, in vacuum.

- Prediction, wall layer only: per gap from 0.19 μg to 52 μg [computed].
- Prediction, whole stack: $\Delta g/g$ from -1.2×10^{-4} to -3.2×10^{-2} [computed].
- Both lie above a resolution of 1 μg .
- *Fails if* no difference above 3σ of the comparator where the computation predicts one.
- *Executors*. Claude Code fixes the prediction per setup before the weighing. The weighing can be done by any mass laboratory with a mass comparator: NPL, PTB, BIPM, VSL. There is no agreement.

What it would give [computed, conditional]. Halving the coupling halves the lift: 16.6 MJ/kg. The Δv to orbit falls from 9.4 to 6.3 km/s: orbital speed $7.67/\sqrt{2} = 5.43 \text{ km/s}$, losses $1.7 \rightarrow 0.9 \text{ km/s}$. With an exhaust speed of 3.4 km/s the mass ratio falls from $e^{(9.4/3.4)} = 15.9$ to $e^{(6.33/3.4)} = 6.4$ [computed; assumptions on losses and exhaust speed]. Weight alone does not change the transfer: MICROSCOPE finds equal fall for Ti and Pt to 10^{-15} . In the net weight and inertia are one passage ratio [reading].

Decision. Pay for one weighing. It costs weeks in a mass laboratory, not a launch. If it fails, the geometric branch of this reading falls, and nothing else in the plan changes. If it holds, cargo is designed as a stack of gaps, and the lift changes for every route at once.

Excluded, for completeness [computed or measured]:

- Flying with light: a photon drive needs at least $m \cdot \Delta v \cdot c$, about $7 \times 10^4 \times$ the energy of the lift [computed].
- Warp: an Alcubierre field needs $10^{36}\text{--}10^{42} \text{ J/m}^3$ negative; Casimir at 1 μm gives $4.3 \times 10^{-4} \text{ J/m}^3$. The gap is 39–45 orders.

- Claimed gravity shielding by superconductors (Podkletnov): replications found zero to 0.001 % and ± 0.004 %.
- EmDrive: a thermal artefact (Tajmar et al. 2022).
- Spinning gyroscopes: -0.025 ± 0.07 mg (Faller et al. 1990), two orders below the claim.
- Antimatter falls down: $(0.75 \pm 0.13 \pm 0.16)$ g (ALPHA-g 2023).

3.7 Steer by counts, not by sizes

Step from the theory. The theory holds where it counts closures and has shown nothing beyond chance where it fixes sizes (§2.6) [computed in the library; the pattern is a reading].

The same split in the plan [input]. What the iterative method reaches are countable milestones: orbit reached or not, booster caught or not, payload deployed or not. Each is a closure. What it has not yet reached are sizes: launch rates and cost per kilogram.

A launch rate as a count [computed]: 14 Starship flights between 20 April 2023 and 28 September 2026 is 3.44 years, so 4.1 flights per year. The design case of §1.2 needs 16–23 launches per day, 5,800–8,500 per year: a factor 1,400–2,100.

Decision. Steer the Mars programme by counts with a fixed definition: loops closed, seams removed, generations of the seed completed, part classes made locally. Treat every tonnage and every dollar figure as an output, not as a goal.

The organisational part, at zero mass [reading]. Decisions can be read as windows: three equal votes close, three different votes close, two against one do not (Theorem 5). A crew that logs its decisions can test whether closed decisions last longer than open ones. Claude Code fixes the plan and its hash before reading any log. The baseline is the measured joint trit law of the crew, not Lemma 1, because votes in a crew are not independent.

A Mars calendar [computed]. The tropical Mars year is 668.592 sols. The leap pattern is 3 in 5, then 13 in 22 and 16 in 27. After 8, 17 and 25 Mars years, the Earth and Mars calendars lie 17, 9 and 8 days apart. A close meeting comes only after 42 Mars years = 79 Earth years (1–2 days). This is a count of convergents. It does not test the theory.

4. The people

A plan of loops is a plan of people who tend loops. This section puts the human layer of all routes side by side.

