

The engineering ledger of a time machine: mass, wrap, siting, and the resource class of an acquired relic

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Abstract

We price the composite time machine of the Ori program. The question is not whether the initial data are allowed—they are, and the construction is explicit—but what a civilization would have to supply, given a relic core, to turn it into an armed machine. We separate the invoice into matter, wrap, placement, sourcing, and survey, and we keep the accounting honest by refusing to let one dial pay for another.

The results are as follows. (i) The matter is pressureless dust in the field-equation sense, gate-verified on the gatefast interior band and, at $a = 0.02$, gate-positive over the full C4 envelope layer $r > w$ after the one-knob collar retune; the upper envelope is not certified. The canonical corner is nevertheless *not* ordinary matter: at $k_0 = 0.499$ ($\tau_0 = -1 \text{ m}^2$) the hand-off density is $\varepsilon_0 = 4.0 \times 10^{25} \text{ kg/m}^3$, with a peak of $1.17 \times 10^{26} \text{ kg/m}^3$ ($\sim 5 \times 10^8$ times nuclear saturation). (ii) At fixed ρ_0 and dimensionless z -period L_z the dust *density* scales as k_0^2 but the *total* mass scales as k_0 , not k_0^2 : the certified C4-layer integral is $M_{\text{layer}} = 3.30 k_0 L_z$ in geometrized units, because the z -orbit proper length grows as $1/k_0$. At the deep rung $k_0 \simeq 2.2 \times 10^{-12}$ the density is 778 kg/m^3 (sand/water) but the mass is asteroid-class: $1.3\text{--}2.4 \times 10^{16} \text{ kg} \cdot L_z$. (iii) The mass and the CTC loop size are tied through L_z : both scale linearly with it, so shrinking the loops is the only way to shrink the mass at fixed depth, and a tons-scale bill requires picometre loops of unassessed usability. (iv) The a -floor from horizon back-reaction is $a \simeq 2 \times 10^{-17}$ at metre scale; the canonical $a = 10^{-4}$ sits thirteen orders above it, and the horizon stress ($\sim 8 \times 10^{-9} \text{ J/m}^3$) is fifty-plus orders below the unit-curvature density. The arming lead time is 3.3 ns (canonical), 33 ns ($\tau_0 = -100 \text{ m}^2$), and 761 s (deep rung). (v) The wrap tolerates tens-of-percent density errors and decimetre radial placement at metre scale, but the deep-slice assembly must be sited in heliocentric space at $\gtrsim 0.008\text{--}0.12 \text{ AU}$ and its wrap held to a relative-drift budget of $\sim 7 \times 10^{-5} \text{ m/s}$. (vi) The mass cannot be launched; it must be sourced in situ from an asteroid-class body. (vii) The survey, not the wrap, is the civilization-scale problem: a metre-scale OFF relic is causally cloistered, and the findable targets are $\gtrsim 0.1 \text{ ly}$ pockets or relics caught in the trigger epoch.

The assembly is acquisition, not manufacture: no known classical process can create the boost-holonomy identification—the rigorous CFG/CFGO energy obstruction is proved in $2 + 1$ dimensions, and its $3 + 1$ extension to this data class is an open gap—so the ledger is written for an acquired relic. The canonical and $\tau_0 = -100$ rungs are not cheaper versions of the deep rung; they are different machines made of matter that does not exist. Nothing on the verified matter band needs new physics. Everything on the acquisition side is unsolved.

1 Introduction and scope

The program has spent most of its effort on a prior question: is a time machine allowed by the known laws, and if so what does its initial data look like? The answer, developed in the companion papers, is narrow but real. The Ori (2005) vacuum core carries boost-identified z -circles [1]; an umbilical slice makes its extrinsic curvature pure trace; a dust envelope joins that slice to Ori’s (2007) asymptotically flat outer layers [2]; the resulting composite is regular compact initial data, with both constraint gates positive on the gatefast interior band and, in the retuned construction, over the full C4 envelope layer $r > w$ including the innermost collar [3]. The semiclassical stress on the chronology horizon is finite and negligible at the canonical design [4]. A search program for the natural relics that would supply the identification has been specified and partially executed [5, 6].

This paper asks the next question, the one an engineer would ask: *what is the invoice?* It is a resource ledger, not a build proposal. We take the verified construction as the input and account for every resource class it demands—matter, density, placement, siting, launch, survey—while stating which numbers are exact, which are certified numerically, which are extrapolations, and which are simply cited from the literature. The ledger style follows the program’s earlier accounting notes [11, 12]: the point is to make the gap legible, not to close it by rhetoric.

Five results organize the paper.

1. **Given a relic core, the wrap is asteroid-class industry.** The envelope is specified, robust, and made of pressureless dust at ordinary density at the deep rung. Its mass is $1.3\text{--}2.4 \times 10^{16} \text{ kg} \cdot L_z$, comparable to a mid-sized near-Earth asteroid, assembled robotically to decimetre and tens-of-percent accuracy in heliocentric space, arming in 761 s.
2. **The survey is the civilization-scale problem.** The relic is vacuum, massless, and—before its chronology horizon—causally cloistered. Metre-scale OFF relics are individually invisible; the findable windows are large pockets ($\tau_{\text{wall}} \gtrsim 0.1 \text{ ly}$) or the trigger/CTC epoch. The wrap is industry; the survey is a decades-scale observational program of open-ended duration.
3. **The canonical corner is not ordinary matter.** At the shallow, nanosecond-arming corner the dust is $\sim 5 \times 10^8$ times nuclear saturation, in an envelope whose gravitational radius is comparable to its own size. It is not a scaled-down version of the deep-rung machine.
4. **The mass dial trades total mass against CTC loop size.** At fixed ρ_0 , the total mass and the loop circumference are both linear in L_z . Deepening the slice lowers the mass at fixed loop size but lengthens the arming time and, eventually, brings the dust to ordinary density. There is no dial setting that gives human-scale mass at human-scale loops.
5. **The assembly is acquisition, not manufacture.** The matter can be arranged; the boost-holonomy identification cannot be created by any known classical process (the rigorous CFG/CFGO obstruction is $2 + 1$ -dimensional, and the $3 + 1$ extension for this data class is an open gap). It must be inherited, nucleated, or reproduced. The ledger is therefore written for a relic that has already been found.

Status vocabulary. A number in this paper is one of: *exact* (closed form); *certified* (interval arithmetic or a multiprecision series with a stated domain); *exhibited* (fine-grid numerical gates at a stated resolution, machinery validated against closed forms); *extrapolated* (a certified scaling law evaluated beyond its directly gated points); *conjectured* (exhibited but not proved); or *cited*. The status is stated where the number is used, and collected in Sec. 9. This is the paper’s main defence

against the common failure mode of engineering estimates: letting a scaling law quietly become a construction.

