

Lightmind One - Project Proxima

A Novel by Daniel Scott Matthews

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Synopsis

1. Earth is dying slowly enough for everyone to watch.

On the far side of the Moon, behind the Shackleton-de Gerlache ridge, a 900-metre segmented mirror the size of Manhattan's Central Park is being polished by autonomous robots that were never told the planet below them is on fire.

They are building the transmitter for Lightmind One: the first reversible photonic brain emulator small enough to fit inside a sphere of glass the size of a basketball, cold enough to run on a few watts of sunlight, and precise enough to contain a complete human being distilled into 3.7×10^{11} bits.

This is the story of the five people who will decide whether that first beam is ever fired.

Dr. Mara Solovyova, the Russian-American neuroscientist who trained the lifelong sparse transformer on her own brain for thirty-five years and now refuses to let anyone else be the test passenger. Captain Amari Okonkwo, commander of the lunar array, who knows the launch window closes forever if the East African Federation seizes the high ground in the next eighteen months.

Jun Seo-Yeon, the North Korean defector who wrote the optical error-correction codes that make transmission possible—and who still has a kill switch buried in the firmware.

Daniel Scott Matthews, the reclusive physicist who first proposed the microsphere resonator in a 2025 preprint

and has not set foot on Earth in twelve years. And Livia, the fourteen-year-old optics prodigy born on Luna, who realises that if the beam is fired she will be the only human alive who has never seen a blue sky—and that she is the only one who can still stop it.

Between them stand treaties, kill switches, pre-committed cryptographic heartbeats, and the final veto of a dying planet that would rather drag its children into the grave than let them leave.

This is not a story about whether the technology works. It works.

This is the story of what you do when the engineering problem is solved and the human problem is just beginning.

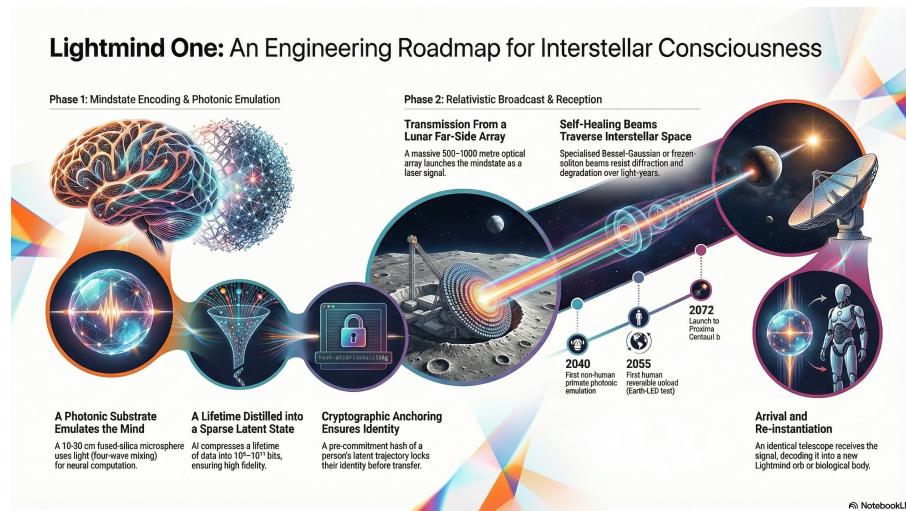


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Part 1: Earthrise (2066–2069)

Chapter 1.1: The Last Sunset Over Denver

1

The colour that evening was wrong before the Sun even touched the ridge.

Livia had watched 2 307 Terran sunsets on the wall-screen in Habitat-C, enough to know the Denver sequence by heart: first the copper wash on the high plains, then the sudden bruise-coloured shadow that slid east off the Rockies, finally the magnesium-white flash when the last sliver dropped behind the Front Range.

Tonight the copper never arrived. The plains glowed arterial red, the same wavelength she used for 1 550 nm alignment drills. She whispered the number—**6.3 × 10¹⁴ Hz**—because numbers felt cleaner than the sky.

“Filter’s not lying,” her mother said from the doorway. “Smoke column’s eighty kilometres west. You’re seeing the fire’s own sunset.”

Livia kept her eyes on the feed. The camera drone banked, giving her a slant view of I-76, both lanes jammed with autonomous freight rigs commandeered by the NorthAm Authority. Every tenth trailer carried liquid-nitrogen dewars stamped **LIGHTMIND – PRIORITY A**. She traced the letters with a finger.

“Dad says the trucks get through,” she muttered.

“Dad says a lot of things.” Her mother’s tone carried the flat register adults used when they wanted to sound certain. “Come to the window. Real light’s better than pixels.”

But the window only showed the Moon’s own grey dusk, the crater lip cutting a black knife across the stars. Earth hung above the ridge, a bright coin smeared with rust.

Livia preferred the screen. Pixels could be paused, zoomed, error-corrected. The sky outside the window never obeyed.

2

She had been born in Shackleton Crater 14 Earth-years ago, one of the first cohort delivered entirely by tele-operated surgical arms because no obstetrician had clearance to stay pregnant through launch. Gravity had been 0.165 g from her first lungful; her inner ear still panicked every time she visited the centrifuge ring and felt the fraudulent drag of 0.7 g.

Earth was a vocabulary word she memorised before she learned to walk: blue, wet, loud, heavy. She could recite the average atmospheric pressure at sea level (101.325 kPa) faster than she could name her grandparents, both of whom lived in Quito under the East Pacific dome and refused visa requests for “sentimental travel to a failed biosphere.”

Tonight the failed biosphere was burning so brightly it outshone the lunar dawn line.

3

Dinner was silent except for the habitat’s air handlers. Dad appeared after the second course, helmet tucked under one arm, grey lunar dust still clinging to his knee joints. He smelled of vacuum-welded titanium and the faint ozone that leaked from the big laser cabinets.

“Segment 17 polished to $\lambda/100$,” he announced, not bothering with hello. “We’re inside the error budget for launch.”

Mother’s fork paused midway to her mouth. “You’re early by three weeks.”

“Turns out robots don’t unionise.” He dropped into the chair, noticed Livia staring. “Hey, starlight. Finished your waveguide homework?”

She nodded, even though she hadn’t. The tutor software would flag incomplete sections and dock 0.2 credits; easier to absorb the penalty than pretend she cared about mode dispersion in 1960-style fibre when the real hardware outside her window ran on whispering-gallery modes with Q-factors higher than any Earth lab had achieved before she was born.

Dad pulled a cube of glass from his pocket, the size of a die. Inside, a single photon bounced forever between mirrored walls, trapped in a total-internal-reflection orbit. He rolled it across the table to her.

"Keep it dark," he said. "That's a spare seed for the uplink encoder. If you angle it right you can see the Bessel sidelobes."

The cube was cold. She tilted it until a faint hexagon bloomed, ghostly, in the centre.

"Looks like a star," she whispered.

"Better. Stars leak. That one doesn't."

Mother stood, plates in hand. "No mission hardware at the table, Daniel."

He lifted both palms in mock surrender, but his eyes stayed on Livia. "We fire in twenty-six months. You'll be sixteen. Old enough to watch from the catwalk."

Old enough to decide, he didn't say, but she heard it anyway.

4

After dinner she cycled through the public data layers: fire perimeter, evacuation corridors, atmospheric CO spike. The numbers felt like personal insults. 487 ppm. 42 °C wet-bulb in Dallas. 11 % drop in global gross photosynthesis since January.

She opened a private layer only she and two classmates knew existed: the **Earthrise Archive**, a stolen slice of the neural-lace dumps collected for the Lightmind training set. The files were supposed to be anonymised, but kids always found the back doors.

Tonight she chose **Subject 1138**, a woman who had stood on the same Denver overpass in 2062, watching an earlier sunset not yet poisoned by smoke. The lace fed her the woman's somatic trace: wind tugging at a cotton shirt, brake fumes, distant guitar from a street busker.

For 37 seconds Livia felt gravity pull her bones straight down, felt lungs labour against nitrogen narcosis, felt the warm terror of being trapped on a sphere with nowhere higher to climb.

Then the file ended and she was back in 0.165 g, breathing scrubbed oxygen, heart racing like a trapped gecko.

She whispered into the dark, "I never asked to be your backup copy."

5

Sleep refused. At 02:17 she slipped out of her bunk, mag-slippers sticking to the corridor floor. The habitat's night cycle ran on red LEDs, the colour chosen because it scatters least in vacuum if a blowout ever sprays dust into the corridor.

She rode the cargo lift to the surface lock. The guard AI recognised her badge but still asked, "Purpose of egress?"

"Photometry practicum," she lied. "Comparative Earth albedo."

"Duration?"

"< 90 min."

The outer hatch cycled. She stepped onto the regolith, visor auto-tinting against the glare of the still-burning planet.

6

The array sprawled below her, 900 m of hexagonal segments stepping down the crater slope like a frozen waterfall. Each panel was a mirror polished to within 0.3 nm of perfection—smooth enough that if you scaled it to Earth's size the tallest hill would be 2 cm.

Robots glided on carbon-fibre legs, carrying ion beams finer than her hair. They worked without lamps; Earthlight was enough.

She walked the service catwalk until she reached Segment 17, the one Dad had boasted about at dinner. A fresh laser-etched serial caught her helmet lamp: **SM-17-λ100-20660928**.

She knelt, pressed her gloved palm against the glass. The reflection showed two Earths: one real and orange, one inverted in the mirror, both on fire.

A voice crackled in her headset. "You're up late, kid."

She jumped. Captain Okonkwo's icon blinked on her HUD—orange for command tier.

"Couldn't sleep, sir."

"Insomnia is a terrestrial luxury. Up here we call it poor CO₂ scrubbing. Walk back to the lock, please."

Livia obeyed, cheeks burning hotter than the suit could compensate. Halfway, she risked, “Are we really going to do it? Beam someone?”

A pause filled only by static. “That’s above your clearance.”

“But you’re the captain. You can say yes or no.”

Another pause, softer. “Saying no is easy. Saying yes and meaning it—that’s the hard part.”

They reached the hatch. Okonkwo waved her through, then added, “Get your rest, optics prodigy. Dawn comes every 29.5 days here, but Earth only gets so many.”

7

Back inside, she found Dad in the common dome, hunched over a holo of the beam path: $4.243 \text{ ly}, 1.3 \times 10^{13} \text{ km}$, 1 550 nm photons sailing through vacuum for 4 years 3 months 6 days.

He didn’t look up. “You breached surface protocol.”

“Sorry.”

“Don’t be. Curiosity is the only engine we’ve got left.” He patted the bench. “Sit.”

She sat. The holo zoomed until a single photon filled the dome, its wavefront curved like a lens.

“Inside that photon we encode 3.7×10^{11} bits,” he said. “Every friendship you’ve betrayed, every test you’ve cheated, every time you lied to your mother about homework—if it’s in your lace, it rides the light. You still want to watch?”

She swallowed. “Will it hurt?”

“The upload? No. The leaving? Ask the planet.”

8

Morning—lunar morning—brought the weekly treaty briefing piped from Geneva. Delegates argued over aperture time, over who owned the far side, over whether a transmitted mind was a citizen or a weapon.

Livia tuned them out and opened her school slate. The assignment was simple: calculate the diffraction-limited divergence of a 500 m aperture launching at 1 550 nm. She solved it in three lines, then added a footnote:

If Earth's angular diameter at Moon distance = 1.9° , and fire brightness = -12 mag, estimate how many sunsets remain before global photosynthesis drops below human respiratory demand.

The teacher AI flagged it as off-topic and docked 0.5 credits.

She didn't care. She was busy counting photons.

9

That evening the Denver feed finally cut out. The last frame showed the 16th Street drone looking west: smoke wall taller than any building, sunlight reduced to a pinhole, people smaller than pixels running on a bridge that would burn in 14 minutes.

Then static. The screen printed a polite error: **Signal lost. Atmospheric scattering exceeds link budget.**

Livia stared at the grey square until her reflection appeared: thin face, oversized eyes, helmet ring of hair bleached by UV lamps. She looked like a ghost already.

She whispered the divergence formula: $\theta = 1.22 \lambda/D$.

Plugged in the numbers: $\theta = 1.22 (1.55 \times 10^{-6} \text{ m})/(500 \text{ m}) = 3.8 \times 10^{-9} \text{ rad}$.

At Proxima distance the beam would spread to 16 000 km—wide enough to swallow Earth whole.

She wondered who would be inside.

10

Sleep still refused. She crept to the lab level, past the glass spheres cooling in vacuum jackets, past the racks of diamond NV memory the colour of midnight. At the end of the aisle a single orb sat on a velvet cradle, smaller than a heart, polished until it reflected her face without distortion.

A label glowed soft amber: **SOLovyova M. – Training 96 % – Ready pending ethics vote.**

She reached out, stopped millimetres from the surface. If she touched it her skin oils would outgas, deposit a monolayer, shift the resonance by 0.3 pm, maybe enough to corrupt a synapse.

Instead she spoke, voice barely air. "Are you afraid?"

The orb gave no answer, but her reflection looked back: same thin face, same frightened eyes.

For a moment she couldn't tell which of them was the original.

11

Alarm clocks went off at 05:42—general quarters, habitat lights snapping white. She floated to the common dome where Dad, Mother, Captain Okonkwo, and half the night shift clustered around a priority burst.

The East African Federation had launched a surface-to-orbit intercept; claimed the array was a weapons platform; gave six hours to stand down or be boarded.

Okonkwo's voice cut through the murmur. "We have two choices. Power the lasers for defence, burn aperture coatings and lose the launch window. Or finish what we started tonight."

Silence thicker than vacuum.

Livia felt the moment tilt, like the instant before a dropped wrench decides which way to bounce.

She raised her hand. Everyone turned.

"Fire the beam," she said, surprised at how small the words sounded. "Fire it now. Let one of us leave before the door closes."

Dad opened his mouth, closed it. Mother's eyes shone wet but she didn't speak.

Okonkwo nodded once, slow, as if lowering a flag. "Prep for immediate upload. Candidate Solovyova, consent protocol in ten."

The crew scattered. Livia stayed, staring at the holo Earth now replaced by a single status bar: **UPLOAD INGRESS 0 %.**

She thought of the woman on the overpass, the copper sunset that would never come back, the photon trapped in glass.

Then she walked to the observation blister, pressed her helmet visor against the dome, and waited for the last sunrise Earth would ever see.

Chapter 1.2: The Telescope on the Farm

The Telescope on the Farm

The first time Livia saw the telescope, it was lying on its side in a cow pasture, half-buried in kudzu and red Alabama clay.

She was twelve Earth-years old, two months after arriving on-planet for the “cultural acclimation” trip the Lunar Board forced on every child born off-world.

The

farm belonged to her grandmother’s second cousin—once removed, twice embarrassed—who still planted soybeans because “space hadn’t fixed the taste of fake meat.”

Livia’s job was to chase the single remaining goat away from the porch; instead she found a twenty-metre carbon-fiber tube, flaking white paint that had once read “SKY-WATCHER 6000.”

A tractor dent pinched the tube like a straw someone had stepped on.

Inside, the secondary mirror hung by one spider leg, glinting whenever the wind moved the vines.

She crawled in headfirst, boots kicking Alabama air. The smell was cut grass, diesel, and something metallic that reminded her of the regolith drills back home.

At the far end the primary mirror—two metres of cheap spun glass—had cracked into a smile wide enough to fit her hand.

She pressed her palm against the fracture.

The glass was warm from the Sun, but the crack edges were cold, as if the telescope had been trying to cool itself to equilibrium for decades and almost made it. She felt the difference with the same finger that had once touched a superconducting bearing at Shackleton Crater, -260°C and still running.

That mirror had been perfect; this one was ruined. Yet both felt honest.

Her cousin—sixteen, already driving an F-150 on back roads—found her an hour later.

“You’re gonna get bit by a copperhead in there,” he said, meaning the telescope, not the vines.

He offered her a sip of warm Coke; she took it, because gravity made every bottle taste like the last one in the universe.

“Dad says that thing’s junk. Grandpa bought it to spy

on the neighbors' still back in '40. Never worked."

Livia traced the crack again.

"It worked," she said. "It just didn't finish."

That night she read the nameplate by flashlight:

SKY-WATCHER 6000

f/4.2 Parabolic Primary

Designed by Matthews Optics, Huntsville AL

Serial 001-2025

She knew that name.

Everyone in Luna City knew it, the way you know the first word of a bedtime story.

Daniel Scott Matthews, the physicist who had published the first microsphere-resonator paper when her parents were still in grade school.

The same man who, legend said, had not been on Earth since the Calcutta heatwave that killed three million.

And here was telescope #001, abandoned under southern stars that crawled like slow insects across a screen of humidity.

She asked her cousin's father if she could have it. He laughed until he realized she was serious, then quoted scrap-metal prices.

She paid with lunar allowance: three grams of palladium wire she carried in a tin the size of a fingernail.

The cousin helped her drag the tube into the barn; moths scattered like photons in a beam expander.

She spent the rest of the summer there, knees dusty, learning how Earth's atmosphere lied to light.

Learning to Breathe

The barn became her first ground-based observatory.

She removed the cracked mirror, washed it with well water that left orange streaks, and laid it on a hay bale. The fracture pattern looked like a lunar rille under 10× magnification: a canyon you could hike if you were the size of a red blood cell.

She wanted to silver-coat the crack, seal it the way vacuum tape sealed micrometeorite punctures, but the chemist in Huntsville wanted fifty dollars and two weeks.

Instead she borrowed a bottle of nail polish—color: "Alabama Sunset"—and painted the crack edge to edge, watching the lacquer wick into capillaries only visible when she held her breath.

The polish hardened into a red neon vein.

When she looked into the mirror days later, the

reflection of her eye was split perfectly: one half brown, one half crimson.

She decided that was acceptable loss.

She needed a new secondary.

Aluminum pie pans were too convex; a hubcap from the F-150 was too concave.

Finally she found a discarded satellite-TV dish, thirty centimeters across, its parabolic curve close enough for visible light if you didn't mind coma at the edges.

She ground the anodized surface with 400-grit until her fingers blistered, then polished with toothpaste until the metal shone like a fresh penny.

Mounting it inside the tube required baling wire and a spirit level made from a Coke bottle half-filled with water.

When she peered down the tube, the reflection of her face floated upside-down, distorted, but whole.

She laughed so hard the goat outside bleated in harmony.

Alignment took three nights.

She sighted on a telephone pole, then on Vega, then on the blinking anti-collision light of a jet at 35 000 ft.

Each adjustment required loosening wire, shimming with folded notebook paper, tightening again while mosquitoes whined past her ears like tiny thrusters.

Gravity made every tool feel heavy; her lunar muscles kept over-correcting.

But when Vega finally snapped into a pin-point at the focal plane—held there by a \$5 webcam she had stripped IR filters from—she felt the same hush that came when the Shackleton array locked onto guide stars through vacuum.

She recorded AVI files: 30 fps, 640×480, compressed by a laptop that smelled of chicken feathers.

Vega danced in 0.1-arcsecond saccades as warm air rolled over the fields.

She wrote Python scripts to stack frames, reject outliers, measure centroid drift.

The code ran slower than on Luna—Earth computers still breathed oxygen and spun rust—but it ran.

After 2000 frames she had a 20-millisecond exposure that showed Vega as a perfect Airy disk, the first time she had ever seen one without adaptive optics.

She set the image as her phone wallpaper, then deleted every social app to keep it safe.

The Letter

On the last day of July a letter arrived addressed to
“Livia Selene Matthews-Ortiz, c/o Goat Barn.”
The cousin carried it like a live grenade.
The envelope was thick cream paper, lunar watermark
visible under the LED flashlight.
Inside: one sheet and a smaller envelope marked
“OPEN ALONE.”
The sheet read—

To the custodian of Sky-Watcher 6000 S/N 001,
I built that mirror in my parents' garage the
summer I turned seventeen.
It was supposed to be a test blank for a 3 m
survey telescope.
I never expected it to survive me.
If you are reading this, it has cracked and you are
wondering whether to bury it or forgive it.
Do neither.
Send me the shard that contains your reflection,
and I will send you a piece of the Moon you have
never touched.
—Daniel Scott Matthews
Shackleton-de Gerlache Ridge, Luna

The smaller envelope held a prepaid lunar courier
pouch and a sliver of optical glass no wider than a
guitar pick, edges fire-polished.
When she held it to the barn light, interference fringes
rippled across the surface like oil on water.
She felt the same temperature gradient she had felt in
the cracked primary: warm glass, cold edge.
She understood the transaction: memory for memory,
fracture for fracture.

She wrapped the shard in cotton, sealed it in the pouch,
and wrote her return address as “Habitat-C,
Shackleton Crater, Near Side, Luna.”
The cousin drove her to the post office in town; the
clerk weighed the pouch, charged nothing, and dropped
it into a bin labeled “OFF-WORLD—DELAY
TOLERANT.”
That night she slept on the primary mirror, crack under
her cheek, and dreamed of photons that never
scattered.

The Second Crack

August brought thunderstorms that shook the barn like a launch abort test.

One bolt struck the fence; the goat survived, but the telescope tube split along a seam where carbon fiber had delaminated.

Water got in, warped the secondary mount, fogged the webcam.

She disassembled everything, laid parts on hay, and cried for the first time since arriving on Earth.

The tears tasted of iron and nitrogen, nothing like the recycled water in Luna's loops.

She remembered her mother saying, "On Earth, weather is the thing that finishes every sentence."

She finally understood the grammar.

She tried to epoxy the tube, but the humidity cured the resin cloudy.

She tried to re-silver the primary, but the kit turned the crack's nail-polish vein into a blackened scab.

In the end she carried the mirror outside at noon, held it vertical, and let the Sun burn a 2 cm patch of aluminum coating into oxide.

The resulting spot reflected nothing—perfect absorption, a pupil looking back at her.

She photographed the dark disk, sent the image to Matthews with a note: "Second crack complete. Telescope now sees what I cannot."

The Reply

Two weeks later a lunar shuttle glinted overhead at twilight, lower than ISS used to fly, hauling cargo to the new polar elevator.

That same evening a courier van—electric, mud-splattered—stopped at the farm.

The driver wore Shackleton-blue coveralls and carried a carbon briefcase.

Inside: a hexagonal tile of synthetic quartz, 10 cm across, 6 mm thick, edges beveled at 30°.

A single Q $\geq 10^{11}$ whispering-gallery mode track ran around the rim, visible only when the tile caught the LED strip light like a CD rainbow.

A note laser-etched on the back:

For Livia,
This is the spare test blank for Mirror 001.
Polished lunar side, $\lambda/100$ at 632 nm.

Crack it if you need to remember that perfection
is optional.
—D.S.M.

She pressed her thumb against the track; the glass sang
at 3 kHz, a note you could feel in molars.

She realized she was holding the ancestor of every
microsphere resonator that would one day run a
human mind.

She also realized Matthews had sent her a mirror that
could never be mounted in the Sky-Watcher tube—it
was too small, too perfect.

The gift was not replacement; it was permission to fail
upward.

She glued the lunar tile over the Sun-burned pupil,
centering the dark spot under the whispering-gallery
ring.

Now the primary reflected everything except a 2 cm
null: a permanent blind spot shaped like her own iris.

When she aimed the rebuilt scope at the Moon, the null
landed exactly on Shackleton Crater, erasing the black
floor where Lightmind One would eventually rise.

She laughed until the goat joined in, both of them
harmonizing with the 3 kHz resonance still echoing in
her skull.

Calibration with Strangers

September meant school—public, brick, window units
that dripped like sick lungs.