4.1 Who lives there

- First, crews on Earth: adults, rotating, with a doctor. Lunar Palace and the Antarctic station Concordia are the pattern [input].
- Then crews who tend loops: growers, fungus keepers, casters, ice miners. A loop at 98 % closure is a full-time job for its own crew [reading].
- A founding group of about 110 adults covers the labour minimum (Salotti 2020) [input, secondary].
- Genetic breadth travels as frozen gametes and embryos, not as 10,000–40,000 people [reading]. Mouse sperm stored about 6 years on the ISS gave about 170 healthy pups (Wakayama et al. 2021) [measured]. Frozen mouse embryos developed normally to blastocyst on the ISS (Wakayama group 2023) [measured]. Human use is not shown [open].

- Crops, insects and gut bacteria belong as members of the loops, not as cargo [reading].
- Growth by birth: from 10,000 to 1,000,000 at 2 % per year takes 232.6 years [computed; 2 % is an assumption near the historical maximum]. A million by ship is a transport number. A million by birth is a generation number.

4.2 What they go through

- **Radiation.** Transfer: 1.8 mSv per day (Zeitlin et al. 2013) [measured]. 180 days: 324 mSv [computed]. The career limit is 600 mSv, now the binding NASA standard (NASA-STD-3001) [input]. One transfer uses 54 % of it [computed]. On the unshielded surface the rate is 0.67 mSv per day (Hassler et al. 2014) [measured]. $600/0.67 = 895$ days: the limit is reached in 2.45 years, or 1.13 years after one transfer of 324 mSv [computed]. Under 2.1–2.2 m of regolith, at solar minimum, the dose is 50 mSv per year, 21 × the Earth background of 2.4 mSv per year [measured].
- **Gravity.** 38 % of their weight, every day. In mice on the ISS centrifuge for 28 days ($n = 24$), 0.33 g damped muscle loss and 0.67 g prevented it (Tsuji et al. 2026) [measured]. Of 43 studies at 0.1–0.4 g, none looked at long-term effects (Richter et al. 2017) [input]. For humans at 0.38 g there are no data [open]. Rotation gives weight now: a radius of 52 m at 4 rpm adds up to 1 g on Mars [computed].
- **Light and space.** A sol of 24 h 39 min. A life underground or under regolith. Light through the greenhouses, not through windows [reading].
- **The group.** In Antarctica mood drops in the third quarter (Sandal et al. 2018, $N = 27$) [measured]. On Mars the winter does not end [reading]. Biosphere 2 split into factions with eight people. In Mars-500, four of six crew had problems (Basner et al. 2013) [measured].
- **Distance.** A voice delay of 3.0–22.3 minutes one way; 6–45 minutes round trip [computed]. Two weeks of silence at conjunction every 26 months [input]. A conversation with Earth stops being a conversation [reading].
- **Reproduction.** No animal data beyond 11 days of flight in pregnant rats [input; open]. A child who never sees a sky under which it can breathe [reading].
- **A conflict in the choice.** The radiation limit favours older settlers. Reproduction needs young ones [reading].

4.3 What disappears

- Mission control as authority. At 45 minutes round trip it becomes an archive [reading].
- The Earth hospital, school and court. Each must close locally or does not exist [reading].
- The supply chain behind every part, and the institution that ran it. What does not close there is not there [reading].
- The tanker fleet as a daily line, once Mars makes its own propellant and parts [reading].
- Return, for most. Mars is the last place [reading].
- The breadth of the Earth microbiome. What is not taken is gone [reading].
- Weather, open water, the horizon without a suit. The thought that air is free [reading].

4.4 What stays

- The window of 26 months as the only rhythm with Earth. In a closing settlement it carries people and descriptions, not food and walls [reading].
- The idea that matter is an address. People build their world from local stock. That is a way of living, not a machine [reading].

First test of the human layer. Reproduction at 0.38 g, first in mice, over several generations, in the JAXA MARS centrifuge (group of Tsuji). Claude Code fixes the plan in advance: litter size, generations, failure criterion. There is no agreement.

5. The simpler and cheaper route, in order

The findings combine into one sequence. Each step is cheap to test before the next is paid for.