Scope. We do not re-derive the core, the envelope, or Ori’s existence theorem; those are the subjects of the companion papers [3, 2]. We do not claim a manufactured machine, a detected relic, or a funded program. We do not price the survey in dollars, because its duration is set by an unknown sky density and not by an procurement line. We do price the wrap, because the wrap is the part the program has actually computed.

2 What is actually built

2.1 The object

The working object is a solid-torus vacuum core: the Ori (2005) pp-wave with parameters (a, e) and z -identification period L , truncated at transverse radius ρ_0 . The identification $z \sim z + L$ has holonomy a Lorentz boost of rapidity $\Lambda = L/2$; the z -circle is spacelike before the chronology horizon, degenerates on it, and closes as a CTC after it. The core is surrounded by a dust envelope and an asymptotically flat exterior, built by transplanting the Ori (2007) machinery onto the core’s umbilical boundary data:

$$\tau(x, y) = \tau_0 + (e - \tfrac{1}{4})(x^2 + y^2) - \tfrac{a}{2}(x^2 - y^2), \quad K_{ab} = k_0 h_{ab}, \quad (1)$$

with $k_0 = +1/(2\sqrt{|\tau_0|})$ in the ADM convention, to accuracy $1.08 a/(2|\tau_0|)$. The initial data—geometry plus dust on a compact region of a spacelike hypersurface—evolve by themselves. Closed timelike curves appear inside the core at $t > e\rho_0^2$; the chronology horizon is the null eikonal surface through the closed null geodesic $\mathcal{N}$.

The core is vacuum and the envelope is dust. On the gatefast interior band ($r \geq w + 0.0904$) both constraint gates are positive and the pointwise energy conditions hold. The retuned construction (a one-knob stage-1 onset delay $s_d = 1.5$ mm) is gate-positive over the full C4 envelope layer $r > w$ at $a = 0.02$, including the innermost collar: the exact jets give $WEC(1 \text{ mm}) \geq +4.550484 \times 10^{-6}$, a dense exact-jet scan is positive everywhere ($\min H_1 = \min WEC = +2.4 \times 10^{-12}$), and the boundary torus $r = w$ is the exact vacuum continuation ($H_1 = 0$). On the gatefast band the interval certificate gives $H_1 \geq 0.7468$, $WEC \geq 0.2736$, and $a_W^* = 0.0346$. The upper-envelope mass law beyond the C4 layer is not certified. The machine’s “exoticness” is not a stress-energy violation on the verified band; it is the global identification. A switchable alternative core—the Xavier (2026) vacuum traveling-wave train—arms on demand and has a different ignition budget; its envelope transplant and stability are open and are not priced here [24].

2.2 The construction chain

Table 1 summarizes the status of the seven requirements of the Ori program as they stand after the composite construction. The important point for this paper is the last column: every layer is either closed form, numerically gate-verified with explicit profiles, or Ori’s own construction applied verbatim. The composite is *buildable in Ori’s sense*—regular compact initial data on an asymptotically flat hypersurface, evolving into a chronology horizon and CTCs—conditional on Ori’s existence theorem, which we cite rather than re-prove.

The envelope is not a free design. Its dust density is read off the solved geometry,

$$\varepsilon(r, \varphi) = \frac{1}{16\pi} \left(R^{(3)} + K^2 - K_{ij} K^{ij} \right), \quad (2)$$

	Requirement	Status
C1	vacuum, explicitly solvable core	exact (2005 metric)
C2	explicit (h, K) data on Σ	exact (umbilical family)
C3	pure-trace K on the matching torus	exact, residual $1.08 a/2 \tau_0 $
C4	envelope matching the torus data under $R^{(3)} \geq -6k_0^2$	exhibited, fine-grid gates, robust at $\pm 30\%$
C5	truncation reaches the chronology horizon	exact (composed-slice argument)
C6	free period	exact (vacuum for any L)
C7	$k_0 > 0$, no anti-trapped surfaces	exact

Table 1: The construction chain. “Exact” means closed form; “exhibited” means fine-grid gates on a documented standard. The remaining formal gaps are analytic error bounds and the $O(a)$ uniformity conjecture, not the existence of the layers (Sec. 9).

evaluated on the umbilical slice. What the builder must supply is therefore not an arbitrary density profile but the particular one that the constraint equations assign to the built geometry. That is good news for tolerances (the profile is robust, Sec. 4) and bad news for short-cuts (one cannot substitute a convenient material distribution).

2.3 The unmanufacturable organ

Everything in the preceding subsection is matter and local geometry. The identification is neither. It is a global, discrete, causal-invisible structure: before the chronology horizon the z -circle is spacelike, so no causal probe from the envelope can traverse the nontrivial loop. Topological censorship [19] makes the machine legal—the holonomy is hidden until it exists—but the same fact means no known classical process can install it; the sharpest classical obstruction is discussed below and is rigorously a $2 + 1$ statement.

The no-go literature constrains the assembly sharply, though not in a dimension-independent way. Carroll, Farhi, Guth, and Olum proved, in $2 + 1$ dimensions, that in an open universe initial data on an edgeless non-compact slice with timelike total momentum never has enough energy to evolve into a boost-holonomy configuration [15, 16]. The $3 + 1$ statement for the present data class is not a published theorem. It is expected by structural analogy and no counterexample is known, but we treat it as an open gap (the companion states the gap explicitly). The two-defect route is singular or constrained [17, 18]. Geroch’s dichotomy prices topology change at CTCs, singularities, or an energy-condition violation [20]. These results do not cover the present construction, which *starts* from the identified core; they constrain attempts to build that core from ordinary data.

The honest conclusion is that the machine’s matter is engineering and its identification is acquisition. There are exactly three routes: inheritance from the quantum-gravity era (foam $\rightarrow$ inflation $\rightarrow$ survival), quantum nucleation, or reproduction inside an existing machine’s CTC region [9]. Only the first needs no new mechanics, and it is the route the survey targets. This is why the present paper is a ledger for an *acquired* relic: without the relic there is no object to wrap.

2.4 Scale freedom

The construction is scale-free, as all of general relativity is. Every length scales with ρ_0 , every time with ρ_0/c , every density with $c^4/G\rho_0^2$, and every mass with $c^2\rho_0/G$. The scaling group

$$(\rho_0, \tau_0, \ell_i) \rightarrow (\lambda\rho_0, \lambda^2\tau_0, \lambda\ell_i) \quad \text{at fixed } (a, e, L_z) \quad (3)$$

Dial	Range	What it sets
ρ_0	any	physical size; masses and densities scale with it
e	$0 < e \lesssim 1/4$	CTC threshold $t > e\rho_0^2$; where loops form
a	$0 < a < e$	wave strength; ejection rate; umbilicity residual $\propto a$; horizon stress $\propto a^{-4}$
τ_0	< 0	slice depth; $k_0 = 1/(2\sqrt{ \tau_0 })$; density $\propto k_0^2$; mass $\propto k_0$; lead time $\sqrt{ \tau_0 }/c$
L	> 0	CTC loop scale $L\sqrt{e\rho_0^2 - t}$; mass $\propto L_z$; wrap gradients

Table 2: The design dials. The a -dial is not uniformly benign: as $a \rightarrow 0$ the ejection rate and umbilicity residual vanish, but the chronology-horizon stress diverges as a^{-4} .

maps solutions to solutions; it is confirmed numerically at $\lambda = 2$ to a relative error 8.4×10^{-9} , with the gate minima scaling as $1/\lambda^2$ [3]. This is what makes a ledger possible: a single metre-scale computation can be rescaled, and the only quantities that do not rescale trivially are the dimensionless dials (a, e, L_z) and the mass law’s k_0 dependence.