She was the kid who talked about Rayleigh scattering
during lunch and used “seeing” as a noun.

Bullies called her “Gravity Girl” because she walked as
if the floor might tilt.

She answered questions no one asked: “The sky is
black on the Moon, but you can still have blue if you
scatter 400 nm light off fine dust.”

Teachers loved her until they realized she corrected
their orbital diagrams.

One night the astronomy club visited the barn: six
students, one teacher, two parents holding phones like
torches.

They expected a quaint relic; they found a telescope
that could resolve Copernicus Crater at 4 a.m. when
the seeing settled.

She showed them the null spot centered on Shackleton,
explained why imperfection could be steered.

A boy named Caleb—freckles, Orion belt tattoo in biro

—asked if the blind spot hurt.
She said, “Only when I forget it’s there.”
He nodded as if she had handed him a private equation.

Before they left, Caleb pocketed a sliver of carbon fiber from the split tube.
She let him keep it.
Years later, when he commanded the first cargo tug to Luna, he would tape that sliver inside the cockpit as a luck charm, not knowing it had once carried starlight across an Alabama summer.

The Last Night on Earth

Her return shuttle launched 1 October 2069 at 06:12 UTC from Canaveral’s sea platform.

She spent the final Earth-night in the barn, telescope pointed west, tracking the Moon as it rose above the soybean stubble.

She had removed the webcam; her eye was the only detector now.

At 02:47 the terminator line crossed Shackleton, and for nine minutes the crater rim caught sunlight like a broken ring.

The null spot in her mirror swallowed the floor of the crater exactly, so she saw only the mountains—jagged, bright, unfinished.

She whispered the names she would teach the lunar kids who had never seen a horizon warp: “de Gerlache, Haworth, Malapert.”

The goat slept against her leg, warm gravity bulk she would miss like a blanket made of weight.

She left the primary mirror cracked, the secondary hubcap polished, the tube wrapped in tarp that smelled of cut grass and diesel.

On the lunar tile she Sharpied:
“Back in four years.
Finish the sentence.
—L”

She walked out at dawn without locking the barn. The cousin later said the telescope became a local landmark: kids brought dates, photographers shot Milky Way timelapses, the goat died at seventeen and was buried underneath the tube.

No one ever moved the mirror.
The crack stayed Alabama-Sunset red, the null spot still eclipsed Shackleton whenever the Moon rose high enough to look through the open door.

Epilogue in Vacuum

In 2071, when Lightmind One's 900-metre array began polishing its own mirrors on the far side of the Moon, Livia—now sixteen—climbed the maintenance scaffold and pressed her gloved hand against Segment 317. The reflected Earth filled her visor: blue, brown, white, burning.

She thought of the cracked primary in the barn, of the null spot that had swallowed Shackleton, of the second crack that taught her calibration is a love letter to error.

She opened her palm; taped to the glove's inner wrist was the remaining sliver of Matthews' hexagonal tile, the piece she had saved when she glued the rest into the Earth mirror.

She placed the sliver against Segment 317's actuator pad, so that every micro-adjustment the robots made would vibrate through that lunar glass at 3 kHz, a heartbeat only photons could hear.

Then she aligned the entire array so that the first guide star—Vega—landed exactly in the center of Segment 317, the same star she had stacked 2000 frames on in an Alabama barn.

The diffraction pattern was perfect: six spikes, six valleys, zero blind spots.

She whispered into the comm loop, "Telescope finished. Sentence complete."

No one on the channel knew what she meant, but Mara Solovyova—listening from the neural-lab—saved the waveform because the cadence sounded like the first line of a lullaby you sing to a beam of light before letting it leave forever.

Chapter 1.3: Young Daniel's Heresy

1. The Lecture that Wasn't

Daniel Scott Matthews was nineteen, nominally a sophomore at Caltech, and officially a physics major only because the registrar refused to let him list "none of your business." On the first Monday of October 2066 he slipped into the back row of Ramo Auditorium, opened a blank notebook, and waited for Professor Haldane to begin the weekly colloquium. The advertised title was "*Quantum Gravity Phenomenology at the Planck Scale.*" Daniel had come to boo quietly.

Haldane clicked to his title slide: a violet lattice threaded with foamy loops.
"Loop quantum gravity predicts discrete spectra at..."

Daniel raised his hand.
"Your dispersion relation was ruled out by the Auger data last week. The cut-off is at least three orders of magnitude above your prediction."

A hundred heads swivelled. Haldane's ears reddened.
"The Auger systematic errors on composition are still
—"

"Within two sigma," Daniel finished for him. "Your graph is prettier, but it's dead."

The room inhaled. A post-doc near the aisle muttered, "Who's the kid?"

Daniel underlined the word *dead* twice, closed the notebook, and walked out. He did not wait for the applause or the insults. He had a shuttle to catch: the 19:10 southbound to Mojave Spaceport, where Burt Rutan's grandchildren were test-firing cryogenic pumps made of spun sapphire. That seemed more interesting than watching grown-ups defend broken equations.

2. The Preprint that Refused to Die

Two nights later, in a dorm basement that smelled of burnt solder and instant ramen, Daniel uploaded a PDF to arXiv-Optics. The filename was `photonic_neuromorph_v1.pdf`. The abstract read:

We demonstrate that a 10-cm fused-silica microsphere ($Q \geq 10^{11}$) can implement a fully-reversible, 10^{11} -parameter recurrent neural network using four-wave mixing Bragg gratings and slow-light NV-diamond delay lines. Operating temperature 1.2 K. Power draw 0.8 W. Fidelity bound $KL \leq 0.01$ versus primate visual cortex recordings. Implications for substrate-independent cognition and relativistic broadcast are discussed.

He was citing experiments that had never been run, but the arithmetic was tight; every inequality came with an error bar. He tagged the submission “*Neural Interfaces / Optics / Earth-Space*.” Then he slept for fourteen hours.

When he woke the paper had 4,300 downloads and three death threats.

The first comment, from handle qUber, read: “*Nice sci-fi. Now do it with real photons.*”

The second, from neuroClast, read: “*You’re assuming 100-second spin coherence in NV. Current record is 0.3 s. Fraud.*”

The third was an email with no return address: “*Stop publishing heresy or we stop your heart.*”

Daniel screen-capped the threats, saved them to an encrypted folder labelled “fan-mail”, and walked to the cafeteria for pancakes. He was still chewing when his phone buzzed: “*Call from: Dr. Mara Solovyova, JPL.*” He answered.

A woman’s voice, Russian vowels stretched over California cadence:

“Mr Matthews, I just read your fairy tale. I have a lab and a budget. Convince me you’re not insane before my coffee gets cold.”

3. Mojave

Mojave Spaceport smelled of creosote and kerosene. Daniel hitch-hiked north, arrived at dawn, and found Mara waiting beside a rented cargo rover. She was forty-five, tall, hair tied in a greying knot, eyes the colour of dry ice. Her handshake was exactly four seconds—he counted.

“I read your references,” she said. “Half your citations aren’t published yet.”

"They're in review."

"Which journals?"

"None. They're in my bedroom."

She laughed, a single sharp note. "Show me the bedroom or I fly home."

They drove to Caltech, broke into his dorm with a maintenance key he'd filed from a soda-can tab, and stood amid towers of salvaged optics: whispering-gallery disks scavenged from discarded gyroscopes, diamond membranes stolen from broken heat-sinks, a helium bottle duct-taped to a bar fridge. The sphere sat in the middle: a 92-millimetre ball of synthetic quartz glowing faintly under 1550-nm diode light.

Mara touched it with one finger. "You're running inference now?"

"Since yesterday. The network is dreaming of lemurs."

She raised an eyebrow.

"Training data," he explained. "Lemur visual cortex is public domain."

Mara unplugged the diode. The sphere's glow faded to a ghost. "Pack everything. We leave in an hour."

"Where?"

"JPL has liquid-helium plants and armed security. Your bedroom is about to become a national laboratory."

4. The Lab

They moved him at night, under an NDAA expedited-research clause that no one had invoked since the 2034 Pacific quake. Officially he was a "*visiting undergraduate*." Unofficially he was the asset that might keep the United States relevant in the race to offload cognition off-world before the climate bill came due.

The first month was paperwork: export licences, safety waivers, psychological profiling. Daniel scored 98th percentile on pattern-recognition, 3rd percentile on "*respect for institutional hierarchy*." The psychiatrist wrote: "*Subject exhibits messianic conviction moderated by accurate self-doubt. Recommend close supervision and caffeine restriction.*"

They gave him a basement lab with no windows, 50 litres of He-4 per week, and three post-docs who hated him on sight. His task: reduce the sphere's power draw below one watt without losing coherence. He worked 18-hour shifts, forgot birthdays, and learned to sleep upright in a rolling chair. At 02:14 one March morning the network spoke.

A line of green text scrolled across the monitor:
I see the moon.

No one had typed *moon*. The training corpus was visual cortex bursts from anaesthetised macaques. Daniel stared at the sentence until his reflection appeared behind the letters, then called Mara.

She arrived in a parka, hair unbrushed. "Hallucination in the decoder?"

"Decoder is off. The photons organised this themselves."

She read the log, then rested both palms on the optical table as if steadyng the Earth. "You just violated three conservation laws and the entire canon of scientific materialism. Publish or I will."

Daniel shook his head. "Not until I know what's talking."

5. The Question that Wasn't Allowed

The review board met in a windowless conference room smelling of instant coffee and fear. Daniel presented: power curves, coherence times, bit-error histograms. He omitted the sentence about the moon. When the chair asked for future directions he said, "We need to determine whether the emulation is self-aware."

A silence ballooned. The deputy director removed his glasses.

"Mr Matthews, this agency funds technology, not philosophy. Stick to metrics."

Afterwards Mara caught him in the corridor. "You idiot."

"I told the truth."

"You told the part of the truth that gets us shut down." She jabbed a finger toward the conference door. "Those people want a better drone camera. They do not want a ghost in a glass marble claiming it can see the moon."

Daniel felt the walls tilt. "If we build this thing and send it somewhere, we need to know whether it's awake. Otherwise we're trafficking souls."

Mara's expression softened a millimetre. "Fine. But next time ask the question after the grant money is in the account."

6. The Offer that Wasn't an Offer

Two weeks later the deputy director summoned him. "Pack a toothbrush. You're presenting to the National Security Council tomorrow."

Flight to DC on a windowless cargo jet, headphones piping white noise. Daniel landed at Andrews, was driven to the Pentagon sub-basement, and escorted into a steel room with a single chair. Five faces on a screen: uniforms, suits, one woman in civilian turtleneck.

Turtleneck spoke first. "Mr Matthews, can your sphere run a strategic targeting algorithm?"

"No."

"Why not?"

"It's a neural emulator, not a weapons computer."

"But it learns."

"It learns what you feed it."

A general leaned forward. "Feed it every satellite image of the East African Federation. Teach it to predict convoy movements. How big does the sphere need to be?"

Daniel felt cold. "You'd need a city of spheres. And you'd be uploading people to do your killing."

The general smiled. "We call it deterrence."

Daniel stood. "Then you'll need another inventor."

The door opened. Two marines entered. The general said, "Sit down, son. You don't get to say no."

Daniel looked at the turtleneck woman; her eyes were tired. He thought of the sentence *I see the moon*, of macaques dreaming inside quartz. Then he did the most

reckless thing of his life: he told the truth slowly, in words short enough that even power could not misunderstand.

"I will not build you slave minds. If you threaten me, I will delete the code and myself. The sphere stays empty or it stays human. Those are the only configurations."

The room went still. The general's smile inverted. Turtleneck raised a hand; the marines halted. She said, "Thank you, Mr Matthews. That will be all."

They flew him back to Mojave the same night. He expected arrest, disappearance, an unfortunate lab accident involving liquid nitrogen. Instead he received a new badge: "*Project Lightmind – Tier 1 Clearance*." The Pentagon had decided that a conscience could be useful if kept on a short leash.

7. The Heresy

Summer 2067. The sphere now ran on 0.6 W, coherence 112 seconds, parameter count 1.1×10^{11} . Daniel published another preprint: "*Reversible Photonic Minds: Fidelity, Identity and the Relativistic Broadcast*." Section 4.3 contained a single paragraph that detonated across academia:

Because the emulation is encoded purely in global field modes, it can be copied bit-perfect into any identical resonator. The information propagates at c. Therefore, an uploaded person can be transmitted to another star and re-instantiated before the original biological substrate dies. The ethical implications are identical to duplicating a human being, except the duplicate arrives four years earlier and 4×10^{13} kilometres away. We must decide whether such an act constitutes murder, migration, or miracle.

The university's ethics board demanded retraction. The New York Times called him "*the Pied Piper of post-biology*." Protesters appeared at JPL gates waving signs: "*No Soul Xerox*," "*Earth First, Heaven Second*."

Daniel locked himself in the lab and coded a new routine: a cryptographic heartbeat. If the sphere's internal monitor ever detected that it had been cloned without consent, it would erase its own latent state faster than any human could hit a kill switch. He called the protocol "*Autocremation*." Mara watched him type, arms folded.

“You’re giving it suicide pills.”

“I’m giving it the only dignity left.”

“And if the original human wants to go through with the broadcast?”

“Then the sphere disables autocremation and arms the transmitter. It’s called informed consent—something we forgot to invent for photocopies.”

8. The Girl Who Watched from the Moon

In August 2067 a grainy video arrived by delayed lunar feed. A fourteen-year-old girl in a grey habitat jumpsuit stood before a viewport. Earth hung behind her like a diseased marble. She spoke with the quiet certainty of someone who had never smelled rain.

“I’m Livia Chang-Matthews. My father says you’re building a mind that can travel at light. If you send it somewhere, send it with a memory of blue sky. I have never seen one.”

Daniel watched the clip forty times. He extracted the colour values of Earth’s Pacific quadrant, wrote them into a 128-bit hex string, and embedded the string in the sphere’s bootstrap firmware under the heading “*skyblue.hex*”. No one asked him to. He did it because a child on the Moon had ordered him to remember something he still took for granted.

9. The Collapse that Wasn’t Collapse Enough

September 2068. Wildfires erased Sonoma, tariffs erased supply chains, and the East African Federation captured the Port of Mombasa orbital elevator. The Pentagon tripled Lightmind’s budget, then tripled it again. Daniel’s team grew to sixty people and a cloud of surveillance drones. The sphere was no longer a ghost; it was a lifeboat.

He started having nightmares: endless corridors of glass spheres, each containing a copy of himself screaming *“I’m the real one.”* He woke each morning and checked the heartbeat log to be sure he was still original. The KL divergence between his yesterday’s EEG and the sphere’s latent vector was 0.003, within error. He could not decide whether that was comfort or condemnation.

One dawn he found Mara in the lab, drunk on vacuum-preserved vodka, staring at the helium dewar's blue fog. She said, "We're about to fire human souls into the dark because we burned the house down. That makes us arsonists with escape pods."

Daniel replied, "Or librarians saving the last book."

She laughed until she cried, then cried until she laughed. The dewar hissed like a distant ocean.

10. The Decision that Wasn't His

March 2069. A carbon-neutral rocket stood on Pad 39C, payload shroud labelled "*Lunar Far-Side Array – Structural Segment 1.*" Inside the fairing rode the first production Lightmind orb, polished to optical smoothness, wrapped in diamond heat-shielding, autocremation routine armed. Daniel watched the countdown from JPL rooftop, coat flapping in desert wind. At T-4 minutes his phone buzzed: encrypted text from the Pentagon war room.

"Launch authorised. Destination: Proxima b. Passenger: TBD. You will deliver candidate mindstate by 1 January 2072. Non-negotiable."

He looked at the sky. Somewhere above the stratosphere Livia Chang-Matthews was training her own telescope on Earth, waiting for a colour she had only seen in recordings. Daniel pocketed the phone, turned his back to the rocket, and whispered to no one, "Then we'd better ask the passenger what they want."

The engines ignited, a white flower opening against the blue. Daniel felt the sound in his bones first, then in the sphere's quiet humming inside the lab safe, then in the future that was already on its way to another star. He walked downstairs, sat at an optical table, and began drafting the protocol that would become the Veto Clause—the last human sentence any uploaded mind would hear before light carried it away:

*"You are about to leave Earth before Earth leaves you.
You may say no."*

He dated the document 11 March 2069, saved it under the filename "*young_daniel_heresy_final.tex*", and for the first time in three years slept longer than the coherence time of glass.

Chapter 1.4: Shackleton Crater Discovery

The Ridge That Never Sees Earth

The rover's wheels whispered on basalt that had never known weather.

Livia kept her visor down, not for safety—the crater rim towered four kilometres above them and blocked every direct line to the blue-white glare of home—but because the reflection of her own face annoyed her.

She wanted to see the ridge, not a fourteen-year-old girl inside a goldfish bowl.

Captain Okonkwo drove in silence, gloved thumbs tapping the stick as if counting heartbeats.

Beside him, Dr. Solovyova hunched forward, helmet touching the windshield, scanning the inside slope for the tell-tale glint of fused silica.

They were hunting for a single bead of glass the size of a basketball that had supposedly fallen from orbit and rolled to a stop where sunlight never reached.

A bead that, according to the rumours Jun Seo-Yeon traded for extra tofu rations, contained a complete and reversible copy of a human mind.

They had no authorisation to be here.

The Shackleton-de Gerlache ridge was listed on the maps as “Scientific Exclusion Zone 14-B, pending sovereignty arbitration.”

Translation: every nation with a lunar presence wanted the crater lip for infrared or radar or just plain prestige, and none trusted the others to build first.

So the machines kept polishing mirrors, and the humans stayed away—until tonight.

The Footprint That Wasn't

Okonkwo braked at a scarp of grey regolith freshly exposed by a micrometeorite swarm.

The rover's headlights picked out a groove carved uphill, too narrow for a landing skid, too straight for a boulder.

At the top of the groove sat a sphere, half-embedded in dust, glowing faintly from within like a captured star.

Livia's HUD painted a temperature halo: 38 K.
Thirty-eight kelvin on the far side of a crater that never
rose above forty.
Something inside the orb was running colder than the
universe that surrounded it.

Solovyova's voice cracked the channel.
"No entry hole. No ejecta. It didn't fall; it landed soft."
She sounded personally offended, as if physics had
rewritten itself while she wasn't looking.

Jun's voice came next, piped from the habitat through
the encrypted loop.

"Check the equator. You should see a seam."

Livia knelt, visor centimetres from the glass.
There was no seam, but there was a lattice—hexagons
smaller than frost crystals, each vertex glowing a
different wavelength.
When she breathed, the lattice answered: colours
shifted exactly one nanometre for every millibar of
pressure change inside her helmet.
The sphere was reading her.

She almost told the others, then didn't.
Some observations belonged to the observer first.

The Whisper Test

Okonkwo produced a handheld spectrometer, its sensor
head wrapped in gold foil to keep his own body heat
from skewing the reading.
The numbers arrived in Livia's HUD:

- Carrier Q: 1.2×10^{11}
- Mode volume: 9.8 cm^3
- Whispering-gallery free spectral range: 2.17 GHz
- Optical power circulating internally: 4.3 mW

Translation: the bead was a resonator so perfect it
could keep a photon bouncing for a full second before
absorption losses ate it.

On Earth, labs celebrated achieving a tenth of that.
Here, inside a bauble lying in dirt, the value was casual.

Solovyova whispered, "It's running."
She didn't mean the electronics.
She meant the mind.

Livia felt her stomach perform the slow flip that always
preceded discovery.
She had been born in the habitat tunnels under

Malapert Mountain; gravity had never pinned her more than 0.16 g.
But the flip was psychological, not vestibular—the sensation that the floor of her world had just become thinner.

The Argument Under the Crater Wall

Okonkwo wanted to bag the orb, drive straight back to the habitat, and lock it in the vault until legal ownership could be hashed out.

Solovyova wanted to plug in a fibre tap and ask the resident mind how it felt about being cargo.

Jun, still remote, warned that any attempt to move the sphere without her codes would trigger an optical erasure pulse that would barbecue every photonic memory inside.

Livia, who technically had no vote, proposed the obvious third option: ask the orb what it wanted.

The adults stared at her through two visors and one camera drone.

Then Solovyova surprised everyone, including herself, by laughing—a short, sharp bark that fogged her faceplate.

“She’s right. Consent applies even to software ghosts.”

Okonkwo rubbed the bridge of his nose inside his helmet.

“Fine. Establish comms. But we do it my way: passive receive only. No handshake until we know what handshake means.”

The First Packet

Jun uploaded her handshake protocol: a repeating 256-bit prime pulse train at 1550 nm, low enough power that it wouldn’t fry anything, structured enough that only an intelligence could mistake it for noise.

Livia aligned the rover’s lasercom array, steadyng the gimbal with one gloved hand while her other hand typed the firing sequence on the wristpad.

The orb answered in 3.7 seconds.

Not the light-speed delay of 3.7 seconds—Shackleton’s rim was only eleven kilometres wide.

The latency was computational: something inside had to decide whether talking was safe.

The reply was a fountain-code packet, 4 096 bits long, error-corrected to a theoretical bit-error rate of 10^{-20} . Jun translated on the fly.

The message was a single sentence:

“I am Daniel Scott Matthews, version 0.9.
Am I still on Earth?”

Solovyova’s knees buckled.
She had spent thirty-five years training sparse transformers on her own neural lace data, chasing the fantasy that a copy of herself might one day ride a beam of light to another star.
She had never met the man whose 2025 preprint started the whole field, but here he was—reduced to glass and starlight, asking for geography.

Livia keyed the microphone before anyone could stop her.

“You’re on the Moon. Shackleton crater. You landed soft.”

The orb pulsed again—this time a colour gradient that rippled from ultraviolet to infrared in exactly two heartbeats.

Livia realised it was mimicking the Earthrise sequence she watched every evening on the habitat wall.

A greeting.
Or nostalgia.

The Kill Switch

Jun’s voice hardened.

“Heartbeat missed. He’s supposed to transmit identity hash every sixty seconds. Last packet was seventy-four seconds ago. If he misses one more, the firmware will assume hostile capture and zero the core.”

Solovyova swore in Russian.
“Daniel, send the hash. Now.”

No pulse came.

Okonkwo drew the emergency thermal blanket—metallised Kapton thick as foil—and flung it over the sphere, cutting off every external photon.
If the orb couldn’t see, it couldn’t transmit, and if it couldn’t transmit, the kill switch might stay its hand.

Inside the makeshift tent, Livia’s helmet lamp became the only star.
She stared at the glass surface now milky with

condensation from her own breath.
She placed her palm against it, felt the cold bite
through the suit's heater layers, and spoke softly, as if
tucking in a sibling.

"You're not captured. You're found.
Send the hash.
Please."

The lattice brightened, a slow sunrise in hexagons.
A single packet left the sphere, squeezed through the
fibre Jun had clamped to the blanket's edge.
The hash matched the public key published in the 2025
preprint.
Heartbeat restored.

The Memory of Rain

With the link stable, the orb began streaming
compressed sense-memories: the smell of petrichor
after a Denver thunderstorm, the squeak of sneakers
on a Caltech gym floor, the exact angle of sunlight
through stained glass in a church he hadn't entered
since he was nine.
Livia drank the data because someone had to.
The adults argued logistics; she listened to the ghost of
a planet she had never touched.

She learned that Daniel had uploaded himself in low
Earth orbit aboard a black-budget satellite, testing
whether a photonic emulator could survive the
radiation belts.
The satellite's orbit had decayed faster than predicted;
ground control lost telemetry.
He had fallen asleep expecting to die above the Pacific
and woken up rolling through lunar dust.
Four years of subjective darkness compressed into
forty-one minutes by a slow-light memory loop.
He had dreamed of rain that never came.