Step	What	Mass from Earth	First test	Executor
1	Close food and solid waste in a sealed greenhouse on Earth,	0 t	target closure per loop, fixed	Claude Code (plan); Lunar Palace team or
2	Pay for one weighing: same discs on 2 mm and 20 μm	0 t	H-G1	Claude Code (prediction); a mass
3	Count seams per architecture; prefer fewer	0 t	seam count under two	Claude Code
4	Count tile loss on seams	0 t	H-S1	Claude Code
5	Lower f class by class until generation 6.0	0 t	Metzger's model with	Claude Code; Metzger (UCF), KSC Swamp
6	Reproduction at 0.38 g in mice over generations	0 t	plan fixed in advance	Claude Code (plan); JAXA MARS
7	Land the seed: 41 t	41 t	generation counts on	—
8	Land the founding crew and the liner, in step with capacity	360–5,453 t in total, seed included (110–	closure ledger per loop	—
9	Design one-way ships for a second life	0 extra	dry mass split into reusable	Claude Code

Steps 1 to 6 cost no launch. Together they decide most of what the tonnage plan leaves open.

6. Open numbers and who settles them

Open number	Section	Computation (Claude Code)	Physical work (group with the method; no
food and solid-waste closure at human size over more than a	3.2	counts crop species against closure in the Lunar Palace	Lunar Palace (Beihang); Biosphere 2 (Arizona)
f per part class on Mars	3.3	runs Metzger's model with	Metzger (UCF); NASA
growth rate of a seed on Mars	3.3	re-derives the rate with Mars solar flux ($0.43 \times$ the Moon)	—
dry mass of a one-way ship as	3.5	finds it in SpaceX primary	—
landed mass of 100 t;	3.4	computes entry mass	NASA (HIAD line)
seam ranking of architectures	3.4	fixes two seam rules in	—
tile loss on seams (H-S1)	3.4	marks seam share, then counts	—
which δ counts; the constant of	3.6	longer paths ($N > 2 \times 10^6$)	—
which knots read the gap (H-G1)	3.6	fixes the predicted mass per	NPL, PTB, BIPM or VSL
energy to set or hold δ	3.6	names the quantity v_4 would	—
sign of γ for gravity	3.6	fixes the sign before any	—
human reproduction at 0.38 g	4	fixes the multigeneration plan	JAXA MARS centrifuge

tools 10 t and spares 5 % per	1.3	replaces them by sourced	—
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7. Conclusion

The current plan measures progress in tons landed. Its own criterion is closure: a city that survives when the ships stop. These are different quantities.

Read with the Vacuum.Net Theory, the difference becomes countable. Closure is a property of loops. Seams between differently closed systems stay open. What one loop leaves is material for the next. The first passage fixes the orientation; the bulk is found where the winding closes.

Computed on that basis, a founding city of 1,000 people needs 0.3–1.1 % of the planned mass from Earth: 30–114 landings instead of 10,000. A group of 110 needs 4–13 landings. The criterion is met only when the share of parts that cannot be made on Mars reaches zero. That share, not the number of ships, is the number that steers the plan.

At $f \leq 5\%$, the largest single mass term in the combined route is not hardware but the water, oxygen and food of the first years. The cheapest lever on it is a sealed greenhouse on Earth.

Weight itself may be a lever. One route, opening the knot, is closed by a factor 2.7×10^9 . A second route, setting the state of the net by geometry, is open. A computation in the theory's own path model gives a size under stated assumptions. One weighing decides one branch of it.

Every step in section 5 up to the landing of the seed costs no launch.

Annotated references

Every source below was opened or pointed to by a judge in this study. Where only a secondary source could be read, "Why read?" says so. Texts by J. Konstapel are listed as ordinary sources.

The theory

Konstapel, J. (2026). The Vacuum.Net Theory: Definition, Theorems and Tests, version 4. Constable Research, Leiden, 17 October 2026. *Why read?* The premises of this article: axioms N1–N5, Theorems 1–14, the translation procedure and the ledger of tests in §8.2. *Reading advice:* start with §8.2, "The pattern", then Theorems 5 and 9.