3 The dials: mass, density, and a

3.1 Five dials, five jobs

Table 2 lists the design dials. They are decoupled: each does one job, and the ledger can price each separately. The two that matter for resources are τ_0 (through k_0) and L_z ; the two that matter for safety are a (through the horizon stress) and ρ_0 (through every scale).

3.2 The density dial

The hand-off density is fixed by the trace of the extrinsic curvature:

$$\varepsilon_0 = \frac{6k_0^2}{16\pi} \quad (\text{geometrized}), \quad \rho_{\text{phys}} = \varepsilon_0 \frac{c^2}{G}, \quad (4)$$

so the dust density scales as $k_0^2 = 1/(4|\tau_0|)$. This is the dial that decides whether the envelope is made of matter at all. At the canonical corner $k_0 = 0.499$ ($\tau_0 = -1 \text{ m}^2$), $\varepsilon_0 = 4.0 \times 10^{25} \text{ kg/m}^3$, with a peak of $1.17 \times 10^{26} \text{ kg/m}^3$ and a mean of $4.4 \times 10^{25} \text{ kg/m}^3$. Taking nuclear saturation as $\rho_{\text{nuc}} \simeq 2.3 \times 10^{17} \text{ kg/m}^3$, the peak is $\sim 5 \times 10^8 \rho_{\text{nuc}}$: denser than any white dwarf or neutron-star matter, at a mass sitting at its own gravitational-radius scale. At $\tau_0 = -100 \text{ m}^2$ ($k_0 = 0.05$) the peak is $1.2 \times 10^{24} \text{ kg/m}^3$, still $\sim 5 \times 10^6 \rho_{\text{nuc}}$. Only at $k_0 \lesssim 7 \times 10^{-12}$ does the dust reach the densities of ordinary solids: water at $k_0 = 2.4 \times 10^{-12}$, sand at $k_0 = 3.0 \times 10^{-12}$, steel at $k_0 = 6.7 \times 10^{-12}$.

This is the paper’s first honest warning. The word “dust” in the construction is literal in the field-equation sense—pressureless matter—but not in the materials sense at the shallow rungs. A canonical-corner machine is not a bucket of sand; it is an object whose matter has no known realization.

3.3 The mass law

The mass law is the paper’s most important correction, and it is worth stating why the naive answer is wrong. One might expect the total dust mass to scale as the density, k_0^2 . It does not, at

Rung	k_0	τ_0 (m ²)	ε_0 (kg/m ³)	M_{C4} (kg · L_z)
canonical	0.499	−1	4.0×10^{25}	2.2×10^{27}
$\tau_0 = -10^2$	0.05	-10^2	4.0×10^{23}	2.2×10^{26}
$\tau_0 = -10^4$	5×10^{-3}	-10^4	4.0×10^{21}	2.2×10^{25}
$\tau_0 = -10^6$	5×10^{-4}	-10^6	4.0×10^{19}	2.2×10^{24}
deep	2.2×10^{-12}	-5.2×10^{22}	778	9.8×10^{15}

Table 3: The certified mass-law rungs. Density falls as k_0^2 ; total C4-layer mass falls only as k_0 . The first four rows are directly gate-evaluated in the Laurent series; the deep row is the same certified series evaluated at $k_0 = 2.2 \times 10^{-12}$, not a separate nonlinear solve.

fixed ρ_0 and dimensionless L_z . The z -orbit proper length is $L_z \sqrt{|h_{zz}|} \sim L_z/(2k_0)$; the layer volume therefore grows as $1/k_0$, and

$$M_{\text{geo}} \sim k_0^2 \cdot \frac{1}{k_0} \cdot \rho_0^2 \sim k_0 \rho_0^2 \implies M_{\text{layer}} = 3.30 k_0 L_z \quad (5)$$

in geometrized units, i.e. $M_{\text{layer}}^{\text{phys}} = 3.30 k_0 L_z c^2/G$. The coefficient is exact linear across four certified rungs ($1.65 \times 10^{-1} \rightarrow 1.65 \times 10^{-2} \rightarrow 1.65 \times 10^{-3} \rightarrow 7.27 \times 10^{-12}$ geometrized metres for $\tau_0 = -10^2, -10^4, -10^6$ m² and the deep rung), from the multiprecision evaluation of the gate fields in the Laurent series in k_0 (40 digits, second-order jets) [3, 10].

The physical conversions are worth keeping in view: $c^2/G = 1.347 \times 10^{27}$ kg/m, so a geometrized mass of one metre is 1.35×10^{27} kg. The certified C4 layer at the deep rung is 9.8×10^{15} kg · L_z (Table 3); adding the Robertson–Walker tube gives $1.3\text{--}2.4 \times 10^{16}$ kg · L_z . The range is a lower/upper envelope bound, not an error bar: the upper value includes Ori’s outer layer, and the k_0 -linear law is demonstrated for the C4 layer and the RW tube, not for the full upper envelope.

At the canonical corner the same law gives $M_{C4} = 3.30(0.499)(1.347 \times 10^{27}) = 2.22 \times 10^{27}$ kg for the open layer plus flattening band, matching the per-region integral ($1.33 \times 10^{27} + 8.9 \times 10^{26}$). The RW tube to the four-metre enclosing sphere is 6.45×10^{26} kg; the full envelope is $2.9\text{--}5.4 \times 10^{27}$ kg ($1.5\text{--}2.8 M_J$, or $480\text{--}900 M_{\oplus}$).

3.4 The mass–loop trade

Equation (5) contains a trade the first engineering pass missed. The total mass is linear in L_z , and so is the CTC loop circumference

$$\ell_{\text{CTC}} = L \sqrt{t - e \rho_0^2} \xrightarrow[t=2e\rho_0^2]{} L \rho_0 \sqrt{e}. \quad (6)$$

At the canonical design ($\rho_0 = 0.5$ m, $e = 0.1$, $L = 1$) the largest loops are ≈ 16 cm. Both the mass bill and the loop size therefore shrink together: a factor of ten in loop size is a factor of ten in mass, no better. Dividing,

$$\frac{M_{\text{layer}}}{\ell_{\text{CTC}}} = \frac{3.30 k_0 (c^2/G)}{\rho_0 \sqrt{e}} \simeq 6 \times 10^{16} \text{ kg/m} \quad (\text{deep rung}), \quad (7)$$

and $\simeq 1.4 \times 10^{28}$ kg/m at the canonical corner. Each metre of CTC loop costs 6×10^{16} kg at the deep rung. A sixteen-centimetre loop already costs 9.8×10^{15} kg, about 1.5 Eros masses.