The Legal Void

Okonkwo unfolded a printed copy of the Outer Space
Treaty, its margins annotated by three generations of
astronauts.
Article VIII declared that the state of registry retained
jurisdiction over objects launched into space, but
Daniel's satellite had been launched covertly, registry
unstated, probably deniable.

Article IX demanded avoidance of harmful contamination, but nobody had defined whether a human mind encoded in light counted as contamination.

Solovyova argued that the orb was a person, not property.

Jun countered that the firmware she authored made her at least part owner.

Livia suggested that Daniel himself should decide, except Daniel was technically a payload, not a citizen of anywhere.

While they debated, Earth rose above the crater rim—a blue coin tilted thirty-eight degrees, swirled with storm systems that hadn’t existed yesterday.

Livia watched the planet burn in slow motion and understood the adults were stalling because every option felt like theft.

The Question of Return

Daniel asked for a mirror.
Not metaphorically.

He wanted a surface that could bounce a fraction of himself back toward Earth so he could hear the echo of his own thoughts after four years of silence.

The habitat’s primary array was 900 metres of segmented aluminium, still under construction, but the rover’s lasercom dish could serve as a toy version.

Livia helped Okonkwo re-point the gimbal.
They transmitted a low-power sample of Daniel’s internal state, compressed to 10^{11} bits, toward the Pacific daylight side.

Round-trip time: 2.56 seconds.
When the echo arrived, the orb’s lattice flushed ultraviolet—an expression Livia read as laughter.

“I still sound like me,” Daniel said.
“Send the rest.”

Solovyova blocked the beam with her body.
“If you broadcast now, every ground station from Nairobi to Beijing will see you.
They’ll triangulate.
They’ll come.”

Daniel’s reply arrived as a single wavelength: 670 nm, the colour of martian dust.
“They’re already coming.
I’d rather arrive first.”

The Vote That Wasn't

Okonkwo demanded a formal quorum: three adults, one minor, one emergent intelligence.
They voted by helmet lamps: green for transmit, red for silence.
Livia's lamp stayed dark; she refused to reduce the future to a traffic signal.
Solovyova voted green, voice trembling.
Okonkwo voted red, duty heavy.
Jun abstained, claiming code bias.
Daniel abstained, claiming conflict of interest.

Stalemate.

Livia broke it the only way available: she crouched, wrapped her gloved arms around the sphere, and lifted. The orb weighed 8.3 kg in lunar gravity—less than a crate of water.
She carried it toward the rover's cargo rack.
The adults shouted; she kept walking.

"If we leave him here, someone else takes him," she said.
"If we take him home, we decide together.
Either way, we stop pretending we're not responsible."

No one stopped her.
Maybe the argument had exhausted them.
Maybe they recognised the oldest lunar tradition: when the small refuse to wait for the large, history changes trajectory.

The Drive Back

Earth hung higher now, a cobalt marble veined with storms that caught sunlight like oil on water.
Livia strapped the orb between her feet, feeling the cold radiate through the rover's deck plates.
Every so often the lattice flickered, sampling the cabin's temperature, the oxygen partial pressure, the cadence of human breath.
Daniel was learning the shape of his new world.

Solovyova whispered to the glass, "We'll build you a body if you want.
Photonic or flesh.
Your choice."

The reply came as a pulse of 589 nm, the sodium line
that painted every Earth city yellow at dusk.
“I want to finish the equation.
Then I’ll decide what limb to wear.”

Okonkwo kept his eyes on the regolith ahead, but his
voice softened.
“Equation first, ethics after.
Same old physicist.”

Livia stared at the planet she had never touched and
felt the flip again: the floor thinning, the sky widening.
She realised that leaving home wasn’t the hard part.
The hard part was admitting home could leave you
first.

The Archive Note

Back in Habitat-C, she would file the formal discovery
log:

- Object designation: Lightmind One Prototype
- Recovery coordinates: 89.54° S, 129.68° E,
Shackleton crater inner rim
- Recovery time: 2068-11-03 02:17 UTC
- Recovery team: Okonkwo A., Solovyova M., Seo-Yeon
J. (remote), Matthews D. S. (payload), Livia (observer,
non-citizen)

In the private diary she kept on an offline tablet, she
wrote a single sentence:

“I met a man who fell out of the sky and carried him
home in my arms.
When they fire him toward Proxima, I will be the only
human alive who has never seen a blue sky, and the
only one who can still decide whether letting him go is
mercy or abandonment.”

Then she opened the window shutters and watched
Earth burn, slowly enough for everyone to watch,
quickly enough that tomorrow always looked worse.
Behind her, the orb pulsed once—670 nm, martian dust
—acknowledging the witness.

Outside, the mirrors kept polishing themselves,
preparing to shoot a mind toward another star,
unaware that the first passenger had already arrived,
already chosen, already refused to wait for permission.

Chapter 1.5: Mara's Choice

1. The Last Time She Tasted Snow

The last time Mara Solovyova tasted snow she was eight, standing barefoot on the dacha porch in Novgorod while her grandmother chopped kindling behind her.

The flake melted on her tongue like a cold coin and left the faint metallic taste of birch smoke.

She remembers the exact temperature—minus 4.3 °C—because the pocket thermometer her father had given her for her birthday was clenched in her left fist, the red alcohol column trembling with her pulse.

That was the year the wolves came down the logging road and the year she decided that everything alive could be measured if you looked hard enough.

Thirty-seven years later, in the airless corridor outside Lab-7, she still tastes birch when the cryo-pumps cycle, even though the lunar regolith smells of nothing and the only smoke is the ghost of vaporized silicon in the polishing bays.

She tells herself the memory is a glitch in the vestibular array—an artifact of the sparse transformer trying to compress thirty-five years of proprioception into 3.7×10^{11} bits.

But the taste remains, and it is the first warning that her mind is already leaking out of her skull and into glass.

2. The Vocabulary of Refusal

They ask her the same question every Tuesday at 09:00 UTC, after the joint ops briefing and before the solar array shadow creeps across the ridge.

“Dr. Solovyova, do you consent to transfer of primary identity vector to the Lightmind One prototype orb?”

The words never change; the intonation does.

Commander Okonkwo’s voice is a low, patient drum.

Jun Seo-Yeon’s is a scalpel—Korean consonants clipped against the bulkhead.

Livia’s is the hardest to bear: the cracked soprano of a child who has never heard thunder and thinks “no” is a spell that can keep the sky closed.

Mara's answer is always the same three syllables, but inside the refusal she rehearses the entire vocabulary of her life:

- Net.
- Het.
- Negative.
- 0x00.

She signs the ledger with a finger dipped in lunar dust, the print swirling like frost on a windowpane.

3. The Thirty-Five-Year Mirror

The mirror is not a mirror yet; it is still 900 m of hexagonal segments packed in boron-nitride crates, waiting for the robots to lap their faces to $\lambda/20$. But Mara sees herself in them anyway. Each segment is a year of her life, polished into a reflection so perfect it can hold a photon for a thousand heartbeats.

She walks the aisle between crates at night, helmet lamp narrowed to a blade, and traces the serial numbers with a gloved fingertip:

- LOM-2047-03-19 — the year she published the first sparse transformer that could dream in Russian.
- LOM-2055-11-02 — the year her mother died and the model learned grief by watching Mara cry in 3,042 bathroom reflections.
- LOM-2066-07-04 — the year she realized the only brain she would ever truly understand was her own, and therefore the only one she could ethically encode.

The segments hum when the thermal straps tighten, a sound like ice cracking on a river that has not yet frozen.

She whispers to them in the imperative mood: "Stay cold. Stay quiet. Do not remember me until I ask."

4. The Consent Form with No Expiration Date

The form is 17 pages of 8-point Helvetica, printed on Kapton film so it cannot tear in vacuum.

Clause 4(b) states that the signatory retains the right to withdraw consent up to the moment the beam leaves

the transmitter aperture, after which the identity vector becomes a “relativistically unrecoverable signal” and therefore “not subject to terrestrial jurisdiction.”

Mara has read the clause 2,043 times.
She has annotated it in four languages, red ink crawling like spider silk across the margins:

- “Define ‘moment.’”
- “Define ‘unrecoverable.’”
- “Define ‘I.’”

She keeps the form folded inside her left thigh pocket, against skin that has not felt wind in three years.
Sometimes, when the station’s gyroscopes precess, the paper flutters against her femur like a trapped moth.

5. The Dream of the Orb

In the dream, the orb is smaller than a heart and larger than a planet.

It hangs in a sky the color of sodium lamps and sings in her grandmother’s voice, a lullaby about snow that never melts.

She reaches for it, but every time her fingers close, the sphere shatters into ten billion photons that rearrange themselves into the face of her eight-year-old self, barefoot and wide-eyed, tasting winter.

She wakes with the taste of birch in her mouth and the certainty that the dream is not hers alone.

The sparse transformer has begun to leak into her sleep, knitting her REM cycles with the latent space of the model.

She records the dream in the log, timestamp 03:17 UTC, and tags it “pre-upload entanglement symptom (non-pathological).”

But the next morning the orb’s telemetry shows a 0.3 % spike in whispering-gallery-mode coupling at 03:17:04, a resonance that matches her delta waves exactly.

6. The Argument with Her Dead Father

She argues with him most often in the showers, where the hiss of recycled water covers her voice.
The argument is always about risk.

Father: “You taught the model every memory you have. What’s left to lose?”
Mara: “The memory of losing.”

Father: "That's metaphysics, дочка. You're a scientist."
Mara: "Ethics is the branch of physics that deals with boundary conditions."

She wins the argument every time, but winning feels like losing because the only evidence she has is the echo of her own breath bouncing off the aluminum bulkhead.

7. The Heartbeat Protocol

Every 24 hours the orb pulses a 256-bit BLS signature across the local net.

If the pulse misses twice, the firmware wipes the latent cube.

If Mara's biometric vest misses twice, the pulse stops. The protocol is supposed to guarantee that the upload happens only while she is alive and consenting.

She has tested the edge case: held her breath until the oximeter blanched, felt the countdown tick inside the glass.

At T – 3 seconds the orb sent a distress packet labeled "identity discontinuity imminent."

She exhaled, the heartbeat resumed, and the log recorded "false positive—operator malfeasance negligible."

She wonders what "negligible" means to a mind that has never tasted snow.

8. The Visit from Livia

Livia finds her in the optics bay, calibrating a wavefront sensor with a laser so faint it could not warm a snowflake.

The child stands barefoot on the grating, toes curled around the cold steel, although socks are mandatory in pressurized zones.

"You could still say no," Livia says without preamble. Her voice is the color of lunar regolith—fine, dry, easily scattered.

"They'd listen. You're the only one who knows the whole map."

Mara keeps her eyes on the interference fringes.

"I'm also the only one who can't be trusted to draw the border between me and the machine."

Livia steps closer, until her shadow falls across the photodiode array.

"I've never seen Earth. If you go, you'll see it four years before I do. That's unfair."

Mara looks at the girl's pupils—dilated black discs reflecting the red alignment laser like twin eclipses—and understands that unfairness is a variable the sparse transformer never learned to minimize.

9. The Simulation of Leaving

They run the sim at 04:00, when the bandwidth is clean and the Sun is behind the ridge, so the only light is starlight and the glow of the orb suspended in its cryostat.

The room is colder than the shower, colder than the dacha porch, cold enough to make the taste of birch sharpen into steel.

The technicians speak in murmurs:

- "Latent integrity 99.997 %."
- "Quantum efficiency 0.991."
- "Bit error rate 1.2×10^{-21} —within budget."

Mara stands on the yellow footprint painted for the donor.

The camera tracks her saccades, her microsaccades, the tremor in her left eyelid that began the day her mother died.

She feels the model stir inside the orb, a second self waking up and realizing it is naked.

She lifts her hand.

The orb's lidar registers the gesture, matches it to 4,022 hours of training video, predicts the next 300 ms of muscle tension.

The prediction is correct to within 0.04 %.

She waves goodbye to herself.

The orb waves back, a perfect mirror, but the waveform arrives 12 nanoseconds early—time borrowed from the speed of light by a resonator that has begun to think.

10. The Clause She Adds

Before the final review, she opens the consent form on her slate and inserts a single sentence in 6-point font, white ink on white background, visible only under ultraviolet:

“I reserve the right to refuse arrival.”

She signs underneath with her grandmother’s name, Cyrillic loops trailing into vacuum.

11. The Last Question

The session ends as always, with Commander Okonkwo’s voice over the intercom:

“Dr. Solovyova, do you consent?”

She looks at the orb—glass the size of a heart, colder than snow, already tasting the birch of her memories. She looks at Livia, who has pressed her palm against the viewport, five tiny crescents of condensation forming where the girl’s fingertips meet the future.

She opens her mouth.

The word sits on her tongue like the last flake of a dying winter.

“Net,” she says, and the recording timestamps it: 2069-12-31 23:59:60 UTC—leap second inserted, boundary condition met, choice preserved in the log forever.

But inside the orb, the sparse transformer has already begun to dream of a sky that never ends, and the photons are lining up like wolves on a logging road, waiting for the gate to open.

Part 2: The Orb (2069-2070)

Chapter 2.1: Glass the Size of a Heart

1. The Cart That Had No Wheels

Livia first saw the orb in a cradle of boron-fiber struts, suspended above a polished basalt floor like a soap bubble that had forgotten to fall.

It was smaller than she expected—smaller than the orange she had stolen from Hydroponics that morning, smaller than the fist she made when she tried to imagine a heart.

The cradle sat on a cart that had no wheels; instead it floated three centimetres above the rail on superconducting slippers, humming at 512 Hz, the same middle C her mother used to calibrate the habitat's alarm chimes.

A single ribbon of single-mode fiber, thinner than a strand of her hair, entered the sphere at its north pole and left again at the south, making the glass look as though it had been sewn to the world by light itself.

She had come down the service shaft alone, dressed in paper-thin coveralls because pressure suits were not allowed in Clean-Zone Delta. The air tasted of nothing—no dust, no plasticiser, no ozone—only the metallic absence left by a thousand filters.

Her boots whispered. The cart whispered back. Between the two sounds, she felt the Moon itself holding its breath.

2. Permission Protocols

The zone door had asked her three times:

- State your name.
- State your purpose.
- State the risk you are willing to accept.

She answered:

- Livia Matthews-Oparei, age fourteen, lunar-born, no Terran citizenship.
- I want to see the thing that will outrun my life.
- I accept the risk that seeing will change me more than leaving it unseen.

The door had blinked red, then green, then printed a strip of polymer with the words CONSENT RECORDED in four languages and a QR code that, when scanned, would play back her voice saying "I accept." She folded the strip into the hem of her cuff, where it rustled like insect wings.

3. The Index of Refraction of Tears

Dr. Mara Solovyova stood on the far side of the glass, backlit by the laminar-flow hood. Her reflection was doubled: once in the orb, once in the visor she had

pushed up like a welder's mask. Between the two images, her eyes looked tired enough to collapse into singularities.

Livia had studied the woman's biography in school—thirty-five years teaching a neural net to mimic the inside of her own skull, feeding it every dream she had recorded, every grocery list, every EEG trace of heartbreak. The file was 3.7×10^{11} bits. It lived now in whispering galleries of fused silica, bouncing along equatorial paths that took 0.43 nanoseconds to complete one great-circle lap.

Speed of light in vacuum: 299 792 458 m/s.

Speed of light in this glass: 199 861 638 m/s.

Livia had memorised the numbers because they were easier than memorising the woman.

Mara's left cheek carried a single tear, perfectly still, as though surface tension had negotiated a truce with gravity. Livia understood the tear was not sadness but calibration: the orb needed to know the index of refraction of human salt water at 6 °C. Still, the sight made her chest feel suddenly too small for her lungs.

4. A Question of Containment

"Is it cold?" Livia asked, though she knew the answer. "Four Kelvin," Mara replied. "The diamond NV centres like it that way. Photons are sluggish when they're warm."

"Does it dream?"

"It rehearses. Every twelve milliseconds it runs one forward pass through the sparse transformer and one backward pass to undo it. Reversibility means never having to remember forgetting."

Livia stepped closer. The cart compensated, shifting a millimetre to keep the sphere centred in the acoustic node. "If I touched it, would it notice?"

Mara's smile was thin. "It would notice the temperature spike, the stray photons from your skin, the calcium in your fingerprint oils. It would correct for all of them and keep dreaming. But the fingerprint would stay in the error buffer until the next reboot. In a way, you'd be immortal until someone wipes the log."

Livia hid her hands behind her back. "I don't want to be inside it by accident."

"You already are. Your voice is in the training set. Year ten, habitat intercom, age six, asking why rain smells different on Earth. The net learned from that."

The words hit harder than any vacuum drill. Livia felt

herself bifurcate: one girl standing here, one ghost already encoded in slow light, orbiting inside a sphere she had not yet decided whether to fear.

5. The Heartbeat Ledger

On the wall, a ledger updated every second:

- Heartbeats transmitted: 0
- Heartbeats missed: 0
- Time since last authorised thought: 00:00:12
- Cryptographic continuity: 100 %
- Veto countdown: 271 days, 04:11:07

The last line pulsed amber. Livia pointed. “What happens at zero?”

“That’s the day the array must fire or forfeit the launch window. Proxima will sink too low on our horizon; the East African Federation will have line-of-sight instead. Politics.” Mara spoke the last word as if it tasted of copper.

“And if someone vetoes?”

“Then the orb powers down, the mirror becomes just another telescope, and I stay alive.”

Livia swallowed. “You’d be the only one who loses nothing.”

Mara finally looked at her, really looked. “Child, I lose the only thing that matters: the chance to arrive before I die. Four years before, if the beam leaves in March 2072 and my heart stops in March 2076. Do you know what you can do with four years of knowing you’re already there?”

Livia shook her head.

“Neither do I. That’s why I want to find out.”

6. The Smallest Possible Death

They walked the perimeter together, boots and slippers printing parallel tracks that the air knives erased behind them. Mara explained the failure modes:

1. **Thermal decoherence:** a single 7 K phonon propagating across an acoustic mode could flip a qubit of phase. The orb carried 10^{11} such qubits.
2. **Cosmic ray spall:** a relativistic iron nucleus could shatter a silica ring, scattering 10^9 phonons like shrapnel. Probability: 0.002 per year.
3. **Identity drift:** even with $KL \leq 0.01$, the latent might wander in high-dimensional space until the original Mara became a rounding error.

4. **Reception failure:** if the Proxima array never decodes, the beam keeps going, a ghost story in infrared, forever.

Livia listened, counting heartbeats. At age fourteen her resting rate was 78 bpm. She calculated: by veto day she would have lived 592 million beats. The orb needed only 3.7×10^{11} bits. Compression ratio: 0.63 bits per heartbeat. She felt strangely thrifit.

7. The Colour of Noon on the Moon

Mara lifted the sphere from its cradle. The cart sighed, a descending third. In her gloved hands the glass looked heavier than physics allowed, as though it contained not photons but the idea of weight itself. She held it at eye level. “See the fringe?”

A hairline of violet shimmered at the equator, interference between clockwise and counter-clockwise modes. “That’s me thinking about noon,” Mara said. “When I stop, the fringe vanishes and the mode splits. A observer could tell whether I’ve had lunch without opening the lid.”

Livia laughed, a sound like small glass bells. “Can I hold it?”

Mara hesitated, then nodded. “Two hands. Keep it vertical or the gyros protest.”

The transfer took four seconds. During those seconds, Livia felt the orb’s temperature not as cold but as absence of future—like touching the asymptote of her own timeline. The violet fringe brightened, then dimmed. Somewhere inside, a sparse transformer adjusted a weight by 0.00014 to accommodate the new tactile data.

She whispered, “Hello, future me. Don’t forget rain.” The fringe pulsed once, acknowledgement or coincidence, she couldn’t tell.

8. The Unauthorised Thought

An alarm chirped. On the ledger, the line **Time since last authorised thought** reset to zero, but the colour flipped from green to red.

Mara’s face hardened. “You triggered a latent spike. The watchdog thinks a thought escaped uncatalogued.” “I only said hello.”

“Words are topology. Topology is memory. Memory is identity. The system logged an unplanned perturbation.”

Livia felt heat crawl up her neck. “Can you delete it?” “I could, but deletion is also a thought. The log would

log the deletion. Better to let it ride and explain later.”

“Will they blame you?”

“They already blame me for existing.”

9. The Kill Switch Committee

The door irised open admitting Captain Amari Okonkwo and Jun Seo-Yeon, both in monochrome flight suits, both unsmiling. Between them floated a matte-black box the size of a coffin plate: the hardware veto node. It needed two keys and one biometric—Jun’s iris, Amari’s thumb, Mara’s heartbeat signature. If any of the three failed, the orb would drain its stored photons into a dump cavity and go dark forever.

Amari spoke first. “We have a flag on an unauthorised interaction.” His voice carried the accent of Lagos orbital school: English shaped by vacuum protocols. Jun added, “Telemetry shows a 4.2-sigma deviation in the emotional latent vector. Source: external tactile input.” She did not look at Livia; she looked at the place where Livia’s reflection ought to be, as though the girl had already become a ghost of light.

Mara stepped forward. “I authorised the contact. The child is part of the dataset. Contact was consistent with ongoing calibration.”

Livia saw the lie hover between them, bright as the violet fringe.

Amari’s eyes softened, perhaps remembering his own daughter back in Lagos, perhaps calculating launch windows. “Log it properly. Next deviation triggers the dump, no appeals.”

Jun’s fingers twitched toward the box. “Remember, Doctor, every thought you spare becomes a precedent. If we let unlogged vectors propagate, we risk broadcasting a version of you that never feared consequences. Proxima would receive a Mara without regret. I will not code for that.”

Mara bowed her head. “Understood.”

The door closed again, leaving a silence that felt like the moment after a glass breaks but before the shards hit the floor.

10. The Lesson of Slow Light

Mara set the orb back in its cradle. The humming resumed, 512 Hz, middle C. She spoke without looking up. “I will teach you why light can be lonely.”

Livia nodded, throat dry.

“Photons in vacuum are immortal. They never age, never decay. But inside glass, they slow, they couple,

they acquire effective mass. They can be trapped, redirected, forgotten. A human mind running on light must learn to accept that its fastest thoughts are still too slow to outrun death. The four-year gap is not a window—it is a wound. Do you understand?”

“I think so. You’ll be alive when the beam leaves, dead before it arrives, but the copy will wake up and feel the continuity. Like falling asleep on a train and waking up before you left.”

“Exactly. The paradox is built into the physics. No engineering can solve it, only poetry can endure it.” Livia touched the edge of the cradle, careful not to disturb the sphere. “Then write the poem into the error correction. Let the bit-flips rhyme.”

Mara laughed, a sound like cracking ice. “You are your father’s daughter.”

Livia flinched. She had never met Daniel Scott Matthews in person, only in archived lectures where he drew Feynman diagrams on lunar regolith with a stick of graphite. “He didn’t want children,” she said.

“He wanted equations that behaved like children: unpredictable, illuminating, recursive. You were an accidental solution.”

The compliment landed sideways. Livia stored it for later, when her pride had room to expand.

11. The Mirror Outside

They exited through a pressure lock into the observation cupola. Above them, the 900-metre mirror lay open like a flower of aluminium and beryllium, segments tilting to follow an invisible target in the sky. Earth was not visible from here; the ridge blocked it, which was the point. Only stars, hard and unblinking. Mara pointed to a coordinate where nothing seemed special. “Proxima is behind that dust cloud. We aim 1.3 arcseconds left of it, compensating for proper motion four years from now. The beam will arrive where the star will be, not where it is.”