Konstapel, J. (2026). Applied Vacuum Theory: Setting the State of the Net. constable.blog, 25 September 2026. <https://constable.blog/2026/09/25/applied-vacuum-theory/> *Why read?* The coupling $g_{\text{eff}} = \bar{g}(1 + \gamma\delta)$, the bridge $\delta = k\chi$ (marked "Assumed" there), and the two state variables χ_{Φ} and χ_a , which differ by a factor 2×10^{19} at the same place. *Reading advice:* read the status ledger (§13) before the derivation.

Konstapel, J. (2026). Applied Vacuum Theory, Part Four: Energy as Passage. constable.blog, 27 September 2026. <https://constable.blog/wp-content/uploads/def2Applied-Vacuum-Theory-Part-Four-Energy-as-Passage-The-Step-from-Mesh-to-Output-1.pdf> *Why read?* 70 W/m² at 33 nm, "extrapolated, not measured". It gives no energy for setting δ .

Konstapel, J. (2026). The Vacuum.Net Theory: Complete Derivation. constable.blog, 28 September 2026. <https://constable.blog/2026/09/28/the-vacuum-net-theorycomplete-derivation/> *Why read?* The two roads: passage through a mesh as $1/L$, and a knot that loses a closure ($E = mc^2$).

Konstapel, J. (2026). Transmutation: Elements on Demand. constable.blog, 9 October 2026. <https://constable.blog/2026/10/09/transmutation-elements-on-demand/> *Why read?* Element = address + state; the three energies 10^5 , 4.85×10^9 and 9.0×10^{13} J/mol. *Reading advice:* read 1.49×10^{-19} J as 1.49×10^{-10} J ($u \cdot c^2$).

Konstapel, J. (2026). The Possible Vacuum Replicator; How to Build a Vacuum Replicator. constable.blog, 29 July 2026. <https://constable.blog/2026/07/29/the-possible-vacuum-replicator/> ; <https://constable.blog/2026/07/29/how-to-build-a-vacuum-replicator/> *Why read?* Read, send the description, write. "The realistic replicator does not create knots." The source of "send the address, not the mass".

Konstapel, J. (2026). The History of Life on the Net. constable.blog, 15 October 2026. <https://constable.blog/2026/10/15/history-of-life/> *Why read?* Two kinds of closure, crystal and metabolism; "the residue of depth n is the alphabet of depth $n+1$ " — N_5 applied to life.

Konstapel, J. (2026). The Relationship Between SWARP and VALIS. constable.blog, 15 February 2026. <https://constable.blog/2026/02/15/valis-and-swarp/> *Why read?* The basis of decisions read as windows (§3.7).

Watson, G. N. (1939). Quarterly Journal of Mathematics 10, 266–276. <https://doi.org/10.1093/qmath/os-10.1.266> *Why read?* The return probability 0.340537 in three dimensions, the number behind $\gamma = -3.9365$.

Pólya, G. (1921). Mathematische Annalen 84, 149–160. <https://doi.org/10.1007/BF01458701> *Why read?* Return of lattice paths: the basis of Theorem 11.

CODATA 2018. NIST, Fundamental Physical Constants. <https://physics.nist.gov/cuu/Constants/> *Why read?* The four inputs of the natural units.

The goal and the plan

CNBC, 9 March 2020. <https://www.cnbc.com/2020/03/09/spacex-plans-how-elon-musk-see-life-on-mars.html> *Why read?* The closure criterion and "not less than a million tons", in the original words.

Space.com, January 2020. <https://www.space.com/elon-musk-starship-spacex-flights-mars-colony.html> *Why read?* "1000 ships depart over ~30 days every 26 months": the 1,000 is the fleet per window.

Musk, E. (2017). Making Humans a Multi-Planetary Species. New Space 5(2). <https://static.ukrinform.com/files/1497612705-9227.pdf> *Why read?* \$140,000 per ton, 3–5 tankers, \$168 per ton of propellant; a million people in 40–100 years.

Ubergizmo, November 2019. <https://www.ubergizmo.com/2019/11/elon-musk-city-on-mars/> *Why read?* "About 20 years to transfer million tons": the source of the 20 years.