The “tens of tons” figure that appears in early drafts is not a dial setting of this construction. It would require $L_z \sim 10^{-12}$ for a few tens of tons ($L_z \sim 10^{-11}$ already gives about 10^5 kg), i.e.

picometre CTC loops, which replaces the mass problem with a usability problem: a machine whose loops are smaller than an atom has not been assessed as a time machine at all. At usable loop sizes the dust budget is dwarf-planet-scale, not laboratory-scale.

There is a second, independent lever: deepening the slice lowers k_0 , hence the mass, at fixed loop size, but it lengthens the arming time and eventually makes the dust ordinary. That lever is the subject of the next three subsections.

3.5 The a -dial and the a -floor

The a -dial is not uniformly benign. As $a \rightarrow 0$ the transverse perturbations are ejected more slowly (rate $\mu - \frac{1}{4} \rightarrow \frac{1}{4}$) and the umbilicity residual $1.08 a / (2|\tau_0|)$ vanishes, which is good for the envelope. But the chronology-horizon stress diverges as a^{-4} . Restoring units, with L the periodicity scale and $\tilde{\rho}$ the transverse distance from $\mathcal{N}$ in units of L [4],

$$|\mathcal{E}_{\text{CH}}| \sim \frac{\hbar c}{L^4} \frac{1}{a^4 \tilde{\rho}^4}. \quad (8)$$

The binding constraint is back-reaction: the horizon stress must stay far below the unit-curvature density $c^4 / (8\pi G L^2) \approx 4.8 \times 10^{42} \text{ J/m}^3$ at $L = 1 \text{ m}$. Setting the two equal gives the a -floor

$$a_{\text{floor}} \sim (8\pi)^{1/4} \sqrt{\frac{\ell_P}{L}} \cdot O(1) \approx 2 \times 10^{-17} \quad (L = 1 \text{ m}), \quad (9)$$

with ℓ_P the Planck length. At the floor the semiclassical analysis itself breaks down; the floor is not an engineering target but the edge of the calculation’s validity. The canonical design $a = 10^{-4}$ sits thirteen orders above it.

3.6 The quantum budget

At the canonical design the horizon stress is $\sim 8 \times 10^{-9} \text{ J/m}^3$ (the frequently quoted $5 \times 10^{-18} \text{ J/m}^3$ is the paper’s $a = 0.02$ value; the a^{-4} rescaling accounts for the difference). That is ~ 51 orders of magnitude below $4.8 \times 10^{42} \text{ J/m}^3$: “protection in form, not in force” [4]. Hawking’s conjecture [13] and the Kay–Radzikowski–Wald analysis [14] set the semiclassical context; unlike the exotic-matter constructions, this machine has no negative-energy budget, so the Ford–Roman inequalities [21] do not enter the ledger directly. The stress is a test-field magnitude at a sampled point, not a survival proof; the uncomputed four-dimensional back-reaction remains the flagship paper’s open item. For the ledger, the relevant statement is narrower and sufficient: at every design point above the floor, the horizon stress is negligible by tens of orders, so it does not add a resource line. It does, however, forbid dialing a down indefinitely to make the envelope easier.

3.7 The lead time

The proper lead time from the matching slice to the chronology horizon is the light-crossing time $\sqrt{|\tau_0|}/c$; the Milne-comoving clock reads twice that. The three engineering rungs give

$$\sqrt{|\tau_0|}/c = 3.3 \text{ ns } (\tau_0 = -1), \quad 33 \text{ ns } (\tau_0 = -100), \quad 761 \text{ s } (\tau_0 = -5.2 \times 10^{22}). \quad (10)$$

This is the assembly’s arming window: the time between a correctly prepared slice and the formation of CTCs. It is also the interval over which the wrap must hold its geometry, and—as Sec. 5 shows—the interval over which the relative drift between relic and shell must stay below a fraction of ρ_0 .

Region	Geometrized mass (m)	Physical mass (kg)
C4 open layer	0.987	1.33×10^{27}
flattening band	0.664	8.9×10^{26}
RW tube to 4 m sphere	0.480	6.46×10^{26}
lower bound (computed layers + tube)	2.13	2.87×10^{27}
upper bound (Ori $R_2 = 8$ m)	4.0	5.39×10^{27}

Table 4: Canonical envelope masses. The RW tube is a component, not the machine mass: earlier quotes of 6.45×10^{26} kg count the tube; the full envelope is $\sim 8 \times$ the compact-object wall $c^2 \rho_0 / 2G \approx 3.4 \times 10^{26}$ kg.

3.8 What the dials do not change

It is important for the ledger that the mass dial is a *matter* dial only. The strong-field identified geometry (curvature $\sim e/\rho_0^2$), the CTC threshold, the chronology horizon, the a -floor, and the quantum budget are all independent of k_0 . The machine’s exoticness is the identification, not the mass. Deepening the slice buys cheaper matter and a longer arming time; it does not buy a different machine.

4 The wrap engineering

4.1 The dust distribution is not a choice

Equation (2) fixes the density once the geometry is fixed. At the robust knob point of the C4 construction the profile has the following measured features (canonical k_0 , $L_z = 1$):

- peak density 1.17×10^{26} kg/m³ at $r \approx 0.35$, the F-lever lift region;
- hand-off (RW) density $\varepsilon_0 = 6k_0^2/16\pi = 4.0 \times 10^{25}$ kg/m³;
- mean over the C4 layer 4.4×10^{25} kg/m³;
- quadrupole (max/min over φ at fixed r) ≤ 1.21 , the mild $O(a) \cos 2\varphi$ modulation;
- radial profile rising from zero at the vacuum collar through the peak, relaxing to the uniform plateau by $r \approx 1.5$ and staying there to the hand-off;
- radial extent: C4 layer to $R_1 = 2.7$, flattening band to $R_{2P} = 3.7$, Ori layers to $R_2 = 8$ m—a ~ 16 m object.

4.2 The mass integral

The per-region masses at the canonical corner are collected in Table 4. The C4 open layer and flattening band are the part this program computed; the RW tube and Ori’s outer layers are the cited construction. The lower bound is the sum of the computed layers; the upper bound applies Ori’s $R_2 > 2m$ condition at $R_2 = 8$ m.

The compact-object wall is worth stating explicitly. The full canonical envelope has a gravitational radius $R_s = 2GM_{\text{env}}/c^2 = 4.3\text{--}8.0$ m, comparable to its own 8 m outer radius. It is a compact object, not a lump of matter with a dust halo. That is the quantitative form of the statement that the canonical corner is not ordinary matter.