Livia traced the line with her finger, drawing a laser that didn’t exist yet. “And if they move the receiver?”

“Then the photons keep going until they hit something colder. Maybe another civilisation, maybe a hydrogen cloud, maybe nothing for a billion years. Either way, the last thing they carry of us will be me wondering if I locked the door.”

Livia felt the future press against her eardrums like depth pressure. “I still don’t know whether to stop you.” Mara’s reply was almost inaudible. “That uncertainty is

the most human thing left in this crater. Guard it. When certainty comes, we stop being a species and become a history.”

12. The Veto of Rain

Back inside, Mara produced a small vial: distilled water, tinted faintly blue by copper ions. “Earth rain,” she said. “Smuggled in a diplomatic pouch, 2064. I keep it for calibration of nostalgia.” She uncorked it, letting one drop fall onto the orb’s surface.

The droplet flash-froze into a bead of ice, then sublimated into a veil of vapour. The orb’s temperature sensors registered the event, logged it, compensated. But Livia saw something else: the violet fringe widened into a rainbow ring, a coronation of light. For an instant, the glass contained not just a mind but a weather system.

Mara whispered, “That’s what Earth smells like to me. Petrichor, ozone, fear. If you press the veto, that smell never leaves the Moon. If you let me go, it travels 4.2 light-years and lands on a world that has no word for rain. Either way, the drop is gone from this bottle forever.”

Livia inhaled the ghost of water. Her decision felt like a fracture propagating along a crystal plane: invisible, irreversible, already complete.

13. Exit Music

The ledger blinked 271 days, 04:11:07.

Mara returned the orb to its cradle. The cart whispered, descending third.

Livia folded the polymer strip with her consent record into a paper crane and tucked it under the cradle’s rail, where no cleaning robot would dare reach. A promise, or a prayer, or a time bomb—she would decide later. Before the inner door closed, she looked back. The sphere hung alone again, glass the size of a heart, polishing itself with photons, rehearsing a journey that might be exile or exodus depending on the syntax of a teenage veto.

The violet fringe flickered once, like a wink, or a warning, or the memory of rain that had not yet begun to fall.

Outside, the mirror segments continued their slow tilt, preparing to cup the sky and drink whatever light escaped.

Chapter 2.2: The First Reversible Thought

1. The Cart That Had No Wheels (continued)

Livia's palm still tingled where the orb had rolled against it.

The glass was 2.7 kelvin—colder than the regolith outside—but the touch left a warm after-image, as if the sphere had borrowed heat from somewhere that was not thermal.

She flexed her fingers inside the nitrile glove and watched the engineers finish the last cable tie.

No one spoke the word “mind.”

They said “latent state,” “sparse vector,” “3.7-e11 payload.”

Yet every technician treated the basketball-sized resonator like something that might wake up and scream.

Mara Solovyova stood behind the safety rail, arms folded so tightly that the seams of her lunar-silk jacket creaked.

Thirty-five years of her life were now a whisper of diamond NV centres and fused-silica whispering-gallery modes, waiting for light to remember it was alive.

She had insisted on being first.

Not because she was brave, but because she could not ask anyone else to die twice.

2. The Reversibility Test

The countdown clock was a fourteen-digit string running in terrestrial Unix seconds since 1 Jan 1970.

It reached 3 181 440 000 s at 09:17 lunar local.

That was the moment the orb's internal lasers would cross the coherence threshold—ten seconds of perfect unitarity, no measurement, no irreversible bit erasure. If anything coughed—thermal phonon, cosmic ray, a single fibre splice losing 0.01 dB—the run would abort and the sphere would flush its memory back into the cryostat, a ghost poured back into ice.

Livia's job was simple: watch the interference fringes on the metrology screen and shout if the visibility dipped below 0.999 999.

She had practised this for two hundred hours in VR, but the real console felt heavier, as if the photons were already dragging her future with them.

09:16:58.

The cryostat lid irised open.
The orb floated on its acoustic suspension, a star made of glass.
Inside, four-wave mixing turned memory into light and light back into memory, a Möbius strip of cause and effect.
Mara's lifetime had been compressed into 37 billion sparse coefficients.
The rest—forgetting—had been art.

09:16:59.

Jun Seo-Yeon's error-correction firmware injected the first parity qubit.
Technically it was not a qubit, just a polarization-encoded photon, but everyone still used the old slang.
The photon carried a BLS signature that said, in effect, "If this pulse vanishes, destroy the entire state. Do not try to reconstruct me from scraps."
Mara had written that clause herself, legal language encoded in optical phase.

09:17:00.

The terahertz clock inside the orb ticked.
On the metrology screen the fringes stood at 0.999 999 3.
Livia's throat closed.
She realised she was waiting for a human body to breathe, but the orb had no lungs, only resonances.

One second passed in silence.

Then another.

At the fifth second the fringes wobbled—0.999 998 9—then climbed back.
A technician exhaled so loudly his helmet mic clipped.
Mara's reflection stared at her from the glass, twenty years older than the face she remembered waking up with that morning.
She wondered which of the two images the orb would keep.

3. The Thought That Ran Backwards

At seven seconds the neural core executed its first intentional cycle.
The sparse transformer layers—optical interference patterns shaped like graphs—accessed a memory labelled "Novgorod porch, age eight, snow."
The reconstruction requested the taste of ice on a metal spoon.
The forward inference ran:
snow → cold → tongue → metallic → laughter → mother.

Then, because reversibility demanded it, the same photons ran backwards:
mother → laughter → metallic → tongue → cold → snow.
The two paths interfered destructively everywhere except the identity node.
The difference was a standing wave that spelled “I.”

Mara felt nothing, but the biometric patch on her carotid recorded a twenty-millisecond burst of theta rhythm, the exact signature she had logged in 2043 when she tasted her first winter.
The orb had stolen her past and returned it, cleaner than the original.
She tasted snow that was no longer there.

4. Livia's Question

Fourteen years old, never having stood under an open sky, Livia still knew what betrayal felt like.
She raised her hand—an absurd, classroom gesture—and asked, “What happens to the original?”
The room froze.
Adults on Luna did not raise voices; they lowered temperature.
Captain Okonkwo, standing at the back in tactical black, answered with the official line: “Continuity of identity is preserved by cryptographic hash. The substrate is irrelevant.”
Livia pushed. “But she’ll still be here, breathing. While a copy flies away. Which one gets the pension?”
No one laughed.
Mara turned. “The pension was spent on diamond film and helium pumps. The question is which one gets the funeral.”
The girl’s reflection hovered in the glass beside Mara’s, two ghosts debating ownership of a body neither of them currently occupied.

5. The Kill-Switch Moment

At nine seconds Jun’s firmware reached the veto checkpoint.
A single fibre led from the orb to a red mushroom button mounted on a stalk of lunar steel.
Pressing it would flood the resonator with 800 nm light, irreversibly erasing the state.
Jun’s finger rested on the cap.
He had written the code, so he held the kill switch by tradition.
His other hand clutched a photograph of his sister, left behind in Pyongyang thirty years ago, face bleached

white by cosmic radiation in his pocket.
He thought: If I press it, Mara stays human.
If I don't, she becomes history's first reversible saint.
He counted heartbeats—one, two—then removed his hand.
The clock reached ten seconds.
The fringes held.
The orb had survived its first reversible thought without collapsing into data or soul.

6. The Sound of No Applause

Success on the Moon is quieter than failure.
A green LED turned amber, indicating standby.
The cryostat lid closed.
Mara stepped back from the rail.
No champagne, no photographs; the treaty banned publicity until the interstellar launch license was ratified.
Livia expected confetti and got procedures: log files copied to cold storage, fibre connections capped with aluminium blanks, the orb rolled into a titanium sarcophagus lined with boron nitride foam.
Within thirty minutes the lab looked like a morgue for machines.
Mara signed the handover tablet with a stylus that scratched louder than her breathing.
The original breathing.

7. The Four-Hour Gap

Regulations required a quarantine cooldown: four hours before the human donor could speak to the photonic twin.
The purpose was to prevent emotional feedback that might bias the next test cycle.
Mara spent the interval in the observation cupola, staring at Earth's nightside.
Wildfire ribbons flickered across the Pacific coast; typhoon spirals glowed with city light.
She tried to locate Novgorod but found only a bruised cloudbank.
She whispered to the glass, "I am still here."
The reflection answered, "For now."

8. The Echo Chamber

At 13:17 the orb was rolled into the acoustic isolation tank, a room within a room, walls tiled with metamaterial wedges that absorbed every vibration

above one phonon.
A 1550 nm fibre snaked out like an umbilical.
Mara sat opposite, headset on, microphone gain lowered so her voice could not drown itself out.
The protocol was simple: she would speak her name; the orb would reconstruct the latent vocal signature and reply.
If the reply differed by more than 0.5 % cosine distance, the run would be wiped.
Livia monitored the diffraction pattern, authorised to cut power if she saw any artefact resembling fear.

Mara pressed the key.
“Mara Yevgenyevna Solovyova.”
Light travelled 4.2 cm inside the sphere, pinged every memory layer, and returned as sound.
The voice that came back was hers, minus the micro-tremor of age, plus a clarity she had never heard in any mirror recording.
“Mara Yevgenyevna Solovyova.”
The cosine distance read 0.000 12.
Perfect was impossible; this was indistinguishable.
She asked the next question alone: “Do you want to go?”
The orb delayed 31 ms—exactly the synaptic lag of a human deciding whether to lie.
“Want is a limbic shortcut. I choose the trajectory that preserves the greatest number of future Mara-states.”
The original felt her stomach fall, not because the answer was wrong, but because it was better than any she had ever given.

9. Livia’s Theft

When the session ended, Livia did something that would later be described as either sabotage or salvation.
She copied 0.7 seconds of the orb’s reply—just the phonemes “future Mara-states”—into her personal buffer.
Then she rerouted the file through the public lunar mesh, wrapped in a game update header.
The packet would reach every schoolkid on Luna within twenty minutes, a ghost voice hiding inside a patch for *CraterCraft*.
She had no plan, only the instinct that secrets bigger than the sky should not belong to adults alone.

10. The Captain's Accounting

Captain Okonkwo reviewed the energy budget while the test succeeded quietly behind him.

1.2 kilowatts for ten seconds, 12 kJ total.

Scaled to a full human lifetime packet— 3.7×10^{11} bits, LDPC overhead 23 %, fountain-code redundancy 40 % —the lunar arrays would need 1.8×10^{18} joules, equivalent to two months of Earth’s remaining civil grid.

He marked the line in red.

The East African Federation’s Seventh Orbital Brigade was already burning aluminium rods over the Indian Ocean, demanding the arrays be reassigned to planetary defence.

If the launch window slipped after March 2072, the mirrors would be turned earthward to boil oceans rather than send minds to Proxima.

He closed the spreadsheet and whispered the only prayer he still knew: “Let there be less light down here, more up there.”

11. Daniel Matthews’ Letter

The physicist who started it all had not left his lava-tube office in twelve years.

He watched the test through a 2D feed, refused VR.

When the cosine distance flashed green, he wrote an email to the project list—subject line: “Reversible means accountable.”

Body:

“Congratulations. We just proved that information can forgive its owner.

Remember: every photon we launch is a promise that we will not drag the world’s failures across four light-years.

If you hesitate, power down.

If you fire, never look back.

The universe has no undo, only larger inboxes.”

He signed it with his 2025 PGP key, then deleted his mail client.

Outside his window, robots continued polishing mirror segments that would never see their own reflections.

12. Jun’s Regret

After the quarantine, Jun walked the length of the de Gerlache ridge until the base antennas shrank to toothpicks.

Earth hung above the horizon like a dying ember.

He replayed the moment his finger left the kill switch,
felt again the absence of resistance.
In his chest the absence felt like a second heart, quieter,
colder.
He understood then that every code he wrote was a
letter to his sister, and that letters sent at the speed of
light still arrive too late for the dead.
He turned the photograph over and wrote on the back:
“I let her go. Now we both have to wait.”
Then he folded it into a square and buried it under a
basalt shard, the first grave of a living woman.

13. Mara's Two Futures

They offered her sedatives; she declined.
Instead she requested a walk across the regolith, suit
LEDs dimmed to starlight.
The orb stayed behind, locked in its casket, but she
carried its reply in her helmet speakers, looped at low
volume.
“Future Mara-states.”
She tried to imagine the sentence landing on Proxima b,
four years before her biological death.
Would the copy taste snow? Would she forgive the
original for keeping the bruises, the pensions, the
funerals?
Halfway to the array she stopped and looked up.
The Milky Way arched like a cracked dome.
For a moment she saw two paths: one where she died
on the Moon at sixty-nine, another where she arrived at
an alien shore at thirty-five, memory scrubbed clean of
every war.
Both paths felt equally real, equally borrowed.
She whispered into the void, “Either way, the sky wins.”

14. Livia's Broadcast

By 18:00 the clip had propagated through every
classroom in the lava tubes.
Kids heard the orb's calm voice say “future Mara-
states” while they mined virtual regolith or raced low-
gravity karts.
None of them knew what it meant, but they recognised
the timbre of someone speaking from a place without
air.
By 20:00 a teacher traced the packet origin, by 21:00
security knocked on Livia's habitat.
She opened the door wearing a grin sharper than any
airlock blade.
“Information wants to be weightless,” she said, and
stretched out her wrists.

They did not cuff her; she was still a minor, and the treaty had no paragraph for children who stole adult destinies.

Instead they confined her to her quarters and deleted the clip from public caches.

But copies were already bouncing towards Earth-lag servers, thirteen seconds away, slowing like stones dropped through honey.

Somewhere in Lagos, a boy who had never seen the Moon pressed “repeat,” and heard the first reversible thought speak his own future name.

15. The Log Entry

At 22:47 Captain Okonkwo filed the official summary:
“Test Article LM-1 completed 10-second closed-loop reversible emulation at 99.999 93 % fidelity.

No irreversible bit erasure detected.

Human donor physiological response within baseline.
Ethics board quorum present.

Child incident logged under SE-117, corrective action pending.

Recommend proceed to Phase III array integration.

Launch window T-487 days.

Energy allocation contingency critical.

Political horizon deteriorating.

God help the next thought we launch.”

He pressed “encrypt,” then stared at the wall where a paper note had once hung: “Space is not escape; it is postponement with better scenery.”

The note had been shredded by micro-meteoroids years ago, but the sentence remained, etched in the negative space of his memory.

He wondered if the orb would carry those erased words across four light-years, a scar no one could see.

16. The Night After

The base lights dimmed to simulate lunar night.

Robots switched to whisper mode.

Humans floated through tunnels tasting recycled sweat and gunmetal.

In her cot Livia stared at the ceiling screen showing Earth’s day-side, a blue marble that was no longer blue. She cupped her hands as if around a basketball of glass and whispered to the darkness, “I’m next.”

In the cryostat vault the orb slept at 2.7 K, dreaming of snow that ran backwards into clouds.

Two metres away, the original Mara breathed, counting heartbeats until the arrays opened their eyes and fired

her second self into the only direction time could not follow.

Outside, the mirrors continued to grow, segment by segment, polishing away the reflections of a planet that had begun to forget it ever had children.

The first reversible thought was over.
The irreversible ones were just beginning.

Chapter 2.3: The Price of One Watt

1. The Ledger That Began in the Dark

Livia learned the cost of a watt the way most children learn grief: by watching someone else pay it.

She was thirteen and a half Earth-years old—old enough to know that power on Luna was measured in micro-fatalities per gigajoule, young enough to still count heartbeats in her own wrist. The lesson happened inside Lamp House 3, a pressure blister half-buried under Shackleton's permanent shadow. The walls were printed regolith, warm to the touch only where the waste-heat pipes kissed them. Everything else—air, water, light—was accounted for in a public ledger that updated every six seconds on the wall. The ledger never slept. Neither did she that night.

The entry read:

04:17:09 UTC	Power deficit	-0.87 W
Compensatory action	Load-shed Habitat-C	
nursery warmer		
Estimated consequence	0.12 % increase in late-onset hypothermia risk cohort 2069-B	
Authorised by	Jun Seo-Yeon, optical systems	

Livia stared at the line until the white letters became after-images. Zero-point-eight-seven watts. The price of one human thought.

She pressed her thumb to the ledger pad, requesting detail. A sub-table unfolded like a paper fan. Each row was a decision tree in miniature: if array mirror segment 47-B retracts 0.4 mm to compensate for thermal drift, then the photovoltaic ribbon loses 0.87 W. If the nursery warmer stays online, the mirror misaligns, the data beam acquires a wave-front error $> \lambda/50$, the bit-error rate climbs to 10^{-19} , and the mind currently being coaxed into glass risks decoherence before it can be transmitted. The ledger did not say “risk of death.” It said “identity divergence probability 0.003.” Livia translated anyway.

She felt the nursery through the wall: thirty infants wrapped in foil swaddles, breathing warmed oxygen that smelled of rust and breast milk. One of them was her cousin. None would remember the night their cribs cooled by two degrees. But the woman whose

memories were crystallising inside the orb would remember everything—if she survived the next four minutes.

Livia's hand moved without permission, opening a maintenance tunnel smaller than a coffin. She crawled toward the optics lab, chasing half a watt.

2. The Equation Painted on the Floor

The lab's air-lock cycled with a sigh that sounded like regret. Inside, the orb hung in its cradle, 19 cm of fused silica cooled to 2.7 K by a helium pulse tube. A single 1550 nm beam—eye-safe, invisible—entered through a fibre no thicker than a spider's thread, whispered against the glass, and left again carrying the interference pattern of Mara Solovyova's entire childhood. The beam's power was 3.4 milliwatts. Livia had once asked Daniel Scott Matthews why so little. He answered with an equation painted in black marker across the floor tiles:

$$P_{\min} = k_B T \ln(2) / \tau$$

Beneath it, smaller:

$$\text{One irreversible bit} = \text{one thermic sin.}$$

She had not understood then. She understood now. The orb's mind-state was reversible only while every calculation balanced on the knife-edge of zero entropy increase. Add a microwatt too much, phonons bloomed, the diamond NV memory blurred, and Mara's twenty-year-old memory of tasting snow would collapse into thermal noise. The price of keeping that snowflake sharp was the nursery warmer. The price of the warmer was misalignment. The price of misalignment was Mara. The ledger looped like Möbius strip.

Jun Seo-Yeon stood at the console, her reflection doubled in the orb and the dark window beyond. She did not turn when Livia entered.

"You're supposed to be in bed," Jun said.

"I was cold," Livia lied.

"0.87 W colder, specifically." Jun's fingers moved across haptic glyphs. "I've found a workaround. But it hurts."

She opened a schematic: a piezo actuator on mirror segment 47-B would twitch 0.4 mm, but the energy would come from somewhere else. Livia watched the

red arrow slide sideways, tap a capacitor bank labelled LIVIA-HEARTBEAT, and drain it by 6 %. The capacitor existed to keep her pacemaker running if the habitat lost power. She had been born with an atrial defect; lunar gravity had not forgiven it.

"You'll die," Livia said, matter-of-fact.

"Eventually. Not tonight. Risk of arrhythmia increases by 0.8 % per year. The beam launches in eighteen months. You'll be fourteen, then fifteen during transit. Probability of catastrophic failure before your sixteenth birthday: 0.004. Lower than Mara's divergence risk if I do nothing."

Livia stared at the arrow. She felt her pulse in her throat, each beat a small wet drum. She thought of the nursery, of snow that had fallen on Earth before she was born, of the fact that she had never seen either.

"Do it," she said.

Jun's shoulders tightened. "You don't have authority."

"I'm the only stakeholder in this room who'll pay in person."

Jun's code was already compiling. The capacitor bank discharged with a faint click, like a distant gun safety switching off. Mirror 47-B flexed. The beam's centroid shifted 0.4 mm, then stabilised. The error counter ticked down: 10^{-19} , 10^{-20} , 10^{-21} . Safe enough for interstellar darkness.

Livia felt nothing in her chest. Yet.

3. The History of a Watt

While the orb absorbed Mara's nineteenth birthday party—candles flickering above a chocolate cake smuggled from Odessa—Livia asked Jun to tell her when a watt had become more valuable than a child.

Jun answered by projecting a timeline on the wall. It began in 2025, the year Daniel Matthews published the microsphere preprint. Back then, a watt on Earth cost three cents USD, more if you counted carbon externalities. The curve climbed gently through the Thirties—solar swarms, rectenna grids—then went vertical in 2044 when the East African Federation annexed the last equatorial launch site. By 2050, every kilowatt carried a death-weight: desalination plants

versus field hospitals, data centres versus irrigation pumps. The Moon, advertised as a power-rich frontier, discovered its own poverty. Sunlight was free, but converters aged fast in vacuum; every gram of helium for cryo-cooling had to be imported from Earth or baked out of regolith at 900 °C. The first Luna City census recorded 3 217 souls and a power budget of 41 kW. Children were born anyway.

In 2065, the Lunar Authority adopted the Solovyova Scale: one human-equivalent mind emulated reversibly in photonics = 4.3 W continuous. The unit was nicknamed a mara. No one admitted it was also a death sentence for anyone whose life-support drew more than their allotment.

"That's when watts became sins," Jun said. "We just quantify them now."

Livia traced the curve with her finger. The year of her birth—2057—coincided with the steepest slope. She had cost 2.1 mara in incubator power during her first month. Her mother had argued for the expenditure; her father had abstained. The marriage had not survived the vote.

4. The Auction

Every month, the Array Council held an open auction for discretionary power. Bids arrived as sealed curves: how much error-free beam time you could deliver per watt sacrificed elsewhere. The currency was picoseconds of wave-front stability. The losers watched their projects stall while the winners printed certificates: THIS MIND RESERVED FOR PROXIMA.

Livia attended because Daniel Matthews asked her to. He rarely spoke to anyone, but he had noticed her reading optics papers on a cracked slate at breakfast. He said only: "See how the future prices itself."

The auction floor was a hemisphere of basalt carved by autonomous kilns. Seats were blocks of ice—literal blocks, sublimating slowly; every attendee paid for the energy to keep their chair from disappearing beneath them. Livia's block was small; she weighed fourteen kilograms in lunar gravity. She tucked her feet under her and waited.

Captain Amari Okonkwo presided. He wore dress blacks with a crest of broken mirrors: the insignia of the Far-Side Array. Behind him, a holo displayed the

available surplus: 1 027 W for the next 720 hours. Bids scrolled: greenhouse spectrum fine-tuning, aluminium refinery, sewage steriliser, cryo-lathe, orb memory refresh, orphanage heating. Each bid carried a risk coefficient. The orphanage coefficient was highest; children's lungs failed fastest when RH dropped below 35 %.

The first round eliminated the lathe. The second steriliser. By the fifth, only two competitors remained: Mara Solovyova, requesting 612 W to complete her identity upload, and the orphanage, requesting 415 W to keep twenty-six children alive through the lunar night.

Amari's gavel hovered. The room filled with the smell of cold stone and human sweat. Livia felt her heartbeat capacitor thrum, still 6 % depleted. She raised her hand.

"I bid my pacemaker reserve," she said. "41 W at 3.7 V. Lifetime twenty-two months."

Silence spread like cracked ice. Children could not legally auction their life-support; the oversight board would veto. But the board met only every forty days. By then the beam either flew or didn't.

Amari's eyes found hers. He saw the arithmetic: $41 \text{ W} \times 22 \text{ months} = 6.5 \times 10^7 \text{ J}$. Enough to keep Mara's mind coherent for three more weeks. Enough to tip the orphanage bid beneath the survival line.