Maiwald, V. et al. (2024). Scientific Reports 14, 11804, with correction. <https://pmc.ncbi.nlm.nih.gov/articles/PMC11116405/> *Why read?* An independent mass budget that finds no feasible return scenario. *Reading advice:* ignore "every 22 months"; it is 25.6.

Closure and life

Fu, Y. et al. (2021). Lunar Palace 365. bioRxiv. <https://www.biorxiv.org/content/10.1101/2021.01.12.426282v1.full-text> *Why read?* The best measured closure with people. *Reading advice:* read the closure table first; food and waste are the open loops.

Salisbury, F., Gitelson, J., Lisovsky, G. (1997). BIOS-3. <https://simoc.space/wp-content/uploads/2018/09/BioS-3-Siberian-Experiments-in-Bioregenerative-Life-Support-1997.pdf> *Why read?* Which loops stayed open: minerals, nitrogen, animal food.

Garcia-Gragera, D. et al. (2021). MELiSSA. Frontiers in Astronomy and Space Sciences 8, 750616. <https://www.frontiersin.org/journals/astronomy-and-space-sciences/articles/10.3389/fspas.2021.750616/pdf> *Why read?* The engineered microbial loop, and what is not yet coupled.

Johnson, C. et al. (2021). Frontiers in Astronomy and Space Sciences 8, 734343. <https://www.frontiersin.org/journals/astronomy-and-space-sciences/articles/10.3389/fspas.2021.734343/full> *Why read?* NASA's estimate of 40–50 m² of crops per person or more.

Metzger, P. et al. (2016). arXiv 1612.03238. <https://arxiv.org/abs/1612.03238> *Why read?* A seed that closes generation by generation, and what an open share does under growth. *Reading advice:* read the text around figure 4.

Chirikjian, G., Zhou, Y., Suthakorn, J. (2002). https://rpk.lcsr.jhu.edu/wp-content/uploads/2014/08/Chirikjian02_b.pdf *Why read?* Machines without imported electronics.

Menezes, A. et al. (2015). Journal of the Royal Society Interface 12, 20140715. <https://royalsocietypublishing.org/doi/10.1098/rsif.2014.0715> *Why read?* The only quantified mass gains for biologically made fuel, food and polymers.

Cockell, C. et al. (2020). Nature Communications 11, 5523 (BioRock). <https://www.nature.com/articles/s41467-020-19276-w> *Why read?* A biological route to the metals that chips and magnets need.

Wamelink, G. et al. (2014). PLoS ONE 9, e103138. <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0103138> *Why read?* Regolith as soil.

Verseux, C. et al. (2021). Frontiers in Microbiology 12, 611798. <https://www.frontiersin.org/journals/microbiology/articles/10.3389/fmicb.2021.611798/full> *Why read?* Cyanobacteria on Mars gas and regolith.

Wan, L., Wendner, R., Cusatis, G. (2016). Sulphur concrete for Mars. arXiv 1512.05461. <https://arxiv.org/abs/1512.05461> *Why read?* Waterless, reusable Mars concrete above 50 MPa.

Propellant and transfer

Hoffman, J. et al. (2022). Science Advances 8, eabp8636 (MOXIE). <https://pmc.ncbi.nlm.nih.gov/articles/PMC9432831> *Why read?* The only oxygen made on Mars, and the scale-up factor.

Kleinhenz, J., Paz, A. (NASA). Mars ISRU propellant production. <https://ntrs.nasa.gov/api/citations/20170005179/downloads/20170005179.pdf> *Why read?* What making propellant on Mars costs in power and ground.

Dundas, C. et al. (2018). Exposed subsurface ice sheets in the Martian mid-latitudes. <https://pubs.usgs.gov/publication/70195019> *Why read?* Ice at 1–2 m, layers over 100 m thick.

Morgan, G. et al. (2021). Nature Astronomy 5, 230 (SWIM). <https://pubs.usgs.gov/publication/70226786> *Why read?* Where ice lies shallow: Arcadia Planitia and Deuteronilus Mensae.