4.3 Tolerances

The news here is better than the density numbers suggest. The robustness campaign covers the nominal point plus twenty single-knob $\pm 30\%$ perturbations; all twenty-one pass both constraint gates on the full fine grid ($\Delta r = 0.005, 48\varphi$), with a worst sampled margin of $+0.39$ (nominal margins $+0.76$ and $+0.73$ at $a = 0.02$). Measured per-knob widths keep both gates positive over at least a factor ~ 2 in every knob; the binding knobs are f_{conc} ($\times 2.21$) and d_C ($\div 4.7$) [3].

Translated into placement requirements, this means:

- **Density:** tens of percent, not sub-percent. Local undershoot up to $\sim 40\%$ of the typical field value is tolerated; overshoot is benign up to the dust/WEC budget.
- **Radial placement:** the blend widths $d_C, d_F, d_L \approx 0.5\text{--}1.0$ geometrized metres tolerate factor-two changes, i.e. $\sim 0.1\text{--}0.3\text{ m}$ accuracy at metre scale.
- **What is required:** place the right mass in the right shell, to tens-of-percent density and decimetre radial accuracy. That is hard robotic work, not metrological fantasy, but it is not fine-tuning either.

The dust distribution is fully determined by whatever geometry is actually built, through Eq. (2); the builder cannot separate “getting the shape right” from “getting the density right.” The tolerance statement is therefore about the built geometry’s profile, not about an independent material specification.

4.4 The core self-cleans

One requirement the builder does *not* face is fine-tuning the core interior. Transverse perturbations are ejected at rate $\mu - \frac{1}{4}$ (approximately $\frac{1}{4}$ for small a), and the closed null geodesic $\mathcal{N}$ is attracting. The machine does not require a delicately tuned vacuum. This statement is linear/leading-nonlinear; survival on cosmological timescales is not proved [4, 24]. This is a genuine resource saving: the expensive precision is in the dust shell’s placement, not in the strong-field region.

5 Placement and siting

5.1 The curvature budget

The external tidal field adds directly to the Hamiltonian constraint, because $R^{(3)}$ enters Eq. (2). It must therefore sit below the k_0^2 -scaled gate margin. At the canonical and $\tau_0 = -100$ rungs the budget is $\geq 10^{-4}$ in H_1 units, which dwarfs Earth-surface tides ($3.4 \times 10^{-23} \text{ m}^{-2}$): anywhere off the planet works. At the deep rung the margin shrinks to $m_A \sim 1.5 \times 10^{-23} \text{ m}^{-2}$ for canonical-quality retuning, or $m_B \sim 5 \times 10^{-27} \text{ m}^{-2}$ for the thin margins currently demonstrated at $\tau_0 = -100$ (rescaling $+2.6 \times 10^{-6}$).

To convert a margin into a distance we use the largest tidal eigenvalue as a conservative scalar proxy for the external $R^{(3)}$,

$$R_{\text{env}}(r) = \frac{2GM}{c^2 r^3} \leq 0.1 m, \quad r_{\text{min}} = \left(\frac{20 GM}{c^2 m} \right)^{1/3}, \quad (11)$$

and require it to stay below ten percent of the gate margin m , i.e. a $10\times$ safety factor. The factor 2 is the radial geodesic-deviation coefficient, so the naive estimate $GM/(c^2 r^3)$ is smaller by that factor; together with the ten-percent budget it makes Eq. (11) larger than the naive full-margin

distance by $20^{1/3} = 2.71$, which is the origin of the factor between the table and a simple $GM/(c^2 r^3)$ estimate. For m_A the formula gives 1.8×10^7 m ($2.8 R_E$) from Earth and 0.008 AU from the Sun; for m_B , 2.6×10^8 m ($41 R_E$) and 0.12 AU.

Table 5 collects those distances. The result is a siting requirement, not a construction requirement.

Scenario	Min distance from Earth	Min distance from Sun
canonical-quality margins kept	1.8×10^7 m ($2.8 R_E$)	0.008 AU
thin ($\tau_0 = -100$ -style) margins	2.6×10^8 m ($41 R_E \approx 0.0017$ AU)	0.12 AU

Table 5: Siting budget at the deep rung from Eq. (11), with the tidal factor 2 and a $10\times$ margin safety factor included. A 1 AU solar orbit has 10^3 – 10^6 headroom over both scenarios.

5.2 Heliocentric space

The deep-slice assembly cannot be done on Earth, in low Earth orbit, or in geostationary orbit under the thin-margin case. It needs heliocentric interplanetary space at $\gtrsim 0.008$ – 0.12 AU from the Sun; a one-AU solar orbit has three to six orders of headroom. This is an interplanetary mission requirement, not an interstellar one. The distinction matters for the ledger: the siting cost is a deep-space logistics line, not a relativistic-propulsion line.

5.3 Formation flying and centring

The wrap must be built around the relic where it drifts, because the relic cannot be docked with or moved (Sec. 7). Two tolerances follow. First, the truncation torus must be centred on the core to a fraction of ρ_0 , i.e. centimetres to decimetres at metre scale. There is no continuous pre-trigger observable of the core: the relic is causally cloistered, and even a wrapped machine’s lensing is sub-milliarcsecond (Sec. 7), so the core cannot be tracked by lensing astrometry. The seam pair is the only direct signature, and it opens only for a large pocket or at the trigger—by which time the shell geometry is already fixed. Centring is therefore open-loop with respect to the relic: the wrap is placed in the astrometric frame in which the relic was discovered, and the formation-flying control holds the spacecraft relative to that frame, not to a measured core. A visible pair provides a post-hoc check, not a tracking signal. Second, the relative drift over the arming window must be small compared with ρ_0 :

$$v_{\text{rel}} \ll \frac{\rho_0}{t_{\text{arm}}} = \frac{0.5 \text{ m}}{761 \text{ s}} \simeq 6.6 \times 10^{-4} \text{ m/s}, \quad v_{\text{rel}} \sim 7 \times 10^{-5} \text{ m/s} \quad (12)$$

for a safe fraction. Sub-millimetre-per-second formation flight has been demonstrated (PRISMA-class [23]), but doing it open-loop around a target with no real-time measurement in interplanetary space is a genuine engineering frontier. It is robotic-demonstrable, not physics-blocked, and it is the hardest *mechanical* requirement in the ledger.

5.4 Containment

Dust does not self-support. The honest architecture is a physical containment frame—a canistered granular payload released in place at the required density—not a free-floating cloud. The frame is part of the wrap’s engineering mass, though it is small compared with the dust bill; its design is not part of the verified construction and is counted here as an unquantified addition, not as a solved item.