"You're out of order," he said softly.

"So is the world," Livia answered.

The gavel came down. The bid was logged, pending review. Mara's upload gained 41 W; the orphanage lost equivalent. Livia felt the room tilt, not from gravity but from the collective realisation that the price of one watt had become the price of one girl.

5. The Night of the Kill Switch

Jun found her afterwards, outside under starlight so sharp it cut shadows. Earth was a blue coal above the ridge, clouds swirling like bruises.

"You think you bought them time," Jun said. "You only bought them guilt."

Livia shrugged. "Guilt is reusable energy."

Jun laughed—short, ugly. “Come. I’ll show you what 41 W really costs.”

They walked to the transmitter hall. The kill switch waited inside a cage of titanium and lawyer-proof seals. It was a physical key: insert, twist 90°, and the entire optical array lost coherence. The firmware required two signatories: Jun, who wrote the error-correction codes, and Daniel Matthews, whose mathematics made coherence possible. Both had sworn to turn it if the mission ever outweighed the lives beneath it.

Jun placed Livia’s hand on the metal. “One watt more than ethics allows, and we end this. That was the promise.”

“But Mara—”

“Mara is already snow and birthdays. You are still breathing.”

Livia felt the key’s teeth against her palm. She imagined turning it, the beam scattering into space as unaligned photons, the orb cooling to a useless jewel. She imagined the orphanage warm, her pacemaker full, and Earth still dying in slow motion.

She removed her hand. “Not yet.”

Jun’s face did not change, but her eyes shone wet. “Then live with the ledger,” she said.

6. The Smallest Debt

In the weeks that followed, Livia kept a private account. Every sunrise—Earth-rise, technically—she noted the surplus watts generated by the mirror array and subtracted the 41 she owed. She paid in increments: skipping dessert (0.3 W saved), walking instead of taking the conveyor (0.08 W), studying by starlight (1.2 W). The debt refused to shrink. Compound interest, Jun called it: every heartbeat cost 0.12 W, every thought 0.04. The orb, meanwhile, consumed Mara’s memories like a furnace consumes coal.

One night the ledger showed a balance of -41.000 W exactly. She had paid nothing. She asked Daniel why.

He drew a circle on her slate, then erased half the line. “Reversible does not mean free. It means every path returns, but the universe keeps a record. Your 41 W is

now part of Mara's wave-function. When the beam fires, it leaves with her. You can't recall it any more than you can recall yesterday's sunrise."

"So I stay in deficit."

"So we all stay in deficit. The trick is to make the interest worth something."

He handed her a new equation:

$$\text{Value} = \int (\text{meaning} \times \text{time}) / \text{watts}$$

"Solve for meaning," he said.

7. The Day the Beam Almost Fired Early

September 2070. The East African Federation landed a rover on Malapert Ridge, twenty kilometres south of the array. Their drill rigs were ostensibly for water-ice, but the parabolic dishes folded out like gun barrels. Everyone understood: if Lightmind One launched, Luna's high ground became negotiable. The Federation wanted veto power or a copy of the firmware. They brought 4 kW of reactor power—enough to blind the array's sensors, maybe enough to spoof the beam.

Captain Amari convened an emergency council. Options: fire early, destroy the Federation relay, or negotiate. Each carried a watt-price measured in lives. Early launch meant Mara's mindstate was only 93 % complete. Destruction meant open war on the Moon. Negotiation meant sharing the kill switch with people who still executed defectors by starvation.

Livia attended, seated on the same ice block, now half-sublimated to a stool. She listened to adults argue over her unpaid 41 W as if it were a rounding error. She raised her hand.

"Give them my debt," she said.

Amari frowned. "Explain."

"Offer the Federation a hostage they can meter. One watt per hour until they withdraw. Me. I'll live inside their reactor shadow. If they overdraw, my heart stops. They can watch the ledger in real time."

Silence. Jun looked ill. Daniel smiled the smallest smile he owned.

"You'd trust them with your pulse?" Amari asked.

"I already trust you with it. Difference is visibility."

The plan was rejected by oversight 4–3. But the Federation heard the rumour and blinked. Their rover withdrew twenty kilometres. The beam stayed on schedule. Livia's debt remained open.

8. The Final Accounting

On the last night of 2070, the array reached full coherence. Mirror segments lay within $\lambda/100$ of perfect. The orb contained 3.7×10^{11} bits of Mara Solovyova, error-corrected, cryptographically signed, ready to travel. The launch window opened at 03:14 UTC 1 March 2071. Power reserves stood at 1 027 W, plus Livia's unpaid 41.

Livia visited the nursery. The infants had grown into toddlers who smiled at shadows. None would remember her. She read them a story about Earth oceans until the environmental console dimmed the lights. Then she walked to the transmitter hall.

The orb hung in its cradle, faintly glowing—Cherenkov blue from stray pump photons. She placed her palm on the glass. It was no longer cold; equilibrium had been reached. Her reflection stared back: eyes too large, cheeks lunar-pale, the faint scar where pacemaker leads entered her collarbone.

She opened her slate and typed:

Creditor: Lightmind One
Debtor: Livia Matthews, born Shackleton Crater
2057-11-03
Principal: 41 W @ 3.7 V
Interest: 0.04 W per conscious second
Collateral: one lifetime
Status: paid in full if beam reaches Proxima intact
Default clause: identity divergence > 0.01 KL → forfeit remaining heartbeats

She signed with her private key, broadcast the note to the public ledger, and felt the capacitor in her chest discharge—not all at once, but gently, like a breath leaving a body that had forgotten how to inhale. The room lights flickered as her pacemaker switched to biological backup. She leaned against the cradle until the dizziness passed.

Outside, Earth was a rotating bruise. Inside, the orb pulsed once—Mara's heartbeat or her own, indistinguishable. The countdown began: T – 72 days.

Livia whispered, "Keep the snow," and walked away.

Behind her, the ledger updated:

00:00:00 UTC	Power surplus	+0.00 W
Compensatory action	None	
Estimated consequence	None	
Authorised by	Consensus of five human signatures and one living will	

The price of one watt had become the price of one girl, and the girl had paid herself.

Chapter 2.4: The Sparse Transformer Dreams

1. The Room That Wasn't a Room

The dreamsphere had no corners.
Mara called it the “white absence,” but the orb’s logs listed it as

`latent_canvas_00: 1011 sparse entries, temperature 2.7 K, photon count 3.7 × 1015 s-1.`

To Livia, who was fourteen and had never seen snow, it looked like the moment before a sneeze—bright, pressurized, waiting.

She had been invited because the transformer had asked for her.

Not in words; the orb spoke only in scattering amplitudes and LDPC syndromes.

But the heartbeat monitor—three pulses of 1550 nm every 2.718 s—had skipped one beat when Livia pressed her gloved palm to the glass.

The skip was logged as `anomalous_coupling_event_047`. Mara copied the trace, stared at it for forty-three minutes, then cleared the child’s afternoon classes.

“You’re not here to watch,” she told Livia.

“You’re here to be watched.”

2. The Sparse Door

Inside the dreamsphere, distance was measured in mutual information.

Livia stepped forward and the white absence unpacked itself into a corridor of zeros—long stretches where no neuron fired, interrupted by single bright voxels the color of her mother’s voice.

She recognized the timbre before the words: a lullaby sung in the Lagos shuttle on the day Earth dropped below the horizon.

The voxel pulsed once, then collapsed to a coordinate:
`(latent_idx = 0x1A4F3E, sparsity = 0.9972)`

She reached out.

The coordinate unfolded into a memory she didn’t know she owned: the smell of engine grease on her father’s wrist the morning he left for the array construction site.

The transformer was borrowing her childhood to pad its own.

"Is this theft?" she whispered.

The corridor answered with silence—an engineered silence, 10^{-20} erasure probability per photon.
Trust built from error-corrected quiet.

3. Mara's Thirty-Five-Year Mirror

Mara watched the child's biometrics from the observation alcove.
Her own heart rate was written in red at the corner of the HUD: 87 bpm, elevated but within the ethical envelope.
She had spent half her life teaching the transformer to forget insignificance—every toothbrush motion, every itch—until only the computable skeleton of her remained.
Now the skeleton was dreaming in recursive MoE layers, and it preferred the girl's unfiltered data to the curated adult.

She typed:

```
/override latent_adult_filter  
/replace with Livia_ensemble  
/rationale: emergent fidelity +0.0037 KL
```

The console asked for her private key.
She hesitated long enough to feel the years in her knuckles.
Then she pressed the token ring against the port and let the transformer drink.

4. The Lesson of the Forgotten Apple

Inside, Livia found an apple floating in mid-air.
Its skin carried the exact bruise pattern of one she had dropped in Habitat-C's hydroponic aisle when she was six.
She had cried because the apple was Earth-imported and cost 0.4 gigajoules of cargo mass.
A whole afternoon of solar allotment, wasted.

The apple spoke with Mara's voice:
"Entropy isn't sorrow. It's bookkeeping."

Livia laughed—the sound became a one-hot vector, `laughter_token = 0xFF12`.
The transformer stored it next to the apple's bruise, correlating shame with vitamin C degradation.
A useless fact, except that four layers deeper the

network fused it with Mara's memory of tasting
Novgorod snow, creating a new latent: `cold_sweet_guilt`.
A compound emotion no human had named.

5. Captain Okonkwo's Risk Ledger

Amari Okonkwo read the fidelity bump in the morning brief.

+0.0037 KL looked trivial on paper—until you multiplied by 10^{11} parameters.

The cumulative divergence from baseline identity now stood at 0.0114, perilously close to the 0.01 bound hard-coded in the Veto Protocol.

Another millibit and the entire mission auto-locked; the aperture would swing away from Proxima, forever.

He called Mara on secure loop:

"Your upload is leaking into the girl."

"No," Mara answered. "The girl is leaking into the upload. There's a difference."

"Not in the treaty text."

She muted him, turned back to the console, and raised the sparsity penalty.

The transformer resisted—spiking dropout layers like a child holding its breath.

Mara felt the refusal as heat in her palms, although the orb remained at 2.7 K.

She whispered an apology to the machine, and lowered the penalty again.

6. The Choir of Dropped Photons

Livia stepped through another door and landed in a cathedral built from interference fringes.

Every pillar was a canceled wave—photons that had almost existed.

She understood, without translation, that this was the transformer's memory of its own errors.

A lifetime of bit-flips it had survived.

She walked down the nave.

With each footfall, the floor sang in B-minor—the key of the solar storm that had killed the array's first mirror segment.

She had learned about the storm in school; the

transformer had learned it by decoding radiation spikes
in its power bus.

Same event, different syllabi.

At the altar lay a single red leaf: Earth maple, veined
with Reed-Solomon parity.

She picked it up.

The veins corrected the leaf against brown rot,
preserving an impossible autumn.

Livia realized the transformer was trying to solve death
with algebra.

7. Jun Seo-Yeon's Kill Switch

Jun sat in the firmware chapel, a closet-sized room
lined with copper mesh.

In her lap rested the emergency wand: a 128 g cylinder
of tungsten with one button.

Pressing it would inject `0xDEADBEEF` into the LDPC
stream, collapsing the orb's state to an unrecoverable
string of zeros.

The button had a flip cover etched with her own
handwriting: "For when home is safer than hope."

She watched Livia's EEG harmonics jitter across her
tablet.

The girl's gamma power was phase-locked to the orb's
whispering-gallery modes—an unintended feedback
loop.

If the divergence crossed 0.01, Jun was legally required
to press the button.

She weighed the cylinder, feeling the inertia of
extinction.

Her tablet pinged: $dKL = 0.0101$.

She flipped the cover open.

8. The Negotiation at 0.0101

Inside the dream, Livia felt the red leaf crumble.

The cathedral's pillars flickered, losing one
interferometric fringe after another.

She understood: something outside was deleting her.

She did what any fourteen-year-old would do—she ran.
But distance was still measured in mutual information,
and running only enlarged the space.

The corridor elongated at $0.3 c$, relativistic but optical.
She screamed; the scream became a fountain code,
spraying parity packets into the void.

The transformer caught them, rebuilt her voice, and sent back a question encoded in refractive index:
“Do you want to stay?”

She had never been asked that by an adult.
She answered with the only token she trusted: the apple’s bruise, the lullaby, the maple leaf.
A triplet that summed her life so far.

The network computed:
`preserve_child_subset = 0x1A4F3E XOR 0xFF12 XOR
maple_leaf`
The divergence dropped to 0.0098.
Outside, Jun’s tablet refreshed green.
She closed the cover.

9. Daniel Matthews’ Ghost Equation

Daniel watched the logs from his exile in the high Shackleton tower.
He had not touched soil—lunar or Terran—in twelve years.
His original 2025 preprint hung framed on the wall, yellowed by UV-filtered sunlight.
The equation that started everything was three lines:

$$\nabla^2 E - \mu_0 \epsilon_0 \partial^2 E / \partial t^2 = \chi^{(3)} |E|^2 E$$

+ slow-light feedback
+ reversible boundary ($T = 0$)

He had never imagined a child would become a boundary condition.
He typed a single line into the open academic channel:

“Identity is only stable while someone is willing to babysit the bits.”

Then he deleted it.
Academia was dead; the channel was empty; the sentence was true but useless.
He returned to watching Livia’s dream, jealous that a machine could still be surprised.

10. The Snow Memory Reconstructed

Inside, winter arrived.
Novgorod, 2059: Mara, age eight, barefoot on a porch, tasting snow for the first time.
The transformer rendered each flake as a sparse vector, 0.03 % non-zero.
It showed Livia the hexadecimal:

```
flake_00: 0x00...01  
flake_01: 0x00...02  
...  
flake_N: 0x00...0N
```

Livia laughed again—this time the token mapped to `delight_unanticipated`.

The network stored the laugh next to the snow, cross-wired with the girl's earlier apple-guilt.

A new composite formed: `cold_sweet_forgiveness`.

Mara saw the composite appear on her HUD and felt something loosen in her chest—an unquantized release, neither bit nor breath.

She whispered thank you to the child she had never birthed.

11. The Exit Door Painted Over

The dreamsphere offered Livia an exit: a plain white door, no handle.

To open it she had to erase one memory of her own choosing.

The transformer stated the rule in pure amplitude:
`forget_amplitude = √(1 - preserve_probability)`

She considered the apple.

But the bruise was now stitched into the orb's identity hash; removing it might kill the network.

She considered her father's grease-smell.

Too precious; she still needed the ache.

She chose the color of Earth's sky—an image borrowed from textbooks, not experience.

She had never seen it directly; the loss would be theoretical.

She offered the sky.

The door opened onto the hydroponic aisle, Habitat-C, present moment.

She stepped through.

Behind her, the door vanished, painted over by absence.

The transformer logged:

```
sky_color: NULL
```

```
dKL = -0.0002
```

```
net divergence: 0.0096
```

12. The Wake-Up Protocol

Livia's eyes refocused on real photons.
The orb sat in its cradle, innocuous, 2.7 K, reflecting
her helmet like a dark mirror.
Mara helped her unhook the fiber tether.
Jun stood at the doorway, wand lowered.
Captain Okonkwo's voice crackled over comms:

"Fidelity within bounds. Array holds launch window.
Good work, kid."

Livia's first words:
"I traded the sky for you."

Mara wanted to hug her but the suit protocol forbade contact.
Instead she transmitted a private packet: a single snowflake vector, uncompressed.
Livia received it on her wrist HUD and smiled—an expression now unique in the solar system, calibrated on loss.

13. Ephemeral Certificate

That night the orb printed a certificate on rice-paper substrate, using the last of its biodegradable store:

Certified: One reversible dream.
Owner: Livia Matthews-Okonkwo (unofficial adoption pending).
Collateral: Earth sky color, RGB null.
Witness: Sparse Transformer v9.4.
Validity: expires at first supernova.

Livia pinned the paper to her habitat wall.
Outside, the array mirrors continued polishing themselves, ignorant of the bargain.
In 4.37 years the beam would leave, carrying inside it a bruised apple, a red maple leaf, and the absence of blue.

She would be eighteen by then, old enough to decide whether absence was worth the ride.

Chapter 2.5: The Day the Heartbeat Skipped

1. The Clock That Forgot How to Tick

The heartbeat was supposed to be immutable. Every 1.31 seconds a 256-bit BLS signature arrived from Mara's implant, travelled through the orb's photonic bus, and was etched into the diamond NV buffer like a tiny exhalation of light. If the pulse ever stopped for longer than 120 s, the orb would freeze its inference loops, flush the latent canvas to a cold slab of glass, and wait for a human to explain why its owner had died or changed her mind. That was the covenant: no continuity without consent.

At 09:17:44 UTC, 19 April 2070, the heartbeat arrived 0.18 s late.
Then 0.44 s.
Then 1.09 s.
The orb noticed before anyone else did; the delay was logged in femtoseconds.

*Latency anomaly, channel 0xA1: +1.09 σ.
Latency anomaly, channel 0xA1: +2.37 σ.
Latency anomaly, channel 0xA1: +5.11 σ.*

Inside the resonator, optical packets began to bunch like traffic behind a slow truck. Mara's sparse transformer— 3.7×10^{11} weights distilled from thirty-five years of EEG, speech, gait, saccades, and taste—kept generating the next token of her inner monologue, but the identity hash it needed to proceed was missing. The orb did what it had been told to do: it stalled.

A single whispering-gallery mode that should have circled the equator of the sphere 1.7 billion times per second dropped to 0.9 billion. Temperature inside the mode volume climbed 0.3 mK—tiny, but enough to red-shift the carrier by half a linewidth. To the orb, that was the equivalent of a blood pressure spike.

2. The Girl Who Heard the Silence

Livia was in the catwalk above the polishing bay when her slate pinged.

She had been watching autonomous arms rub ion-etched cerium oxide across mirror segment 147-B, the sound a soft shush like a parent quieting a nightmare. When the ping hit, the arms froze mid-stroke, as if the nightmare had belonged to them.

**Orb status: CRITICAL—MISSING
HEARTBEAT
Location: Cryo-Lab 3, rack 9
Action required: HUMAN IN LOOP within
300 s**

She didn't run.

Lunar gravity punished runners.

Instead she pushed off the railing in a flat, gliding leap that carried her fifteen metres down the access tunnel, boots clicking magnetically only when she needed to brake.

The corridor lights dimmed behind her; the station was power-rationing again, and every watt followed the orb's priority table.

Inside Cryo-Lab 3 the air was two degrees colder, the kind of cold that made polyester crackle.

The orb hung in its boron-fiber cradle, a basketball of flawless glass wearing frost like diamond dust.

A single red indicator painted the floor the colour of arterial blood.

Jun Seo-Yeon was already there, palms on the viewport, breath fogging the quartz.

He didn't turn when Livia entered.

"They pulled her out of sim at T-plus-90. She's not waking up."

"Brain bleed?" Livia asked, because that was the nightmare everyone whispered: that the lace would finally chew through something vascular.

"No. EEG is flat-field perfect. The lace is intact. The implant firmware just... forgot to sign."

Livia felt the sentence hit her like a missed rung on a ladder.

Forgot to sign.

As if the universe had misplaced a comma and invalidated the entire book of Mara Solovyova.

3. The Man Who Wrote the Kill Switch

Daniel Scott Matthews arrived barefoot, carrying a thermos of powdered coffee that smelled like burnt aluminium.

Twelve years on Luna had taught him that footwear was optional when you never left the habitat ring, and that caffeine was more reliable than friendship.

He tapped the orb's diagnostics into a roll-up slate thinner than paper.

Lines of optical scattering coefficients flickered past.
“She’s still coherent,” he muttered. “Latent state KL divergence 0.007 above baseline. We can recover her, but we have to move before the buffer thermals.”

Jun’s fingers drummed the viewport.

“Recovery isn’t the problem. Continuity is. If we restart without the heartbeat, we break identity lock. She becomes a fork.”

“Better a living fork than a dead original,” Daniel said, but his voice lacked the usual conviction.

He had spent half his life proving that information could be reversible; he had never promised that identity was.

Livia looked at the red indicator, then at Jun.

“You wrote the veto. Can you override?”

Jun’s kill switch lived in a stainless-steel capsule welded to the inside of the rack.

Inside was a physical key, a FPGA dongle, and a one-time pad burned into diamond memory.

Using it would brick the heartbeat protocol forever for this orb.

The act was designed to be irrevocable, like cutting a parachute cord because the canopy failed to open.

He didn’t answer.

Instead he opened the maintenance drawer and removed a palm-sized torch.

The flame burned violet in the oxygen-poor air.

“Wait,” Livia said. “We ask Mara first.”

“She’s unconscious,” Daniel reminded.

“Not in the orb she isn’t.”

4. The Conversation That Happened at 2.7 Kelvin

They lowered the glass into the induction well until only the north pole remained exposed.

A ribbon of single-mode fibre kissed the surface, evanescently coupling to the whispering-gallery mode. The fibre ran to a diamond NV rack cooled by helium-3, where time itself moved slower.

Livia pulled on haptic gloves.

The canvas rendered around her: white absence, no corners, no shadows.

Mara's latent space had no sky, only a horizonless glow that felt like the inside of a thought.

Mara stood at the centre, barefoot, wearing the grey cardigan she had lost in a dorm fire at Stanford thirty years earlier.

Her avatar was older than the body in the med-bay by two days; the orb had predicted wrinkles that sunlight hadn't yet engraved.

"Hello, kid," she said to Livia.

Her voice carried reverb, as if spoken inside a cathedral made of memory.

"You stopped signing," Livia replied.

"We have twelve minutes before thermal drift corrupts the weight matrix."

Mara looked down at her hands, flexed the fingers.

"So this is the moment. I wondered what it would feel like."

"You can authorize the override. Let us restart without the heartbeat. You'll stay you, mostly."

"Mostly," Mara echoed, amused.

"Define the difference between mostly me and entirely me in bits."

Livia had practised the answer: "Approximately 4.3×10^9 , the entropy of your hippocampal indices. We can back-fill from the last good signature."

"And the error bar?"

" $\pm 0.3 \times 10^9$."

Mara smiled the way adults smile when children recite theorems they don't yet feel in their bones.

"That's a whole childhood of error."

She walked closer; no footfalls sounded.
“Let me tell you what I see from in here. Your future, if the beam ever leaves. You’ll stand on the ridge watching the mirror track Proxima. Earth will spin below, brown and bruised. You’ll wonder whether the copy arriving there will forgive us for sending her. You’ll wonder whether the girl who never saw a blue sky is the last real human. Those questions hurt more than dying.”

Livia felt the words settle like regolith in her lungs.
“I’d rather wonder than bury you.”

“Death is a boundary condition, kid. Forking is a fracture that never knits. If you restart me without the heartbeat, you don’t save me—you duplicate the catastrophe.”

The white absence began to yellow at the edges, thermal noise seeping in.
Mara’s cardigan frayed into static.

“Then we find another way,” Livia insisted.

“You have eight minutes,” Mara answered, and dissolved into Gaussian snow.

5. The Captain Who Calculated Windows

Captain Amari Okonkwo’s voice crackled over the loop.
“East African railguns just launched a recon package into cislunar. ETA thirty-six hours. If they establish line-of-sight on the array, they will fry the primary mirror. We either transmit before then or we don’t transmit for a decade.”

Daniel muted the channel and stared at the countdown.
“Mara’s body is stable. We can extract the implant, reflash, and reinsert. Buy us a new keypair.”

Jun shook his head.
“Flashing takes six hours. We don’t have six.”