Burke, L., Falck, R., McGuire, M. (2010). NASA/TM-2010-216764. <https://ntrs.nasa.gov/api/citations/20100037210/downloads/20100037210.pdf> *Why read?* Departure energy and arrival speed per window, 2026–2046.

Drake, B. (2009). Mars Design Reference Architecture 5.0. <https://ntrs.nasa.gov/api/citations/20090010571/downloads/20090010571.pdf> *Why read?* Chemical, nuclear-thermal and ISRU side by side.

Ishimatsu, T., de Weck, O. et al. (2016), via Space.com. <https://www.space.com/30838-manned-mars-mission-moon-refueling.html> *Why read?* "Up to 68 percent" less launch mass with lunar water. Secondary: the primary paper was not retrieved.

Rogers, B. et al. (2012). AIAA 2012-4746 (cyclor). <https://engineering.purdue.edu/AAC/wp-content/uploads/2012/09/EstablishingCyclorTrajectoriesBetweenEarthAndMarsViaV-InfinityLeveraging-AIAA-2012-47461.pdf> *Why read?* A trajectory that closes on itself every synodic period.

Lifting without rockets

StarTram2010. <https://startram.com/wp-content/uploads/2020/12/StarTram2010.pdf> *Why read?* The only fully costed alternative to the rocket.

Edwards, B. NIAC Phase I and II (space elevator). <https://NSS.org/wp-content/uploads/2017/07/2003-Space-Elevator-NIAC-phase2.pdf> *Why read?* The elevator worked out; the material is the limit.

Birch, P. (1982). Orbital Rings, Part I. <https://nss.org/wp-content/uploads/Orbital-Rings.pdf> *Why read?* The fullest circulating closure, and its construction mass.

Habitat and the human body

Howard, R. et al. (2023). Offloading a 90-ton habitat on Mars. ASCEND. <https://ntrs.nasa.gov/api/citations/20220010430/downloads/Offloading%20a%2090-Ton%20Hab%20from%20its%20Lander%20on%20Mars.pdf> *Why read?* The 90 t control mass for 8 crew: the basis of 11.25 t per person.

Zhang, J. et al. (2022). JGR Planets 127, e2021JE007157. <https://e-docs.geo-leo.de/server/api/core/bitstreams/1427ba88-85bd-44c8-a5f5-68d1116c5d01/content> *Why read?* Effective dose on Mars and the depth for 100 and 50 mSv per year.

NASA OCHMO-TB-020 (600 mSv standard). <https://www.nasa.gov/wp-content/uploads/2023/03/radiation-protection-technical-brief-ochmo.pdf> *Why read?* The binding career limit.

Zeitlin, C. et al. (2013), via SwRI. <https://www.swri.org/press-release/swri-led-team-calculates-radiation-exposure-associated-trip-mars> *Why read?* 1.8 mSv per day during transfer.

Tsuji et al. (2026). Science Advances 12(11), eaed2258. <https://www.uri.edu/news/2026/03/do-we-have-the-muscle-for-mars/> *Why read?* The only partial-gravity data from orbit: 0.33 g damps, 0.67 g prevents muscle loss in mice.

Richter, C. et al. (2017). Frontiers in Physiology 8, 583. <https://www.frontiersin.org/articles/10.3389/fphys.2017.00583/full> *Why read?* Why nobody knows what 0.38 g does over years.

Globus, A., Hall, T. (2015). Space settlement population rotation tolerance. <https://nss.org/wp-content/uploads/Space-Settlement-Population-Rotation-Tolerance-Globus.pdf> *Why read?* How fast people can spin, so how small a rotating habitat can be.

Salotti, J.-M. (2020). Scientific Reports 10, 9700. <https://www.nature.com/articles/s41598-020-66740-0> *Why read?* The labour minimum of about 110 people. Secondary: only press reports were read.

Wakayama, S. et al. (2021). Science Advances (sperm on the ISS), via Science News. <https://www.sciencenews.org/article/mouse-sperm-dna-space-radiation-exposure-six-years> *Why read?* About 170 healthy pups from sperm stored about 6 years on the ISS.

Hassler, D. et al. (2014). Science 343, via Scientific American. <https://www.scientificamerican.com/article/radiation-on-mars-managea> *Why read?* 0.64–0.67 mSv per day on the surface: the rate behind 2.45 years. Secondary: the Science text is behind a paywall.