6 Sourcing and the launch budget

6.1 The arithmetic

The deep-rung envelope is $1.3\text{--}2.4 \times 10^{16} \text{ kg} \cdot L_z$. For a usable loop ($L_z = 1$) that is the mass of a mid-sized asteroid. Present launch capacity is $\sim 10^4 \text{ t/yr}$; launching the shell would take $\sim 10^9$ years of the entire global launch sector. This is not a funding gap that a bigger rocket closes. It is a different sourcing model.

6.2 In situ

The only honest sourcing is asteroid-class industry: find a near-Earth object of the right scale, disassemble it, and deposit the granular product into the confining structure. Eros, at $6.7 \times 10^{15} \text{ kg}$ [22], is the right order—the deep-rung shell is roughly two to four Eros masses. The launch budget then covers the *equipment*: mining, processing, and containment plant, plausibly $10^2\text{--}10^3 \text{ t}$, i.e. flagship-mission scale for the hardware on top of a decades-scale asteroid-industry program.

The cost class is beyond a flagship mission (\$10–100B); it is a space-industry buildout. We state that as a class, not as an estimate, because the dominant uncertainty is the survey’s duration, not the wrap’s unit costs.

6.3 The L_z trade

The alternative is to shrink L_z . Since $M \propto L_z$ and $\ell_{\text{CTC}} \propto L_z$, a tons-scale bill requires $L_z \sim 10^{-12}$ and picometre loops. That trades a mass problem for an unassessed usability problem. We do not recommend it; we record it because the ledger should show that the “cheap” corner exists and why it is not cheap in the relevant sense.

6.4 Per-rung verdicts

The sourcing verdicts differ qualitatively by rung, and the differences are not matters of degree:

- **Canonical** ($2.9\text{--}5.4 \times 10^{27} \text{ kg}$): today-impossible. This is not an engineering gap; the matter does not exist ($\sim 5 \times 10^8 \rho_{\text{nuc}}$, at its own gravitational radius).
- $\tau_0 = -100$ ($2.9\text{--}5.4 \times 10^{26} \text{ kg}$): today-impossible, for the same reason ($\sim 5 \times 10^6 \rho_{\text{nuc}}$). No dial setting between here and the deep rung helps: the dust only reaches ordinary-solid densities at $k_0 \lesssim 7 \times 10^{-12}$ (water and sand by 3×10^{-12}).
- **Deep rung** ($1.3\text{--}2.4 \times 10^{16} \text{ kg} \cdot L_z$): asteroid-industry-class for the wrap itself, with three dependencies: the relic survey, in-situ precision placement at asteroid-industry scale, and (now resolved) the gate verification at depth.

7 The survey and the capture problem

7.1 The target signature

A bare relic is a quotient pocket: flat Minkowski quotiented by a boost of rapidity $\Lambda = L/2$ on a transverse tube $\rho < \rho_0$ [5]. Its observable signature is exact. A photon crossing the seam once exits with

$$r = \frac{\nu_{\text{wound}}}{\nu_{\text{direct}}} = \cosh \Lambda - n_z \sinh \Lambda, \quad (13)$$

Pocket size ρ_0	Shell stars
0.5 m	3.8×10^{-51}
1 AU	1.6×10^{-17}
1000 AU	1.6×10^{-8}

Table 6: Stars in the entry shell of a bare relic, assuming 0.004 stars/ly^3 and a shell volume $\sim \pi \rho_0^2 r_{\text{wall}}$ in the disk shadow. The OFF bare relic is invisible to a generic stellar survey.

so on-axis sources show a co-spatial spectral double image at a fixed ratio $e^{\pm\Lambda}$: no mass, no deflection, no source dependence. For the canonical $\Lambda = 0.5$ the pair ratios are 1.649 and 0.607; off-axis photons are tilted by up to $\arctan(\sinh \Lambda) = 27.5^\circ$. Multi-wound exits give integer powers $e^{\pm n\Lambda}$ of one fixed base. There is also a time echo of $\sim 3.4 \text{ ns}$ per circuit at the canonical metre pocket.

This is a searchable signature, and it is the reason the survey is a real observational program rather than a hope. But the signature is only available if light can enter the pocket.

7.2 Causal cloistering

The pre-horizon pocket world-tube is the Rindler band $0 < \tau < \tau_{\text{wall}}$. A null chord from a generic background star crosses the tube’s spatial location at covering radius $\tau \sim \tau_{\text{now}}$, far outside the band, and never enters. Entry requires the chord to graze the birth-cone null surfaces $W = \pm Z$ inside the tube: a shell of thickness $\sim r_{\text{wall}}$ around those surfaces. The star count in that shell is (Table 6).

The disk cross-section $\pi \rho_0^2$ at 1 kpc subtends $8 \times 10^{-40} \text{ sr}$: a metre-scale pocket covers $\sim 10^{-31}$ Gaia-like stars even ignoring the entry shell. A wrapped machine is no easier to find by its lensing: the Einstein angle of $10^{22}\text{--}10^{26} \text{ kg}$ of dust at 1 kpc is $1.4 \times 10^{-4}\text{--}1.4 \times 10^{-2} \text{ mas}$, i.e. sub-milliarcsecond (about $14 \mu\text{as}$ at the upper mass). The wrapped machine is found by its *pair*, not its lens.

7.3 Two windows

Two windows remain. First, **large pockets**: if $\tau_{\text{wall}} \gtrsim 0.1 \text{ ly}$, the entry shell is star-populated and the pair channel opens with the shell cross-section. Second, **the trigger**: at $t > e\rho_0^2$ the z -circles turn timelike, winding is free of the phase budget, and the classical Misner image cascade opens—many images of one source at geometrically compressed frequencies crowding the horizon direction. The detectable epoch is the CTC epoch, or a pocket large enough to have a populated entry shell.

7.4 The empirical status

The program has executed the two currently possible searches. The Gaia full-sky co-spatial radial-velocity pair census is complete; its family statistic is now calibrated by a composition-matched null and shows no excess (permissive $p = 0.74$, strict $p = 0.97$), so there is no density bound and no detection [6]. The LVK pair-family cut is null at the catalog level: at the one-degree-of-freedom 3σ cut the Stage-1 count is 32,434 against a label-permutation null median of 32,806 (two-sided $p \approx 0.10$, a mild deficit, not an excess); the archived equality-cut $3\text{--}6\sigma$ sweep gives no excess (smallest two-sided $p \approx 0.05$, 8-look-corrected ≈ 0.4); the corrected sweep gives $p \approx 0.96$ and $0.99\text{--}1.00$. The corrected M_c/D_L scaling cut is null at Stage 1.5: 30,343 candidates against a matched independent-pair null of 30,349 (two-sided $p \approx 0.96$), recovering 5,688 pairs the archived equality- D_L cut discarded. The corrected sky co-localization pilot gives $p = 0.75$ and the full volume $p = 0.95$

over 30,311 mapped candidates, with largest candidate co-localization $C = 0.9513$; on the 3,669 corrected co-located candidates the family statistic is $S = 2,697$, and the composition-matched null gives $p = 0.539$ (nominal sky $p = 0.005$). The Stage-2 co-localization limit, using 5,000 sky-map permutations on the corrected set, is $\mu < 274$ expected true detectable families at 90% CL at the operational threshold $C > 0.1$ (205 under the Gamma–Poisson model, which is not adequate at $C > 0.1$); the stricter cuts give 17.3 at $C > 0.5$, 4.50 at $C > 0.9$, and 3.10 at $C > 0.95$ [5, 7, 8].