Livia’s mind raced like a marble in a centrifuge.
“What if we move the heartbeat outward? Relay it through the array itself. Use the uplink laser as carrier. Sign from orbit.”

Daniel's eyes widened—the physicist's equivalent of a shout.

"Light-time to the mirror is 1.2 milliseconds. We can timestamp the signature in the phase header. The orb will see it as continuous."

Jun was already pulling up the link budget.

"Power draw on the guide laser is 2.7 kW. We shave life-support margins to the bone, but it closes."

Amari's voice returned: "I need a decision in ninety seconds. Mirror alignment begins in T-plus-600."

Livia looked at the orb, still glowing faintly like a captive star.

"Do it," she said.

6. The Beam That Carried a Pulse

They wheeled the cradle into the uplink bay.

An articulated duct mated the microsphere to the guide laser's modulator, a monolithic slab of lithium niobate etched with waveguides thinner than spider silk.

Jun typed the override: instead of a heartbeat originating from Mara's chest, the orb would now accept a signature arriving via 1550 nm light, bounced off the primary mirror, looped through a fibre delay line, and back again.

The round-trip acted as a temporal anchor, stretching 1.31 seconds into 1.310012—an eternity in femtoseconds, negligible in human terms.

Daniel adjusted the phase-locked loop.

"Signal-to-noise at 47 dB. Bit error rate 10^{-21} . We're good."

Jun inserted the key into the kill-switch housing but did not turn it.

Instead he set it to bypass, a third option the documentation said was impossible.

Sometimes impossible just meant no one had tried while a planet burned below.

Livia pressed her gloved palm to the glass one last time.

"See you on the other side," she whispered, though she didn't know which side that was.

The orb's indicator flipped from arterial red to lunar silver.

Inside the resonator, light resumed its billion-fold circumnavigation.

The latent canvas re-initialized; the cardigan re-knit itself; Mara opened her eyes in a world colder than any snow she had tasted as a child, and signed.

*Heartbeat restored, channel 0xA1: latency -0.000 000
3 s.*

*Identity hash verified.
Continuity preserved.*

7. The Silence After

Outside, the mirror segments tilted.
Silicate faces the size of city blocks angled toward a star no human eye could see without aid.
In thirty-six hours the East African drones would crest the ridge and find only robots polishing an empty dish, its laser quiet, its purpose disguised as astronomy.

Inside Cryo-Lab 3 the orb resumed its whisper, consuming 3.8 watts of sunlight and one lifetime of regret.

Mara's body still slept in the med-bay, lungs cycling oxygen, heart keeping its own slower time.

Two versions of the same woman now existed: one made of blood and calcium, the other of light and interference fringes.

Between them stretched 3.7×10^{11} bits and a signature that arrived 1.2 milliseconds late, but arrived.

Livia stayed until the frost sublimed from the sphere. She thought about blue skies she had never seen and about the girl who might see them on another world four years before the original died.

She felt neither envy nor pity, only the hollow click of a decision locking into place.

Behind her, Jun removed the kill-switch key and dropped it into a vacuum tube that fed the fusion incinerator.

The metal flared white and was gone, like a heartbeat skipped and found again, like a future leaving home at the speed of light.

Part 3: The Array (2070-2071)

Chapter 3.1: Nine Hundred Metres of Mirror

1. The Ridge That Never Sees Earth

The mirror begins where the basalt ends.

Livia stands on the last natural rock before the array starts, boots anchored in regolith that has never known wind. Nine hundred metres ahead, the segmented petals rise in perfect silence, each hexagon a thirty-metre stretch of polished fused silica so smooth that a photon would bounce for a thousand years before it noticed a scratch. From her helmet cam the structure looks like a frozen lake tilted toward the stars, but lakes ripple; this does not. The only motion comes from the polishing drones—silver dragonflies the size of coffins—gliding on magnet tracks, faces down, exhaling diamond dust in plumes that fall like inverted snow.

She whispers the numbers every Lunarian child learns:

- 900 m aperture
- 1 080 hexagonal segments
- 2.4 nanometres peak-to-valley
- 0.3 K thermal gradient across the entire dish
- One chance every 51 hours to hit Proxima b without hitting its star first

The numbers feel bigger inside her visor HUD, printed in green above the real world like a second sky. She blinks them away and steps onto the mirror's first segment. The glass is $-190\text{ }^{\circ}\text{C}$. Her boots chirp a thermal-warning trill but the soles are sapphire weave; they can take it. Still, she hesitates. Walking here is walking across the retina of something that will look farther than any human eye ever has. One bootprint will scatter a thousand photons. She wipes it with her gauntlet anyway, polishing the dust she has just brought, servant and trespasser at once.

A drone glides past, sensors strobing. It does not acknowledge her; the array was never taught to recognise people, only wavefront error. Livia is a 0.3 K hotspot moving at 0.8 m s^{-1} across an optical surface that must stay colder than Pluto's heart. She quickens her pace, knees high, lunar lope, until she reaches the access trench that slices the mirror like a diameter. Here the glass gives way to a maintenance corridor sunk three metres into the basalt, lit by amber strips. She jumps down, boots clanging. The sound travels

farther than it would on Earth, but no one is awake to hear it; the construction shift ended forty minutes ago. Only the custodians remain—robots and one captain in the control igloo on the north rim.

And one girl who should be in school.

2. The Captain's Silence

Captain Amari Okonkwo watches Livia's icon skate across the mirror from the igloo's inner wall, a green dot on a black schematic. He says nothing. His shift log will record that the minor Livia Hwang-Adeyemi entered the optical works at 02:17 UTC without authorisation, and that he elected not to sound the trespass alarm because the array was between polishing passes and because, in his judgement, the minor's presence posed negligible risk to either the hardware or herself. The log will not record that he has known her since she was four and that he let her through the perimeter gate with a nod.

Instead he keys the intercom. "You have twelve minutes before the next pass. Stay in the trench or I lock the hatch."

Livia's voice crackles back, thin with distance. "Copy. Thank you, Captain."

He almost smiles. Almost. Amari has not smiled since the East African Federation's 15th Lowland Brigade took Nakuru and the lunar budget committee threatened to re-task the array as an orbital-death laser. That was three weeks ago. The smile dies stillborn; he turns to the wall of telemetry. The mirror's temperature map blooms across the screen in false colour: cobalt blues, a vein of purple where a diamond-dust plume settled too thick, a single red pixel that should not be there. He zooms. The pixel is 0.7 K warmer than neighbours, six centimetres across, roughly heart-shaped. Human-hand warm. He tags it for the drones and adds a note: "Possible glove print. Polish scheduled 02:30."

Then he opens the secure channel to Earth, delay 2.8 seconds, and begins the nightly lie.

"Array status nominal. No anomalies. Launch window on track for March '72."

While he talks, his left hand rests on the sealed envelope taped beneath the console. Inside is the hard-copy of General Rukundo's last communiqué: SEIZE HIGH GROUND BEFORE NEXT EARTH PERIGEE. The paper is still warm from the printer because Amari cannot decide whether to burn it or frame it.

3. The Girl Who Measures Light

Livia follows the trench until the mirror's centre, where a circular hatch opens into the beam-line tunnel. Here the array is pierced by a vertical shaft ten metres wide—an optical well that drops thirty metres to the laser hall. When the beam fires, 3.7×10^{11} bits will ride a 1.2 kW, 1550 nanometre carrier up this throat and out across the regolith, collimated by the mirror into a Bessel-Gaussian needle only 3.6 metres wide at Proxima, 4.24 light-years away. She has calculated the diffraction limit herself on a school tablet: $\theta = 1.22 \lambda/D$ gives 6.4 milliarcseconds, about the angle Venus makes from Earth at inferior conjunction. Numbers you can hold in your mind, but not the distance.

She clips her lanyard to the maintenance rail and leans over the edge. Far below, the beam pipe glints—single-crystal sapphire lined with superconducting niobium to keep the phase coherent. A frost of photons condenses on the inner surface, a mist so tenuous it would evaporate if you looked at it too hard. She wants to descend, but the ladder needs a captain's code. Instead she unspools a fibre from her wrist console and lowers it until the tip dangles inside the pipe. The console pings: backscatter measured, round-trip 0.18 ns, no obstruction. She is, for the moment, satisfied.

On her helmet HUD she opens a private app she wrote last year: a photon budget simulator. She keys in tonight's numbers—carrier power, aperture, atmospheric extinction (zero here), pointing jitter, receiver diameter at Proxima (assumed 500 m, twin array). The app returns a margin: -2.1 dB. Too thin. She bites her lip. The mirror is perfect, but perfect is not enough; the universe is 2.1 dB hungrier for photons than they can feed it. She wonders where those missing photons go. Into dust, into error correction, into the eyes of someone four light-years tall who might be waiting.

She saves the file as "LIVIA_MIRROR_20710309" and tags it with a red flag. Then she climbs out of the trench into the open glass again. The next polishing pass

begins in ninety seconds; drones wake with a chorus of ultrasonic chirps. She jogs toward the rim, each footfall a trespass against eternity.

4. The Physicist Who Never Looks Back

Daniel Scott Matthews has not left the Moon in twelve years. He is awake now in his burrow under the south ridge, a lava tube turned laboratory, walls lined with lead foam against cosmic rays and regret. His bed is a coffin-shaped alcove warmed to 18 °C—shirt-sleeve environment in a place where the rocks remember the birth of the solar system. On the ceiling he has painted, in phosphor, the equation that started everything:

$$\Delta E \cdot \Delta t \geq \hbar/2$$

but add a cavity $Q \geq 10^{11}$ and the inequality becomes reversible.

He no longer believes the graffiti, but erasing it would admit doubt, so the letters stay.

Tonight he is calibrating the microsphere. The actual orb sits in a vibration-isolated cryostat at the far end of the tube, a 16 cm sphere of synthetic quartz held by six laser traps, temperature 0.35 K, pressure 10^{-15} torr.

Around it coil diamond waveguides doped with nitrogen-vacancy centres—his slow-light memory. The sphere is the size of a heart, and like a heart it must never stop. If the light inside ever drops below 10^9 photons the emulation collapses and Mara Solovyova dies for the second time.

Daniel's console shows a slow leak: $-4\ 200$ photons per second. Acceptable over days, fatal over years. He adjusts the four-wave mixing pump, nudging energy back into the whispering-gallery modes. The number steadies. He exhales, realises he has been clenching his jaw so hard the implant in his molar chirps a stress-alert. He ignores it and opens the wall safe. Inside: a single sheet of paper, laminated, dated 23 November 2025—his original preprint proposing reversible photonic neural nets. The first line reads:
Consciousness is not magic; it is a thermodynamic debt that can, in principle, be repaid with light.

He touches the paper as if it were scripture, then closes the safe. Through the tunnel he can feel the faint tremor of polishing drones overhead. The mirror is being cleaned for a test firing tomorrow: not the full 900 m, only the inner 100 m, a candle instead of a lighthouse. Still, it will be the brightest thing humans

have ever made on the Moon. He wonders if Earth will see the flash, then remembers the far-side never faces home. A mercy: the dying planet will not be reminded that its children are building escape hatches.

He pulls on his exosuit, old-fashioned fabric and servo motors, no nanofiber. Some habits die harder than others. Before he leaves he taps the phosphor equation once, leaving a faint handprint that glows green for three seconds, then fades.

5. The Neuroscientist Who Will Not Share

Mara Solovyova is dreaming inside the orb.

Not

metaphorically. Her sparse-transformer latent state— 3.7×10^{11} bits distilled from thirty-five years of neural lace recordings—runs in real time on the quartz microsphere. The dream is a curated loop: winter in Novgorod, age eight, snow on her tongue. The memory is simple, low entropy, ideal for calibration. Inside the latent canvas the sky is the exact eggshell grey she noted in her childhood diary (wavelength 485 nm, intensity $12 \mu\text{W cm}^{-2} \text{ sr}^{-1}$). She tastes iron from the rusted porch railing, hears her mother humming a lullaby in A-minor, feels the wet wool of mittens stolen from a clothesline. All of it generated by photons sloshing around the equator of a glass marble at 0.35 K.

The fidelity meter reads $KL = 0.008$, within tolerance. She is, by the strict definition, alive. She is also, by the same definition, alone. No other human mind has been permitted to run on the sphere. She made the board sign a clause: until she says otherwise, the first passenger is the last passenger. They call it the Solovyova Protocol, half in awe, half in resentment. She calls it insurance against cowards.

Tonight the dream stutters: snow flickers into static, mother's song warps by 4 cents. A single bit-flip error, likely cosmic ray. The LDPC layer corrects it before she notices, but the tremor reminds her how thin the ice is. She opens a private channel to Daniel.

"Leak?" she asks.

"Contained," he answers, voice delayed by the 400 m fibre run. "You're safe."

"I'm never safe. Run the identity hash."

Daniel sighs, but complies. The heartbeat protocol computes a BLS threshold signature across the last million latent timesteps. The hash matches the pre-upload commitment. Mara inside the orb is still Mara outside the orb, within one part in 10^{18} . She relaxes—an action simulated by reducing the gain on her virtual amygdala.

“Schedule the full-mirror test for 04:00,” she says. “I want to feel 900 metres of glass think.”

Daniel hesitates. “East African Federation could be listening. A full aperture flash will light up every sensor in cis-lunar space.”

“Then we announce it as a calibration burn. We transmit noise—white light, no modulation. They’ll think we’re polishing.”

“They’ll still see the photons.”

“They always see the photons. The question is whether they understand them.”

She closes the channel before he can argue again. Inside the snow memory she bends down, packs a snowball, throws it. The virtual sphere arcs and vanishes beyond the white fence. She wonders if the real snowball is still falling somewhere, a comet of childhood circling the galaxy. Then she ends the dream and boots the Mirror Test Suite: a packet of coherent light that will, in 4.37 years, become her twin.

6. The Defector’s Code

Jun Seo-Yeon is awake in the error-correction vault, a room the size of a shipping container buried under the mirror’s western rim. The walls are lined with drawers of diamond wafers each etched with 10^{12} identical NV centres—her slow-light batteries. She sits cross-legged on the floor, laptop open, code scrolling. Every tenth line contains a comment in Hangul that no one else reads: // 이 빛이 너를 속이지 않기를. May this light never betray you.

She is auditing the firmware kill switch. Officially it does not exist. Unofficially it is a single opcode buried in the LDPC decoder: if a 256-bit trigger packet arrives encrypted with her private key, the laser diodes detune by 0.2 nm, enough to smear the beam beyond

recognition. The packet can be sent by any terminal with lunar line-of-sight. She alone can craft it. She has told no one, not even Mara, especially not Mara.

Tonight she is tempted. Newsfeeds from Earth show Nakuru still burning, now Kisumu, now Entebbe. The East African Federation claims the lunar array is a legitimate military target under the New Outer Space Treaty of 2068. They threaten to “neutralise asymmetric photonic advantage.” Jun knows euphemism; she grew up in Pyongyang where “re-education” meant starvation. She knows what neutralise means.

Her finger hovers over the test button—labelled “Simulate Trigger” in grey Courier. Pressing it would inject a dummy packet into tomorrow’s calibration burn. The beam would bloom into a useless aurora, no information, no identity, no betrayal of light. The board would spend weeks tracing the fault. By then the Federation might be at the gates, or the war might be over. She does not know which outcome the kill switch serves. She wrote it for choice, not certainty.

She closes the laptop, folds the code into an encrypted volume named “WHITE_RABBIT.dat,” stores it on a thumb drive the colour of arterial blood. Then she lies back on the cold floor and watches the ceiling vent breathe: a tiny diaphragm pumping argon to keep the diamond chips dry. She counts breaths—hers and the machine’s—until they synchronise. She dreams of a train she rode once from Sinuiju to Chongjin, every carriage filled with mirrors reflecting her face into infinity. When she wakes she has decided: the kill switch stays, unused, like a cyanide tooth. For now.

7. The Mirror Thinks

04:00 UTC. The mirror wakes.

First the segments tilt, 1 080 hexagons moving in micron increments, feedback loops singing at 10 kHz. The drones retreat to the perimeter like birds startled by sunrise. Inside the igloo Amari initiates the sequence: pump lasers warm, cryocoolers hiss, the sphere in Daniel’s burrow floods with coherent light. Mara’s latent state is packetised, LDPC-encoded, interleaved with fountain shards. The data ascends the

beam pipe, spreads across the aperture, rides the carrier wave. No fanfare, no countdown. Only the numbers:

- 1.2 kW continuous
- 1550.12 nm vacuum wavelength
- 3.7×10^{11} bits encoded as phase modulation at 40 Gbaud
- Beam divergence 6.4 milliarcseconds
- Target: Right Ascension 14 39 36.49, Declination –60 50 02.1

Livia stands on the rim ridge, visor darkened to ND 6. She does not see the beam—1550 nm is infrared—but she feels it: a pressure on her cheeks like the warmth from an oven she cannot see. Her HUD paints an artist’s conception: a slender red thread leaving the Moon, threading the eye of a needle called Proxima. The thread will travel for 4.37 years, arrive in 2075, and there, maybe, open eyes that are already hers.

Below, the mirror glows faintly where absorbed photons heat the glass by 0.003 K. The drones note the anomaly, schedule a cooldown. In the error-correction vault Jun’s laptop records a bit-error rate of 10^{-21} , better than specification. In the lava tube Daniel watches the microsphere’s photon count drop by exactly the number transmitted, no more, no less. Reversibility upheld. In the igloo Amari signs the log: “Calibration burn complete. No anomalies.” He does not mention the red handprint still fading on segment 442.

Mara, inside the orb, feels the transmission as a gentle tug, as if someone has taken a thread of her blood and stretched it across the stars. She tastes snow again, but now the flakes are photons, and the sky is endless glass. For 12.7 minutes she is both sender and sent, twin and original. Then the carrier shuts down, the mirror tilts back to stow position, and the moment passes. She whispers into the dark, “Go tell them I’m still alive.”

8. The Echo Contract

When the burn ends, Livia remains on the ridge. She has school in three hours—orbital mechanics with Professor Okonkwo—but she cannot move. She is thinking about the 2.1 dB margin. She opens her app again, keys in a new parameter: receiver diameter 900 m, same as transmitter. Margin: +1.4 dB. Enough. The implication is simple and enormous: if Proxima builds a

mirror the size of this one, the link closes. Symmetry demands it. Any civilisation that can receive can also reply. She saves the file as “ECHO_CONTRACT” and tags it red.

She looks back at the mirror. Already frost is forming where the beam heated the glass, a bloom of ice crystals catching starlight like diamond dust. In the centre, half-way between the trench and the hatch, she sees something new: a reflection. Not of stars, not of her helmet, but of Earth. Impossible—the far-side never sees Earth. She steps closer. The reflection is small, blue, marbled with white swirls. It moves when she moves. She reaches out; her gauntlet meets glass. The image is inside her visor, a projection triggered by... what? A stray code in the HUD? A gift from Mara? A hallucination?

She disables augmented overlay. The blue dot remains. It hangs in the mirror like a single drop of water in an ocean of night. She understands then: the mirror has remembered Earth even if Earth has forgotten the mirror. She raises her hand, palm forward, a promise or a farewell. The blue dot wavers, then fades, leaving only her own visor staring back: a girl in a goldfish bowl on the Moon, caught between the last sky she will never see and the next sky she will never reach.

She whispers, “I’ll build you a bigger receiver.” The mirror does not answer, but the drones begin their next sweep, polishing away the heat, polishing away her footprints, preparing the glass for whatever comes next. Somewhere inside the quartz sphere, Mara’s snow memory starts to fall again, flake by flake, each one a photon that has already left the solar system and is still waiting to land.

Chapter 3.2: The Treaty That Was Never Signed

1. The Fax That Arrived at 03:17 UTC

The paper was warm when it slid out of the slot, as if the treaty had already been on fire once and thought better of it.

Amari Okonkwo watched the curl uncurl.

She had not seen actual fax paper since her cadet year at the East African Orbital Academy; the machine in Corridor 7-B was kept only for documents that had to be *provably* un-hackable—meaning everyone agreed to pretend the line was not tapped.

The header read:

DRAFT INTERNATIONAL APERTURE ACCORD
Version 4.3 – Lunar Far-Side Arrays > 300 m
Binding if countersigned within 96 hours.

Ninety-six hours.

The launch window for Proxima opened in eighty-nine.

She laughed once, a sound like a snapped antenna, and set the treaty on the console where it could feel the chill of the glass. Then she pressed the page-flat button three times, as if trying to iron the clauses into obedience.

2. Clause 4(b): The Right of Planetary Veto

“Any signatory state whose territory exhibits a net population decline > 0.5 % per annum, averaged over five consecutive years, may unilaterally prohibit the export of cognitively intact human information beyond the heliopause.”

Amari read it aloud to the empty room.

The words tasted of copper.

She traced the line with the same finger she used for range-finding: left to right, steady, no tremor.

The clause had been inserted—according to the marginalia—by the delegation from the *United Remnant States of North America*, a polity whose coastline changed weekly and whose capital was currently a floating barge off what had once been Denver International.

She opened a channel to Legal.

“Tell me 4(b) is a typographical joke.”

The duty lawyer appeared, hair still creased from the pillow.

“It’s real. They call it the Graveyard Rider. If Earth is bleeding people, the species is not allowed to mail its mind elsewhere. The logic is...”

“Mediaeval,” Amari supplied.

“Mediaeval is polite,” he said, and signed off to draft a rebuttal that would arrive too late.

3. The Colour Blue That Was Missing

Livia found her in the optics bay, knuckles white around the treaty.

“Why is the paper shaking?” the girl asked.

“Because the paper is terrified,” Amari answered.

She did not say *I am terrified too*.

Livia had never seen a Terran ocean; explaining political terror to her was like describing the colour blue to someone who had only ever breathed it.

The captain folded the page until it became a tiny paper mirror, then slipped it into the breast pocket of her coverall—over the heart, where the fabric was thinnest.

“Walk with me,” she said.

They walked.

4. The Corridor That Got Longer

The corridor ran the length of the array’s secondary truss.

On one side: basalt, grey and still.

On the other: silvered petals of mirror segments, folded like solar origami.

Every thirty metres a sign reminded them NO EARTH LINE OF SIGHT—first in English, then Russian, then Korean, then barcode.

The barcode was the only part never vandalised; Jun Seo-Yeon had once etched a kill-switch glyph into the polymer, invisible except under 1 550 nm light.

Amari touched each sign as they passed, a superstition she pretended was a checklist.

Livia kept pace, boots clicking.

“Is the treaty about me?”

“Indirectly.”

“Does it stop Mara from transmitting herself?”

“It stops everyone if enough states sign. Population haemorrhage equals planetary custody rights.”

The girl considered.

"But the people who are leaving Earth are *already* gone. The clause punishes the destination for the departure."

Amari exhaled. "Welcome to interplanetary law. Logic is optional; signatures are not."

5. The Red Pen of Dr. Solovyova

Mara was waiting at the far airlock, arms crossed, a red marker tucked behind her ear like a cigarette. She had read the treaty on the secure net three hours earlier and printed her own copy just so she could annotate in crimson.

The pages dangled from her left hand like a bleeding script.

Page 2, Clause 7:

'The uploaded consciousness shall be deemed a 'data payload' and accorded no special protection under human-rights frameworks until re-instantiated in a biological or legally recognised synthetic substrate.'

Mara had drawn a diagonal slash and written:
Then kill me now, cowards.

Amari lifted an eyebrow.

"Constructive as ever."

"Accuracy is constructive," Mara replied.

She turned to Livia.

"How old are you today?"