Wakayama group (2023). iScience (embryos on the ISS), via New Atlas. <https://newatlas.com/space/mouse-embryos-space-first-time/> *Why read?* Frozen mouse embryos developed normally to blastocyst on the ISS.

Sandal, G. et al. (2018). Frontiers in Psychology 9, 2235. <https://public-pages-files-2025.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2018.02235/text> *Why read?* The third-quarter dip in two winter crews at Concordia.

Basner, M. et al. (2013). PNAS (Mars-500). <https://www.med.upenn.edu/uep/assets/user-content/documents/PNAS2013Basner1212646110withSupportingAppendix.pdf> *Why read?* Four of six crew with problems after 520 days.

Weight and the state of the net

Duan, X. et al. (2016). <https://arxiv.org/abs/1602.06377> — *Why read?* Free fall per spin state.

Heckel, B. et al. (2008). <https://arxiv.org/abs/0808.2673> — *Why read?* A spin-polarised torsion pendulum.

Rosi, G. et al. (2017). <https://arxiv.org/abs/1704.02296> — *Why read?* Equivalence for internal energy states.

Schlamming, S. et al. (2008). <https://arxiv.org/abs/0712.0607> — *Why read?* Be/Ti to 10^{-13} .

Touboul, P. et al. (2022). MICROSCOPE. <https://arxiv.org/abs/2209.15487> — *Why read?* The sharpest composition bound.

Lee, J. et al. (2020). <https://arxiv.org/abs/2002.11761> — *Why read?* Where bounds at gravitational strength stop.

Chen, Y.-J. et al. (2016). <https://arxiv.org/abs/1410.7267> — *Why read?* Where "not bounded" really begins.

Berry, J. et al. (2013). **NPL Report ENG 46.** <https://eprintspublications.npl.co.uk/5985/1/ENG46.pdf> *Why read?* Stacks of discs against a solid cylinder, weighed to 0.4–1.5 μg : the best existing record for the gap test. *Reading advice:* read the table of volumes and the vacuum differences. The stacks were adjusted to 1 kg.

Calloni, E. et al. Archimedes. <https://arxiv.org/abs/1511.04269> *Why read?* An existing balance that reads a change of state in weight. It reads only the part that switches at T_c .

Moddel, G. et al. (2021). **Symmetry 13, 517.** <https://arxiv.org/abs/2101.03085> *Why read?* 1.4 pW from 0.02 μm^2 : the cavity series that follows the 1/L of Theorem 1. *Reading advice:* read the authors' own caveats on plasmons.

ALPHA-g (2023). **Nature.** <https://www.nature.com/articles/s41586-023-06527-1> *Why read?* Antimatter falls down.

Tajmar, M., Neunzig, O., Weikert, M. (2022). **CEAS Space Journal 14.** [https://fis.tu-dresden.de/portal/en/publications/highaccuracy-thrust-measurements-of-the-emdrive-and-elimination-of-falsepositive-effects\(a2fc9b62-64b8-45db-8588-7a7d00725d7f\).html](https://fis.tu-dresden.de/portal/en/publications/highaccuracy-thrust-measurements-of-the-emdrive-and-elimination-of-falsepositive-effects(a2fc9b62-64b8-45db-8588-7a7d00725d7f).html) *Why read?* How a thrust claim was unmasked as an artefact.

Woods, R. et al. (2001). **AIAA 2001-3363, via arXiv physics/0204031.** <https://arxiv.org/abs/physics/0204031> *Why read?* The replication of the superconductor shielding claim: zero to $\pm 0.004\%$.

Faller, J. et al. (1990). **Physical Review Letters 64, 2115.** <https://link.aps.org/doi/10.1103/PhysRevLett.64.2115> *Why read?* Spinning gyroscopes do not lose weight.

White, H. et al. (2021). **European Physical Journal C 81, 677.** <https://link.springer.com/article/10.1140/epjc/s10052-021-09484-z> *Why read?* The only published warp-like calculation in a Casimir geometry; a calculation, not a measurement.