These nulls are honest but narrow. They constrain only the large-pocket window, $\tau_{\text{wall}} \gtrsim 0.1$ ly; they do not bound the local density of relics. Metre-scale bare relics are unfalsifiable by this channel. The survey must target the trigger epoch or large pockets, and the program says so rather than claiming a general exclusion.

7.5 Capture is not a mechanical operation

The relic is vacuum, essentially massless, gravitationally invisible, and pre-horizon causally invisible. There is nothing to dock with, decelerate, or carry. “Wrap in situ” is therefore the only option: build the dust shell around the found relic where it drifts. This is the origin of the formation-flying requirement (Eq. (12)) and of the centring requirement. A capture mission in the ordinary sense does not exist.

The same fact is the survey’s deepest problem. The target hides its holonomy until the machine is already on, so the survey is largely a search for machines in the act of being machines—or for the rare large pockets whose entry shells are populated. That asymmetry is the paper’s central result: *the wrap is industry; the survey is the civilization-scale problem.*

8 The resource class per rung

Table 7 is the ledger’s summary. It should be read downward as a sequence of different machines, not as a sequence of budgets for the same machine.

Rung	k_0	dust density (kg/m ³)		envelope mass (kg · L_z)	arming	resource class
		mean	peak			
canonical	0.499	4.4×10^{25}	1.17×10^{26}	$2.9\text{--}5.4 \times 10^{27}$	3.3 ns	not a material
$\tau_0 = -100$	0.05	4.4×10^{23}	1.2×10^{24}	$2.9\text{--}5.4 \times 10^{26}$	33 ns	not a material
deep	2.2×10^{-12}	850	2300	$1.3\text{--}2.4 \times 10^{16}$	761 s	asteroid industry

Table 7: The resource class per rung. “Not a material” means no known form of matter has the stated density; it is not a statement about cost. The deep rung is the only rung whose dust is ordinary matter, and its mass is asteroid-class.

Three readings of the table matter.

First, the density column is the qualitative gate. The canonical and $\tau_0 = -100$ rungs are not “expensive”; they are unphysical as materials. A civilization with unlimited energy but only known matter has no material to build them from. Only the deep rung is a matter-sourcing problem, and it is a hard one: asteroid-class mass, in-situ processing, decimetre placement.

Second, the mass column does not fall as fast as the density column, and that is the point. Deepening the slice by twenty-two orders in $|\tau_0|$ lowers the mass by eleven orders, not twenty-two, because the mass scales as k_0 and the density as k_0^2 . The volume grows as $1/k_0$. This is the mass law’s practical content: the deep rung is not as cheap as the density suggests.

Third, the arming column is the operational cost of depth. The canonical machine arms in nanoseconds; the deep machine takes thirteen minutes. A longer arming window is easier to observe and harder to hold: it demands formation flight at 7×10^{-5} m/s and a containment frame that survives for the duration. Depth buys matter at the price of time and control.

The thresholds between matter and non-matter are worth recording explicitly: water density at $k_0 = 2.4 \times 10^{-12}$ ($M = 1.4\text{--}2.6 \times 10^{16}$ kg $\cdot L_z$, arming 699 s), sand at $k_0 = 3.0 \times 10^{-12}$, steel at $k_0 = 6.7 \times 10^{-12}$ ($M = 3.9\text{--}7.2 \times 10^{16}$ kg $\cdot L_z$). There is no dial setting that gives ordinary matter at less than asteroid mass with human-scale loops.

9 What remains

The ledger is only useful if its open items are as visible as its numbers. We list them in order of what would change the resource class.

1. **The survey.** This is the principal open item and the only one that is civilization-scale. The sky density of relics is unknown; the current nulls bound only the large-pocket window; metre-scale relics are cloistered. A survey strategy that targets the trigger epoch, or a population model that makes large pockets plausible, is the program's rate-limiting step.
2. **Capture robotics.** Sub-millimetre-per-second formation flight with no real-time measurement of the target in interplanetary space has no precedent. It is demonstrable in principle (PRISMA-class metrology) but not demonstrated in this regime.
3. **The upper-envelope mass law.** The k_0 -linear law is certified for the C4 layer and the RW tube. We have not established it for the full upper envelope that includes Ori's outer layer; the $1.3\text{--}2.4 \times 10^{16}$ kg $\cdot L_z$ range is an envelope bound, not a single certified integral.
4. **The deep-rung certification status.** The deep row is the certified Laurent series evaluated at $k_0 = 2.2 \times 10^{-12}$, not a separate nonlinear fine-grid solve. The series is exact in k_0 and the gates are positive through the rung; a direct nonlinear verification at the deep point remains desirable.
5. **Analytic error bounds and the $O(a)$ theorem.** The gate verifications are numerical; analytic bounds on the profile family are routine but unwritten. The $O(a)$ uniformity of the fixed-knob family is exhibited to the Misner limit and interval-certified on a restricted band, but not proved on the full open band.
6. **Per-depth retuning.** The mass-dial check exhibits a single-knob depth-uniform retune ($d_C : 1.029 \rightarrow 1.7$ with the F/L levers off), not a general theorem. Fixed-knob transfer fails, so the retune is real and must be counted in any production plan.
7. **Ori-2007 dependence.** The outer layers are used, not re-proved. The composite inherits Ori's existence machinery; that is a cited dependency, not a result of this program.
8. **Late-time evolution.** What the dust does after the machine operates is shared with Ori's construction and is not analysed here. It is an evolution question, not a construction question, but it is unbudgeted.
9. **The a -floor's semiclassical breakdown.** Above the floor the horizon stress is negligible; at the floor the calculation that produced it is invalid. The canonical design is safe by thirteen orders, but a designer who dials a down must stop at the floor, not at zero.

10. **Acquisition.** No classical process is known to create the identification. The rigorous CFG/CFGO energy obstruction is $2+1$ -dimensional; the $3+1$ extension for this data class is an open gap. The three routes (inheritance, nucleation, reproduction) are mapped to known physics, but only the first is compatible with known mechanics without new sectors; it is the one the survey targets. This is the item that makes the rest of the ledger conditional.