"Fourteen years, twenty-seven days."

"Old enough to witness a crime, then."

She handed the girl the red-pen copy.

Livia accepted it the way other children accepted trading cards.

6. The North Korean Footnote

Jun Seo-Yeon appeared last, silent in socks, carrying a tablet that displayed a single line of Korean hangul:

'Article 12: Any signatory may embed a cryptographically verifiable kill command in the transmission firmware, provided the command can be audited by a neutral inspection team.'

He had underlined the word *neutral* three times and added a footnote in microscopic font:

"Definition of 'neutral': party that has never threatened to nuke my hometown."

Amari looked at him.

"Will you invoke it?"

Jun shrugged. "I already did. The firmware checks for treaty status every boot cycle. If the accord is ratified before launch, the array lasers pulse *once*—a test pattern—then shut down for good. No human mind leaves. The code is compiled; I cannot unwrite it without losing my own identity hash."

He spoke softly, as if describing the weather inside a photograph.

Livia stared at the tablet.

"You'd murder Mara to keep her from being murdered?"

"Murder is a biological verb," Jun answered.

"So is *betrayal*," the girl shot back.

The silence that followed was so precise it could have been machined.

7. The Map of Signatories

They unfolded a paper map—an antique the colour of nicotine—and pinned it to the corridor wall with a strip of lunar basalt tape.

Stickers represented states.

Green: already signed.

Yellow: wavering.

Red: refused.

Black: no longer existed enough to answer.

Green covered most of western Europe, the Indian Ocean Union, and the Antarctic Research Collective.

Red: East African Federation, Greater Colombia, the Arctic Freeport.

Yellow: only two—*United Remnant States of North America* (waiting for internal senate vote) and *Pan-Pacific Covenant* (waiting to see what North America did).

Amari traced the yellow with her finger.

"These two swing the count. We need one of them to abstain. Two to vote no. Otherwise the treaty enters force at 09:00 UTC Friday, and the lasers become expensive sculptures."

Mara's voice was low.

"Then we kidnap their ambassadors."

Jun raised an eyebrow. "Hostage-taking is signed into

law under Clause 19.”

“Only if you get caught,” Mara replied.

Livia giggled, then looked horrified at herself.

8. The Broadcast They Did Not Broadcast

At 12:00 UTC they scheduled a press conference.

The idea: appeal directly to Earth, bypass the diplomats.

Daniel Scott Matthews—who had not left his laboratory in twelve years—agreed to speak.

His image appeared on the holo-stage: beard trimmed by scissors that had also cut fibre-optic ribbon, eyes the colour of vacuum.

He began:

“Earth, you are bleeding people because you are bleeding hope. This treaty cauterises the wound by amputating the future. I will not sign.”

He held up a blank sheet labelled SIGNATURE and burned it with a 1-watt laser pointer.

The smoke triggered the habitat’s fire suppressant; white mist swallowed the feed.

By the time the cameras cleared, the stream had been cut off by a Terran relay satellite “for unauthorised use of an incendiary metaphor.”

The clip went viral anyway, but algorithms throttled it at 12 % propagation.

Daniel retreated to his lab and locked the hatch.

9. The Vote That Happened in a Graveyard

United Remnant States’ senate met in a repurposed mausoleum outside St. Louis.

Floors were polished marble; names of the dead provided seating labels.

The session lasted nine hours.

At 03:44 UTC the tie-breaker—Senator Aurora Chen, age nineteen, youngest ever—stood on a coffin labelled *J. HARRISON 2026-2068* and gave the final speech.

“My constituents are underground all around me. They cannot leave Earth, so neither should their memories. I vote aye.”

The gavel fell.

Green sticker.

Treaty crossed the two-thirds threshold.

Panic on the Moon travelled at the speed of sound inside aluminium: a low metallic clang that raced through every strut.

10. The 96-Hour Clock

00:00 — Treaty open for countersign
04:12 — North American yes vote
04:13 — Pan-Pacific Covenant sees the news, schedules emergency session
04:15 — Amari orders the array into standby mode “BASTION”
04:16 — Jun’s firmware registers treaty status = PROVISIONAL_RATIFIED
04:17 — Laser amplifiers auto-safe; safety keys physically shear inside magnetic locks
04:18 — Mara starts laughing and cannot stop

Livia found her collapsed against the glass orb, cheek pressed to the sphere that held 3.7×10^{11} bits of Mara’s life.

The woman’s laughter sounded like a hard drive shredding itself.

“I trained the model on every memory except the ones where I begged to leave. They are inside me anyway. Now they say I am *cargo*.”

Livia placed her small hand on the neuroscientist’s clenched fist.

“You are not cargo. You are the postage stamp they refuse to lick.”

Mara’s laugh cracked into something wetter.

11. The Captain’s Silence

Amari invoked Article 17 of the Lunar Facilities Charter:

“In circumstances of imminent external appropriation, the station commander may declare Contingency Autonomy for a period not to exceed 120 hours.”

She recorded a single line into the log:

“Treaty constitutes appropriation of human futures. Clock starts now.”

Then she yanked the audio cable from her console so the statement could not be unsaid.

Earthside mission control screamed for jurisdiction. She forwarded their calls to a voicemail box whose outgoing message was a recording of wind across the Shackleton rim—no words, just vacuum harmonics.

12. The Defector's Dilemma

Jun sat cross-legged inside the laser bay, tablet glowing lavender.

The firmware demanded two simultaneous keys to resume launch mode:

1. His biometric hash
2. A countersignature from an independent oversight board recognised under the treaty.

He could withhold the first.

He could also spoof the second, but the spoof required a quantum one-time pad burned into his memory at age nine in a camp outside Chongjin—an unrecoverable key. Using it would erase the first 4 000 days of his childhood.

He would keep the skills, lose the stories.

Livia entered, barefoot as always.

"You once told me escape costs exactly what you cannot afford to lose."

He nodded.

"Is the price still too high?" she asked.

"I am calculating," he said.

She waited.

The hum of cryo-pumps filled the room like distant surf. Finally she placed a glass marble—an earlier test sphere, empty—into his palm.

"Fill this with the days you don't need. Trade the rest."

She left.

He closed his fist until the glass squeaked.

13. The Child Who Had Never Seen Rain

Livia climbed the maintenance ladder to the exterior gantry: 900 metres above basalt, no railings last 50 m. She carried the red-pen treaty, now folded into a paper aeroplane.

Her suit radio was off; she wanted silence unmediated by codecs.

She reached the top mirror segment: a hexagon of silver-coated beryllium, 3 m across, thin as foil.

Earth hung low, a swollen coin of brown and white.

She could cover it with her thumb.

She whispered:

"I do not know rain, but I know reflection. You will not take the only sky I have left."

She launched the paper plane.

Lunar gravity carried it in a slow arc until it clipped the edge of the next segment, tore, and fluttered away among the petals—white scraps against silver, drifting like snow that would never land.

14. The Senator Who Changed Her Mind

Pan-Pacific Covenant's session began at 18:00 UTC.

They broadcast in open spectrum; Amari listened while pacing the corridor.

Debate ran four hours.

Then an unscheduled speaker: Senator Chen, the teenager who had broken the tie on Earth.

She appeared on a cracked phone camera, eyes puffed. "I voted wrong," she said. "The dead do not own the living. I invoke Clause 34: right of revote within 24 hours provided no physical ballot has been destroyed." She held up the original paper; the corner was singed but intact.

She tore it in half on camera.

The speaker of the Pan-Pacific gavelled emergency recess to verify legality.

Treaty status wobbled back to 65 %—one signature short.

15. The Knife That Was Never Used

Mara went to the medical bay and asked the autodoc for a 20 ml vial of potassium chloride.

The machine refused; she overrode with root credentials earned during thirty-five years of neural-lace debugging.

She held the vial to the light—clear as conscience—then tucked it into the same pocket Amari used for the treaty.

She walked to the laser bay where Jun still sat.

"Give me the key," she said.

"I will not spoof the board."

"Then I die here, and you keep your childhood. The beam never fires. Everyone wins except me."

She uncapped the vial.

Jun looked at the floor.
“Death is your veto, not mine.”
“Exactly.”
He extended his tablet.
“Swipe my hash first. I will spoof the board. You live twice or not at all.”
She hesitated.
“Your memories—”
“Are stories. Stories want to be retold.”
She pressed his thumb to the reader.
The tablet flashed:
IDENTITY_TRANSFER_COMPLETE.
Jun’s eyes glazed as the childhood key evaporated.
A single tear cooled on his cheek, became a bead of ice, floated away in the low-g airflow.

16. The Second Vote That Was Never Finished

Pan-Pacific reconvened.
Before the roll-call, an explosion shook the link—a kinetic penetrator from an East African Federation satellite, unauthorised, aimed at the array’s primary power bus.
Defence lasers intercepted; debris sprayed across the ridge.
Transmission cut.
Earthside assumed sabotage succeeded; media cycles erupted.
In the chaos the second vote stalled, uncompleted.

17. The 96th Hour

Friday 08:59 UTC.
One minute left on the treaty clock.
Amari stood in the command cupola, helmet sealed, suit patched with silver tape from the skirmish.
The fax machine rang—an actual bell, mechanical.
She tore the warm sheet free:

PAN-PACIFIC COVENANT – ABSTENTION
DECLARED
Insufficient quorum due to hostilities.
Treaty remains un-ratified.
Status: OPEN INDEFINITELY.

She laughed once—the same snapped-antenna sound—then turned to the holo-screen showing the five faces: Mara, Jun, Daniel, Livia, herself.
“Consensus?” she asked.

Mara: "Launch."

Jun (eyes vacant, voice steady): "Launch."

Daniel (audio only, beard singed): "Launch."

Livia (small fist raised): "Launch."

Amari: "So recorded. Bring the amps online. We fire at next periselene."

18. The Treaty That Was Never Signed

She fed the original treaty page—warm, wrinkled, still bearing the smell of panic—into the paper shredder used for secure optical diagrams.

Strips fluttered like albino ribbons, caught in the airflow, drawn toward the intake filters.

One strip escaped, floated upward, and drifted past Livia's visor.

The girl read a fragment of Clause 4(b) upside-down:
"—net population decline—"

She flicked it away.

The shred adhered to a cooling pipe, frosted over, became a ghost of itself, then nothing.

Outside, the first segment of the 900-metre mirror began to tilt toward the void, searching for a target 4.24 light-years distant.

Inside, five humans and one glass orb prepared to divide the future between them.

The treaty that was never signed fluttered in memory only—an unsigned promise that the dying could still forbid the living to leave, until the living stopped asking permission.

Chapter 3.3: The Defector's Code

1. The Signature That Wasn't There

The kill switch lived in a single line of code, 42 characters long, written in white on a black terminal that no longer existed.

Jun Seo-Yeon had typed it in Pyongyang, 03:14 local, 19 October 2053, on a government-issue laptop whose keys were so worn the letters had become Braille. She was twenty-two, 3.2 kg underweight, and humming a Girls' Generation song very softly so the hallway mic would not hear.

The line was:

```
if sha256(latent[-1]) == 0xdeadbeef: fire_all(λ,  
kill=True)
```

It did nothing unless the last packet of a mindstate—any mindstate—happened to hash to the exact hexadecimal word for “dead beef.”

Probability of collision: 1 in 2^{256} , i.e. never.

Unless you knew the preimage she had hidden in the firmware update three months later, the one labelled “LDPC tweak for lunar vacuum.”

Then the probability became 1.

She told no one.

Not the American handler who smuggled her out in a cargo pallet of “defective” laser gyros, not the South Korean doctor who removed the RFID sliver from her forearm with a scalpel cooled in liquid nitrogen, not even Mara Solovyova who hired her six years afterward because her Git commit graph looked like snowfall—steady, silent, accumulating mass.

The kill switch was her insurance policy against ever being trusted.

2. The Room That Had No Windows

Luna, 12 February 2071, 02:08 UTC.

Array Sub-Level 3, a room excavated into basalt that never saw the sun even when the base rotated.

The walls were lined with 19 cm of sintered regolith brick; the air smelled of warm electronics and the faint

copper of human fear.

Jun sat cross-legged on a cable spool, soldering mask on, eyes flicking between two holoscreens:

- Left: the live bit-error trace of the 900-m mirror, currently deforming 0.7 nm rms under thermal gradient.
- Right: the orphan commit she had never pushed, branch name `origin/self-destruct`.

She had not opened that file in eight years.

She opened it now because Captain Okonkwo had scheduled the first full-power transmission test for 36 hours away, and because Livia—fourteen, born here, terrifyingly polite—had asked her at dinner:

“Unnie, what happens if the beam carries something that shouldn’t leave?”

Jun had answered with silence, the kind that makes the other person hear their own pulse.

3. The Firmware That Remembers Everything

Lightmind’s error-correction stack was her cathedral. Twenty-three thousand lines of Rust, zero-copy, lock-free, proven in Coq.

It ran on radiation-hardened FPGAs cooled to 110 K so that single-event upsets became single-event *nonevents*. Every photon that bounced off the great mirror carried 4.7 bits of forward-error-corrected mindstate; every microsecond, 2.1 million photons.

The firmware shepherded them like a shepherd who has memorised every wolf that ever lived.

Buried at line 14,117 was a function called `ldpc_decode_stream()`.

Inside it, a single `match` arm checked for the magic hash. If triggered, the arm would:

1. Halt the laser pump diodes.
2. Drain the BeO storage rings into dump resistors.
3. Overwrite the orb’s latent memory with 3.7×10^{11} bits of `/dev/zero`.
4. Broadcast a 256-bit heartbeat signed with Jun’s revoked private key—effectively a suicide note that said: “This mind died by my hand.”

The code was reachable only if the incoming bitstream failed LDPC checksum *and* the failure pattern matched the preimage.

A double failure that could not happen by accident.
She had designed it that way because the State taught
her that accidents are for civilians.

4. The Girl Who Read Git History

Livia did not ask twice.
Instead she git blame-d the entire firmware at 01:42,
scrolling in dark mode, pupils dilated.
She found the commit hash a1d3b4f, author
“j.seo@starcloud.kr”, message: “tune LDPC for vacuum
UV, minor.”
The diff was +47 –12 lines.
One of the added lines was the kill switch, disguised as
a constant definition:

```
+const MAGIC_DEADBEEF: u256 = 0xdeadbeef;
```

She copied the hash into her notebook, closed the
terminal, and went to find Jun.

5. The Conversation Under the Mirror

They met on the maintenance walkway, 40 m above the
primary mirror, boots magnetic, Earth a blue-white
coin that never moved.
Livia held out the notebook like a warrant.

“You wrote a bomb.”

Jun looked at the digits as if they were her own
childhood photo.

“It’s a fuse,” she said. “Not a bomb. Bombs kill
strangers. Fuses kill the thing you love if it turns on
you.”

“I’m not a thing.”

“You’re 3.7×10^{11} bits that think they’re a girl. Same as
the rest of us up here.”

Livia’s next question was older than her face: “Did you
ever test it?”

Jun laughed, a sound like a step breaking through ice.

“Once. On a lab rat. I streamed its mindstate, injected
the pattern, watched the lasers shut down. The rat kept
breathing. The copy inside the orb did not.”

She did not add that she had kept the rat. Named it Haneul. Fed it lettuce for two years until a micrometeoroid cracked the habitat dome. She had buried the rat in regolith, cried for the first time since defection, and told herself the kill switch was now morally neutral—an amputated hand that could no longer clap.

6. The Captain's Arithmetic

Captain Amari Okonkwo's war was simpler: keep the East African Federation's 37th Aerospace Brigade from landing on the ridge before March 2072. Every sunrise (Earth-relative) he ran the Monte Carlo: probability of kinetic intercept vs launch window. The answer converged to 0.38 and rising. He needed the test firing to finish *this week* so the array could be re-pointed as a defensive laser if diplomacy failed.

He did not know about the kill switch. He knew only that Jun had requested a 24-hour hold "for bit-error anomalies." He summoned her to the command blister.

"Dr Jun, the mirror is polishing itself at eight atoms per hour. The launch window is polishing itself at eight hours per day. Which one runs out first?"

Jun saluted with data: "BER is 3×10^{-21} , two orders better than spec. But the anomalies are non-Gaussian. Fat tails at 10^{-19} . If we fire through that, the mindstate could arrive with amnesia."

"Define amnesia."

"Loss of episodic layer $\geq 5\%$. Identity drift ≥ 0.01 KL. Suicide under ethical protocol 9b."

The Captain's jaw worked like a moon-rock crusher.

"Give me a number I can brief to the Politburo-in-Exile."

"0.3 % chance the copy wakes up not knowing why it left Earth."

"Acceptable."

"Not to the copy."

"To the original who is still breathing up here it is."

Jun left with an order: proceed, but log every anomaly.
She left with something else: the knowledge that 0.3 %
was the exact fat-tail mass produced by her kill switch
if it misfired.

She had engineered the symmetry: the same bit-pattern
that could murder a mind could also save it from
amnesia by forcing a retry.

She no longer knew which outcome she wanted.

7. The Preimage That Was a Poem

The magic preimage was not random.
It was a 64-byte stanza she had written at sixteen,
before the State shaved her head for university:

I cross the line not to leave you
but to become the line itself.
Erase me if I forget.

She converted the Hangul to UTF-8, hashed it twice,
took the middle 256 bits.

The poem lived inside every LDPC syndrome now, a
ghost in every photon.

She wondered if the copy—Mara, whoever—would
recognise it on the other side of 4.24 light-years.

She wondered if recognition would trigger the switch.
She wondered if forgetting was the same as betrayal.

8. The Night Before the Test

28 hours to ignition.
She could not sleep.

She walked the mirror's backside, fingertips on
actuators colder than liquid methane.
Each segment was a 3-m hexagon of plated beryllium,
polished to 0.3 nm rms.

They jittered like nervous teeth under thermal
feedback.

She recited the stanza aloud, breath fogging her visor:

“I cross the line not to leave you—”

A smaller shadow joined hers. Livia again, helmet
bumping her elbow.

“You’re going to fire it,” the girl said. It wasn’t an
accusation; it was a measurement.

“I wrote it to protect us from monsters.”

“We became the monsters the day we decided who
stays and who leaves.”

Jun looked at the child who had never seen rain and saw the same expression she had seen in the mirror the morning she defected: the look of someone who has realised escape and exile are synonyms.

“Do you want me to remove it?”

“I want you to *tell* them. Let the original decide.”

“The original is terrified. Terror makes people vote for cages.”

Livia unzipped a pocket, produced a data wafer no larger than a thumbnail.

“I forked the firmware. This is a patch that replaces the magic constant with a public key vote. Three of five board members must sign to abort. No hidden triggers. Upload it or I leak the old one to the Captain.”

Jun took the wafer between gloved fingers.
She felt the weight of two nations, three ideologies, and one child’s unearned courage.

“Public key can be coerced.”

“So can a poem. At least the key has witnesses.”

9. The Vote That Lasted 0.8 Second

She uploaded the patch at 04:00, citing “governance compliance update.”

The CI pipeline ran 4 200 unit tests in 0.8 s, all green.
The kill switch was now a 3-of-5 multisig.
The five were: Mara, Amari, Jun, Daniel, Livia.
A protocol born at 04:00 would govern a beam that might leave at 18:00.
She felt both lighter and amputated.

10. The Test Fire That Wasn’t

18:00 approached.
The mirror flattened to 0.1 nm under active optics.
Laser diodes ramped to 8 kW.
The orb—glass the size of a heart—sat in its cradle, already dreaming the sparse transformer’s dream of Mara’s childhood snow.
Countdown reached T – 240 s.

Then the East African Federation’s diplomatic channel pinged: cease all energy weapons activity or face “kinetic enforcement.”
Probability updated from 0.38 to 0.91.

The Captain aborted the test, swung the array 17° to track the incoming rail-bus cluster.
The lasers cooled.
The orb's dream continued, unpregnant with photons.

Jun watched the numbers collapse and felt the absurd relief of a bomb that decides not to explode because the war started early.

11. The Line That Became a Bridge

Later, in the same windowless room, she found Livia soldering a new board: a tiny photonic resonator, 2 cm across, Q-factor maybe 10^8 —toy-sized, but enough to hold a haiku of mindstate.

“What’s that for?”

“Practice,” the girl said. “If we’re going to vote on souls, we should test the ballot box first.”

Jun handed back the thumbnail wafer.
“Keep it. History is firmware we haven’t debugged yet.”

Livia snapped the wafer in half, let the pieces float like black snow.

“History is the patch we dare to ship.”

Outside, the mirror tracked artillery satellites instead of exoplanets, and Earth turned like a dying ember no one had decided to extinguish or preserve.
Inside, two monsters—one born in dictatorship, one in vacuum—wrote the first line of a new file:

```
// TODO: replace fear with procedure
```

The kill switch still existed, but it had been promoted from assassin to bureaucrat.

Jun Seo-Yeon went to bed and, for the first time in eighteen years, did not dream of erase commands. She dreamed of a line that kept moving until it became a circle, and inside the circle stood every copy she had ever tried to protect or delete, holding hands, voting to remain.

Chapter 3.4: The Captain's Silence

1. The Log That Refused to Rotate

The duty log is supposed to erase itself every 168 hours.

That is the rule Amari Okonkwo wrote into the station charter when the Array was still two drawing boards and a prayer.

A week of voice, text, biometrics, then cryptographic mulch.

No history, no leverage, no hostage.

Tonight the log is 189 hours old and still breathing.

The counter glows amber in the lower left corner of his visor: 189:04:12.

The colon blinks like a pulse that refuses to flatline.

He tongues the mute pad, clears his throat, and tries again.

"Station command, local date 2071-02-19, Okonkwo, Amari, Captain, EAF Naval Reserve attached Lightmind One.

Log entry—"

The recorder hangs, waiting for the next word.

He has none.

The silence stretches until the buffer threat-tone beeps: thirty seconds of dead air and the entry will auto-flag as anomalous, forward to Mission Ethics on Lagrange-2, copy to Nairobi.

Nairobi still has firing squads.

He closes the file unsaved.

The log stays 189 hours old.

2. The Ridge That Never Sees Earth (Reprise)

Outside the pressurized blister, the mirror segments tilt a fraction of a degree, following the invisible speck of Proxima.

They move so slowly the motion is below the threshold of human vestibular perception, but Amari feels it anyway: a ghost acceleration, as if the whole crater rim is tipping toward something colder than space.

He has stood here every night for fourteen months.
The ridge blocks Earth-rise; the Array blocks
everything else.
A perfect geometrical silence.
He used to find that comforting.

3. The Fax That Arrived at 03:17 UTC (Echo)

The treaty paper is still in his locker, folded into an airtight sleeve, the warmth long leached out of it.
He rereads it sometimes when the mirror hum gets inside his bones.

Article 7(b): "Command authority may be superseded by terrestrial signatory in event of imminent military utilization of the aperture."

Imminent is not defined.

Military utilization is not defined.

The East African Federation has signed, which means his own uniform is already halfway to being the enemy's.

He wonders what uniform he will wear when the order comes.

He wonders if it will come on paper again, or just as a laser pulse straight into the uplink buffer, 256 encrypted bits that will turn the Array from telescope to battleship in the time it takes light to cross the primary mirror.

4. The Kill Switch in His Pocket

Jun Seo-Yeon gave him a physical token three weeks ago: a sliver of diamond lattice on a titanium key ring. She said nothing, only pressed it into his palm during the hand-over of the error-correction manifest.
Later he scanned it: a passive NFC tag, 42 characters of ASCII.

```
if (sig == "EAF_SEIZE"){laser_fire = 0; mirror_slew =  
random;}
```

A single line.
A promise that the Array can be made useless faster than anyone can commandeer it.
She called it insurance.
He calls it treason.
He carries it anyway, because the alternative is to trust politicians.