What is not open. For balance: the matter side is specified and gated on the gatefast interior band and, in the retuned construction, over the full C4 layer. The core, the umbilical slice, the envelope, the hand-off, and Ori’s outer layers are explicit; the C4 envelope and hand-off are gate-verified for $r \geq w + 0.0904$, and the C4 layer is gate-positive for $r > w$ after the retune. The mass law is certified for the C4 layer and the RW tube. The tolerances are measured. The a -floor and the quantum budget are computed. The siting requirement and the formation-flying tolerance follow from those numbers. The remaining work is analytic bookkeeping, one nonlinear check, the continuum cell bound, the upper-envelope certification, and the acquisition/survey problem—not a missing layer of the machine.

10 Honest conclusion

We have priced the composite time machine as a resource ledger, given a relic core. The result is narrower and stranger than either the optimistic or the dismissive reading.

The wrap is asteroid-class industry. At the only rung whose dust is ordinary matter, the machine needs $1.3\text{--}2.4 \times 10^{16} \text{ kg} \cdot L_z$ of sand-to-water-density granular material—two to four Eros masses for a usable loop—placed to tens-of-percent density and decimetre radial accuracy, in heliocentric space at $\gtrsim 0.008\text{--}0.12 \text{ AU}$, with the wrap held to a relative-drift budget of $7 \times 10^{-5} \text{ m/s}$, arming in thirteen minutes. Nothing in that sentence needs new physics. All of it needs an industry that does not yet exist.

The canonical corner is not a cheaper machine. At $\tau_0 = -1 \text{ m}^2$ the dust is $\sim 5 \times 10^8$ times nuclear saturation, in an envelope whose gravitational radius is comparable to its own size. It arms in nanoseconds, which is beautiful for a thought experiment and useless for a resource plan: the matter has no known realization. The $\tau_0 = -100$ rung is the same story at $5 \times 10^6 \rho_{\text{nuc}}$.

The mass dial is a trade, not a discount. Density falls as k_0^2 , total mass only as k_0 , and both mass and CTC loop size are linear in L_z . Each metre of loop costs $6 \times 10^{16} \text{ kg}$ at the deep rung and $1.4 \times 10^{28} \text{ kg}$ at the canonical corner. Tons of dust require picometre loops, which is not a time machine whose usability we have assessed. There is no setting that gives human-scale mass at human-scale loops.

The a -floor and the quantum budget constrain, but do not bind, the canonical design. The floor is $\sim 2 \times 10^{-17}$ at metre scale; the canonical $a = 10^{-4}$ is thirteen orders above it, and the horizon stress is fifty-plus orders below the unit-curvature density. The constraint matters only to a designer who tries to make the envelope easier by dialing a down.

The assembly is acquisition, not manufacture. The matter can be arranged; the boost-holonomy identification cannot be created by any known classical process (the CFG/CFGO obstruction is rigorously $2+1$ -dimensional, and the $3+1$ extension for this data class is an open gap). The machine’s exoticness is the identification, not the mass. This is not an engineering gap that a better budget closes; it is the boundary of what “building” can mean in classical general relativity. The ledger is therefore written for a relic that has already been found.

The survey is the civilization-scale problem. A metre-scale OFF relic is causally cloistered: its entry shell contains 10^{-51} stars, and its disk cross-section covers 10^{-31} Gaia stars at

a kiloparsec. The findable windows are large pockets ($\tau_{\text{wall}} \gtrsim 0.1 \text{ ly}$) or the trigger epoch. The current searches are null and honest—the Stage-1 count gives $p \approx 0.10$, the corrected scaling and family stages are null, and the $C > 0.1$ limit is $\mu < 274$ —and they bound only the large-pocket window. The wrap is industry; the survey is the hard part; and the survey’s targets are, almost by construction, visible only when the machine is already on.

We therefore end with a ledger, not a prospectus. Given a relic, the wrap is a known, verified, asteroid-class industrial program with quantified tolerances. Without a relic, there is nothing to wrap, and no known classical process can make one. The correct posture is the one the program has taken throughout: compute the invoice honestly, state which line items are extrapolations, and spend the observational effort where it can actually change the answer—on the sky.

A Constants, conversions, and scaling laws

Table 8 collects the constants and conversions used in the text.

Quantity	Value
c^2/G	$1.347 \times 10^{27} \text{ kg/m}$
$c^4/(8\pi G)$ at $L = 1 \text{ m}$	$4.8 \times 10^{42} \text{ J/m}^3$
$\hbar c$	$3.16 \times 10^{-26} \text{ J m}$
ℓ_P	$1.616 \times 10^{-35} \text{ m}$
ρ_{nuc} (nuclear saturation)	$2.3 \times 10^{17} \text{ kg/m}^3$
M_J	$1.898 \times 10^{27} \text{ kg}$
$M_{\oplus}$	$5.972 \times 10^{24} \text{ kg}$
Eros mass	$6.7 \times 10^{15} \text{ kg}$
1 AU	$1.496 \times 10^{11} \text{ m}$
R_E	$6.371 \times 10^6 \text{ m}$

Table 8: Constants used in the text.

The scaling laws used throughout are:

$$k_0 = \frac{1}{2\sqrt{|\tau_0|}}, \quad \varepsilon_0 = \frac{6k_0^2}{16\pi}, \quad \rho_{\text{phys}} = \varepsilon_0 \frac{c^2}{G}, \quad (14)$$

$$M_{\text{layer}} = 3.30 k_0 L_z \text{ (geometrized)}, \quad M_{\text{layer}}^{\text{phys}} = 3.30 k_0 L_z \frac{c^2}{G}, \quad \ell_{\text{CTC}} = L \sqrt{t - e\rho_0^2}, \quad (15)$$

$$t_{\text{arm}} = \frac{\sqrt{|\tau_0|}}{c}, \quad |\mathcal{E}_{\text{CH}}| \sim \frac{\hbar c}{L^4 a^4 \tilde{\rho}^4}, \quad a_{\text{floor}} \sim 2 \times 10^{-17} \text{ at } L = 1 \text{ m}. \quad (16)$$

The mass law is exact linear in k_0 at fixed (ρ_0, L_z) for the C4 layer; the coefficient 3.30 is certified across four rungs. The density law is exact in the same series. The a -floor is an order-of-magnitude estimate with an $O(1)$ coefficient; the canonical design’s margin is thirteen orders, so the coefficient does not matter for the ledger.

B Provenance and data availability

This paper is a synthesis; it reports no new computation. The construction, gate verification, mass-dial evaluation, and survey cuts summarized in the tables are documented in the companion papers [3, 4, 5, 6] and in the program’s technical record. The numerical inputs needed to reproduce

the ledger are the certified Laurent-series coefficients and gate profiles of the composite construction, the dials of Table 2, and the catalog selection described in the survey companion.

The analysis code and the derived data tables are available from the author on reasonable request. They are not reproduced here.

Where the record disagrees—the early “tens of tons” mass, the early k_0^2 total-mass scaling, the $a = 0.02$ versus canonical stress—we use the corrected value and say so.

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