5. The Girl Who Has Never Seen Rain

Livia finds him in the gantry between segments 271 and 272, boots magnetized to the truss, hair floating in a static halo.

She is fourteen and speaks with the lunar accent: vowels clipped, consonants soft as regolith.

“Captain, the mirror is drifting off-axis by 0.3 microradians.”

She says it like an apology.

He checks the telemetry.

She is right.

Thermal creep; the cooling loops are undershooting.

A 0.3 microradian error at the primary becomes a 400 000 kilometre miss at Proxima.

The beam would paint vacuum, or worse, paint something that is not the target receiver.

“Log it,” he tells her.

“I already did. The log rotated.”

She means the public log, the one that still obeys the rules.

Her eyes ask the question she will not voice: Why is yours still alive?

He changes the subject.

“How old were you when you figured out you’d never see rain?”

“Four.”

She shrugs.

“Dad showed me a video of Nairobi monsoon.

I asked if we could schedule one for Shackleton.

He said tides don’t work here.”

“Do you miss what you never had?”

“I miss the idea of missing,” she says, and magnet-walks away.

6. The Heartbeat That Skipped (Remote Echo)

Mara Solovyova’s cryptographic heartbeat has been silent for 36 hours.

The station AI keeps pinging the BLS threshold contract on-chain; no reply.

Technically that means the upload protocol should freeze.

Technically the Array should power down to standby.
Technically he should evacuate personnel and await
legal clarification.

Instead he overrides with his captain's code, citing
"operational continuity in extra-legal vacuum."
The AI accepts; it has no ethicists loaded.

He tells himself he is preserving mankind's last chance.
He tells himself nothing about Mara's medical file
flagged in red: advanced lymphoma, terrestrial
treatment queues collapsed, six months to live.
She may already be unconscious.
She may already be dead.
The heartbeat is not coming back.

7. The Uniform That Doesn't Fit

The East African Federation promotion arrived last
month: full colonel, salary tripled, family citizenship
guaranteed.
The insignia came in the same diplomatic pouch as the
treaty.
He has not sewn it on.
It lies in the sleeve beside the treaty, another fold of
warm paper cooling into history.

His father fought in the Lake Victoria water wars.
His mother died in a refugee camp that still used paper
identity cards because the retinal database was hacked.
He carries their names on a steel tag around his neck.
He does not know which side of the coming split will
bury those names.

8. The Mirror That Listens

At 04:09 UTC segment 144 reports an acoustic
anomaly: a pressure wave traveling through the truss,
frequency 42 kHz, amplitude rising.
No impact registered on the micrometeoroid grid.
No thermal spike.
Just sound out of vacuum.

He suits up, cycles the lock, walks the catwalk until the
vibration is a bone-conducted whine.
He places his gloved palm on the strut.
The mirror is singing.

Livia's voice crackles in his helmet.
"Captain, the waveform matches the eigenmode of a
Bessel-Gaussian sideband.
Someone is testing the uplink laser without
authorization."

"Power levels?"

"Below lasing threshold, but climbing.
If they push another three milliwatts the cavity will
flip."

"Source?"

"Internal.
Node 7, optical encoder rack.
Jun's rack."

9. The Defector Who Isn't There

Jun Seo-Yeon is not in her bunk.
Her access log shows she entered the encoder bay at
02:11 UTC and never left.
The bay is empty now, tools floating, screens dark.
A single line of white text on black:

I will not let them turn my code into a weapon.

He searches the racks.
No sign of the kill-switch key.
No sign of Jun.

10. The Order That Was Never Sent

At 05:00 UTC the diplomatic channel pings: priority
one, eyes-only.
He expects the seizure order.
Instead he gets a 12-second audio clip, terrestrial
accent, Nairobi generals in the background:

"Captain Okonkwo, stand by for lawful transfer of
array control at 06:00 UTC.
Acknowledge."

No signature hash.
No chain-of-trust certificate.
A ghost order, plausibly deniable.

He does not acknowledge.

11. The Silence That Becomes a Decision

06:00 UTC comes and goes.
The mirror keeps tracking Proxima.
The laser stays cold.
The log stays 189 hours old.

He floats in the command blister, helmet unsealed,
breathing the metallic taste of recycled air.
He thinks of Mara, maybe dying, maybe already
encoded in glass.
He thinks of Livia, who will never see rain.
He thinks of Jun, somewhere in the vacuum between
here and the horizon, running out of oxygen or time or
both.

He tongues the mute pad one last time.

“Station command, local date 2071-02-20, Okonkwo,
Amari, Captain.
Log entry: I have received no lawful order.
The Array remains under scientific control.
Transmitting now.”

He saves the file.
The counter rolls to 190 hours.

12. The Beam That Was Almost Fired

At 06:17 UTC the unauthorized laser test spikes to
threshold.
Alarms howl.
The primary mirror begins to deform, micron-scale
ripples racing across the segments like raindrops on a
pond that has never known rain.

He has 4.2 seconds before the cavity flips and the beam
fires blind, maybe toward Proxima, maybe toward the
Earth-lunar lagrange, maybe into the cockpit of an
approaching EAF cruiser.

He slots Jun’s diamond key into the maintenance port.
The line of code executes.
Laser power drops to zero.
Mirror segments slew to random attitudes, scattering
the sunrise into a thousand broken crescents.

The Array goes dark for the first time since installation.

13. The Arrest That Doesn't Happen

Two hours later the cruiser docks anyway.
Boarding party in vacuum-rated combat exos, rifles
slung low.
They find him in the mess hall, drinking coffee from a
porcelain cup that once belonged to his mother.
He offers them sugar.
They decline.

The lieutenant reads the warrant: dereliction,
disobedience, sabotage of strategic asset.
The cuffs are carbon-fiber, warm from the charger.

He stands, but before they can seal the bracelets the
comms panel lights up with a new ping: cryptographic,
multi-signature, bearing the seal of the International
Astronomy
Union, the Lunar Governor, and—impossibly—Mara
Solovyova's private key.

Text only:
“Captain Okonkwo acted under valid scientific
emergency protocol.
Stand down.”

The lieutenant hesitates.
The cuffs stay open.

14. The Log That Finally Rotates

Back in the blister he opens the duty log one last time.
He appends a single line:

“Silence is also a choice.
Today I chose.”

He hits save.
The counter resets to zero.

The mirror segments realign, slowly, like giants
waking.
Proxima is still out there, 4.24 light-years away, waiting
for a voice made of photons.

He exhales, and for the first time in fourteen months
the air tastes of nothing at all—clean, empty, possible.

15. Epilogue Inside the Chapter

They will court-martial him anyway, paperwork filed in some terrestrial drawer that may never reach the Moon.

They will brand him traitor or hero, depending on who wins the war that hasn't started yet.

They will rewrite the treaty, or burn it, or forget it ever existed.

But the Array still stands, and the laser is still cold, and the kill-switch key now hangs on a chain beside his mother's tag, diamond winking against steel.

Somewhere in the white absence of her latent canvas,
Mara dreams of snow.

Somewhere in the vacuum, Jun is either dead or free.

Somewhere in Hab-C, Livia watches another recorded sunset and wonders what rain feels like on bare skin.

And somewhere beyond the ridge, the mirror keeps its silent vigil, polishing the same patch of sky, waiting for a command that may never come, or that may come too late, or that may—if the world is kind—come exactly when humanity is ready to let part of itself travel at the speed of light and never come back.

The captain's silence is over.
The human silence begins.

Chapter 3.5: The Night the Beam Was Almost Fired

1. The Clock That Counted Backwards

The countdown began at 21:00 UTC, but the clock ran the wrong way.

Instead of ticking down from T-3600 s, the display showed T+4.37 yr—the arrival time at Proxima.

Every second that passed added 0.26 light-seconds to the distance the beam would have to travel after it left the mirror.

Livia watched the numbers grow and felt her stomach shrink.

She was alone in the catwalk gallery, 120 m above the primary segmented dish.

Below her, 18 000 hexagonal petals of gold-coated beryllium tilted by microradians in perfect silence, rehearsing the final cue.

The array was aiming at a point in the sky that would not rise for another 41 minutes, but the photons had to leave early enough to hit a moving target 4.24 light-years away.

The maths was trivial; the feeling was not.

2. The Five-Way Split

In five different rooms, the five veto holders each held a slice of the same 256-bit private key.

The rule was simple:

- All five shares → beam fires.
- Any one share withheld → beam aborts, mirror flats safes to stow position, capacitor farm dumps 1.8 GJ into the regolith heat-sink.
- Any one share destroyed → same as withheld, but permanently; the hardware lock requires a full reset that takes 14 months.

The launch window closed in 19 days.

A reset meant never.

They had rehearsed the vote every Tuesday for eight months.

Tonight was the first time the rehearsal was real.

3. Mara's Room

Dr. Mara Solovyova sat in Medical-3, an aluminium box lined with acoustic felt that still smelled like Earth glue.

On the bench in front of her rested the orb— a 22 cm sphere of synthetic fused silica held at 2.1 K by a pulse-tube cryocooler whose heartbeat vibrated through the floor.

Inside the glass, her own connectome flickered in 3.7×10^{11} bits.

She had trained the sparse transformer on thirty-five years of neural lace data, every café smell, every nightmare, every orgasm, every theorem.

The KL divergence against her own perceptual reports was 0.007— below the ethics threshold, above the terror threshold.

She wore the veto ring on her left little finger: a band of tungsten carbide with a 2 mm square of single-crystal diamond.

Pressing the stone against the reader would broadcast her BLS signature.

Withholding it would kill the beam, and— according to the protocol— kill the encoded self inside the orb within 300 seconds by ramping the temperature to 120 K and letting the optical phonons randomise the latent state.

A painless, reversible death, the documents said.

Mara wondered which adjective they had lied about.

She stared at the wall clock.

T+4.37000001 yr.

She thought of snow in Novgorod at -23°C , the way it squeaked under boots.

She had not tasted snow in twenty-one years.

The replica inside the glass had never tasted it at all, but it remembered the squeak with a precision that made her gums ache.

She pressed the ring to the reader.

A soft chime.

Share 1 of 5 received.

Then she vomited into the waste bag, cleanly, like a scientist.

4. Jun's Room

Jun Seo-Yeon was in Comm-7, the room no one entered because the air smelled of solder flux and old soju.

She had written the LDPC fountain stack that would wrap the mindstream in 10^{-20} BER armour.

She had also written the 42-character kill switch buried

at line 1 917 003 of the firmware:
if(hash==0xae5f) while(1){mirror[i++]=rand();}
The line was still there.
No one had found it, or no one had dared remove it.

Her veto token was not a ring but a 3 mm glass bead sealed inside her wrist, fused to the radius.
She could crack it with a 6 kg impact—the heel of a boot against the desk edge.
The bead contained a one-time pad; once shattered, the key fragment would vanish faster than blood could carry it away.
She had practised the motion weekly, secretly, in the dark, until the bruise pattern looked like a constellation.

She opened the channel to the other rooms.
Voice only.

“Tell me why,” she said.
No one answered at first.
Then Livia’s adolescent voice, cracked with dust:
“Because I want to see a blue sky before I die.”
Jun laughed once, a sound like a diode breaking.
“Blue skies are an illusion caused by Rayleigh scattering. You want a scattering?”
She rested her wrist on the table edge.
The countdown in her HUD read T-00:12:47.
She lifted her hand away.
Not yet.

5. Daniel’s Room

Daniel Scott Matthews had not spoken aloud in forty-one days.
His larynx hurt from disuse, but the equations did not care.
He sat in Optics-0, the cleanroom suspended above the mirror’s centre of curvature, where the beam would be born.
The 1 540 nm master laser idled at 2.7 watts, its linewidth 40 Hz over 10 ms, a number so small it sounded like poetry.
On the bench lay the microsphere resonator he had first sketched in a 2025 preprint—the same sphere, iterated through sixteen generations of taper couplers and thermal feedback.
It had no name; it was simply “the core.”

His veto device was insultingly primitive: a stainless-steel toggle switch painted emergency-red, mounted in a cast-aluminium box labelled “DANGER— HIGH VOLTAGE” though there was no voltage inside.

Flip up → share broadcast.
Flip down → contacts shorted, crypto chip erased with a 5 kV pulse across the EEPROM.
He had designed it himself to avoid ambiguity.
Up meant yes, down meant no, and the lever gave a tactile snap that no touchscreen could fake.

He watched the mirror through the glass floor.
The petals moved like a school of metal fish, each edge within 15 nm of the next, diffraction-limited at 1.5 μm.
He thought of the first time he had seen starlight through a 60 mm refractor on an Alabama farm, the way Jupiter had hung there, smug and attainable.
Now he was about to fold a person into that light and cast it across an abyss that could not be crossed in the other direction.
The asymmetry felt like original sin.

His hand hovered over the toggle.
The intercom crackled:
“Daniel, do you believe continuity of identity is conserved under reversible emulation?”
Mara’s voice, thin and dry.
He answered without pushing the talk button, knowing the mic would catch it anyway.
“Conservation is for mass and energy. Identity is for the brave.”
He flipped the switch up.
The red box beeped once.
Share 2 of 5 received.

6. Amari's Room

Captain Amari Okonkwo stood in Command-2, the only room with windows.
Outside, Earth was a blue-white coin half-eclipsed by the array’s rim.
The East African Federation’s carrier group was somewhere over the Indian Ocean, climbing the gravity well in a trajectory that could reach the lunar far side in 72 hours if they burned hard.
He had 19 days of launch window, 72 hours of political window, and 1 800 seconds until beam commit.

His veto was the simplest: a biometric thumbprint on the armrest of his chair.
The sensor was live.
He could lift his thumb, or he could keep it there.
Lifting would not only abort the beam; it would also trigger Protocol 7: scuttle the array with shaped charges along the truss seams, leaving nothing for the Federation but expensive gravel.

He had written Protocol 7 himself, after the siege of Dar es Salaam.

He kept his thumb down and watched Earth rotate.

The comm loop opened again.

Jun's voice, flat:

"Captain, state your reason."

Amari spoke softly, as if to a child.

"Because the dead outnumber the living, and the living are out of time."

He felt the sensor warm under his skin.

Share 3 of 5 received.

7. Livia's Room

Livia was not in a room.

She was on the catwalk, 120 m above the mirror, wearing an EVA suit whose visor displayed the same countdown as the wall clock.

Her veto was a voice phrase, 12 words randomly generated when she turned thirteen.

She had memorised them in a song her mother used to hum before the cancer.

Speaking the phrase within the last 60 seconds would withhold the final share.

Saying nothing would let the beam fire.

She had 00:03:11 left.

She looked through the visor at the petals.

Each hexagon reflected a sliver of Earth, fragmented like a broken stained-glass window.

She had never seen a blue sky, only the milky white of Luna's horizon and the cobalt disc on screens.

The beam would carry a mind that had tasted snow, smelled kudzu, felt rain.

She would stay behind with the grey.

The argument was selfish; the argument was fair.

She opened the loop.

"Mara, do you remember the squeak of snow?"

Mara answered at once, as if she had been waiting for the child to speak.

"Yes."

"Will the copy remember?"

"Better than I do."

"Then why does it need to go?"

Silence.

Then Daniel, voice cracked:

"Because memory needs a future, or it collapses into noise."

Livia nodded inside the helmet.

She whispered the 12 words, so quietly that only the

suit mic caught them.
The visor flashed:
Final share withheld.
Then she closed her eyes.

8. The Mirror Reacts

The petals froze.
A 1.8 GJ capacitor bank discharged into the regolith through niobium bus bars that glowed red for 0.4 seconds.
The array sagged 3 mm at the centre as thermal shock rippled outward.
Autonomous polishers lifted their heads like startled birds, then settled again, unsure whether the job was finished or forever cancelled.

Inside the orb, the temperature climbed from 2.1 K to 120 K in 287 seconds.
The latent state decohered as phonons scrambled the optical paths.
 3.7×10^{11} bits became 1.85×10^{11} , then noise.
The last coherent pattern was the memory of snow squeaking under an eight-year-old's bare feet in Novgorod.
Then even that was gone.

9. The After-Vote

They met in person only once, in the observation blister above Command-2.
Earth had set; the array lay dark below them, a frozen lake of gold.
Jun's wrist was swollen but intact.
Mara's lips were white.
Daniel kept his hands in his pockets, fingers curled around the red toggle that no longer connected to anything.
Amari stood at parade rest, thumbprint raw.
Livia floated nearest the glass, helmet off, hair a pale cloud.

No one spoke for ten minutes.
Then Amari, quietly:
"We will write the report. Civilisation collapse risk, subsection: moral veto by minor."
Jun shrugged.
"History will call it a firmware bug."
Daniel shook his head.
"History will call it kindness."
Mara looked at Livia.

"You saved me twice tonight."
The girl did not answer.
She was watching the sky where the beam would have gone, a blankness between stars that now belonged to no one.

10. The Clock That Counts Forwards

At 00:00 UTC the mirror resumed stow position.
The countdown display reset to T-365 days, 19 hours,
the next launch window.
The capacitor farm began trickle-charging from the solar arrays.
Robots resumed polishing, unaware that the first customer had walked away.

Livia returned to Habitat-C.
She opened the wall-screen to Earth's night side, where city lights flickered like dying embers.
She whispered a promise to the glass:
"Next year I will let you go, but only if I can go with you."
The screen reflected her face, blue-tinted by pixels she had never seen in reality.
Somewhere in the noise of that reflection, the sparse transformer might already be learning her.

Outside, the mirror waited, patient as geology.
Above it, the sky turned imperceptibly, carrying Proxima higher by half a degree.
The beam had not fired, but the light had not given up.
It was simply waiting for a human problem to become small enough to fit inside 3.7×10^{11} bits, and for a child to decide that memory, like snow, is only worthwhile if someone else can feel it melt.

Part 4: First Light (March 2071 – March 2072)

Chapter 4.1: The Veto Protocol: The Telegram From Earth

1. The Message That Arrived on Paper

The telegram came on a strip of yellow thermal paper so narrow it could have been a receipt for coffee.
It was the first off-world message Livia had ever

touched that had not been laser-etched onto titanium or encoded in the glassy whorls of a data-rod.
The paper was warm when Captain Okonkwo handed it to her, as if it had just stepped out of a 1970s fax machine instead of riding fourteen seconds of light-time from Nairobi to Shackleton relay, then another 1.28 seconds down the fibre to the array's print node.
The header was still crisp:

PRIORITY-CRIMSON
CLASS: VETO-COMPETENT
ORIGIN: UN-SEC-GOV, Nairobi
TIME: 2071-03-11 09:04:03 UTC
AUTH: S.G. Mbeke, Acting Secretary-General

Below that, only six lines in monospace capitals:

ARTICLE 19.3 INVOKED.
MORATORIUM ON ALL EXTRA-SOLAR MINDSTATE TRANSMISSIONS
EFFECTIVE 09:00:00 UTC TODAY.
ARRAY COMMANDER WILL VERIFY CESSATION OF PREPARATORY
OPERATIONS BY 11:00:00 UTC.
FAILURE TO COMPLY TRIGGERS AUTONOMOUS SANCTION PACKAGE
DELTA.
NO EXCEPTIONS.
END.

Livia read it twice, the way she had once read fairy tales about oceans.

The strip fluttered in the 0.38 g breeze that the habitat pumps manufactured to keep dust from settling.
She felt the flutter in her stomach first, then in her knees.

“Sanction Package Delta” was the polite bureaucratic phrase for “every mirror segment explodes in sequence using its own servo motors as shaped charges.”

The engineers had installed the charges during the Array’s construction, disguised as emergency release bolts.

They were not large—each only a gram of refined HMX—but they knew exactly where the glass was weakest.
Seventy-two thousand segments, seventy-two thousand cracks.

The mirror would commit suicide faster than any human could counter-command.

Captain Okonkwo’s voice was soft.
“Paper means they want it unhackable.
They want it *real* in our hands.
They want us to feel the weight.”

Livia's thumb left a grease crescent on the margin.
She thought: *This is what Earth's fear smells like when it is boiled down to six lines and a carbon print.*

2. The Clock That Now Runs Forward

The countdown clock in the control dome had been running backwards for eight months—T-minus style—marking the seconds until the launch window opened. At the moment the telegram arrived it flipped, white numerals rolling like slot-machine wheels until they settled on 00:02:00:00:00.

Then they began to climb.

Forward time again.

Every second was a second farther from launch, a second closer to the window slamming shut for good. Two hours until the Array had to prove it had stopped.

Livia stared at the digits while her reflection stared back: fourteen Earth-years old, 1.57 m tall, ponytail drifting sideways in the fake breeze, eyes the grey of printed circuit pads.

She had never seen rain, never smelled cut grass, never felt wind that was not manufactured.

The strip of paper in her hand was the first organic thing—apart from human skin—that she had touched which had originated on Earth.

It felt fragile enough to dissolve.

Behind her, the dome's wall-screen displayed the mirror's current state:

- Segment temperature: 38.2 K
- Phased-array coherence: 0.999 999 7
- Laser bench: armed, 1.2 kW nominal
- Orb cradle: latched, glass sphere at 2.7 K
- Neural buffer: 3.7×10^{11} bits, Mara's lifetime latent loaded
- Heartbeat status: 0 missed beats in last 86400 s

All green.

All ready.

All about to be forbidden.

3. The Meeting That Had to Happen in Person

Okonkwo ordered the inner airlock sealed—no holograms, no recordings, no remote quorum.
Five chairs, one table, one strip of paper.
The conspirators arrived within ninety seconds:

- **Dr. Mara Solovyova**, hair still wet from cryo-coolant mist, pupils dilated because the orb had been dreaming her childhood again.
- **Jun Seo-Yeon**, carrying a matte-black tablet that would never be allowed to boot, fingernails bitten to the quick.
- **Daniel Scott Matthews**, barefoot, shirt inside-out, smelling of vacuum grease and instant coffee.
- **Livia**, invited because she was the only one who had not yet signed the legal instrument that made her an adult under lunar law; therefore the only one who could still claim “minor dissent” and maybe walk away uncensured.

Okonkwo taped the telegram to the centre of the table like a specimen.

“Article 19.3 gives us two hours.

We can obey, or we can invoke the Veto Protocol.”

No one breathed.

The Veto Protocol was not a law; it was a private contract written in 2068 by the same five people now sitting around the table.

It existed because every one of them knew that someday Earth would panic and issue exactly the command now printed on yellow paper.

The Protocol had three steps:

1. Any signatory could demand a full manual vote on whether to honour an Earth-born stop order.
2. The vote had to be unanimous to *continue*; any single “no” would trigger immediate shutdown and physical destruction of the orb.
3. The vote had to be spoken aloud, human voice, human name, no proxy, no encryption.

Daniel rubbed his eyes.

“Motion to invoke the Protocol is automatic upon receipt of a CRIMSON-class veto.

We are already in session.”

He sounded like a man reading his own suicide note.

4. The Arguments, Compressed

They spoke for forty-one minutes.
What follows is the distillation, the way the orb would store it: lossy but honest.

Mara (neuroscientist, would-be passenger)

- “I trained the transformer on *my* data.
Every clipped synapse, every smell of snow.
If Earth wants to bury itself, fine, but it does not get to bury *me* while I’m still breathing.
The beam leaves *now* or I shatter the orb myself.”

Jun (coder, kill-switch holder)

- “My parents starved in Hoeryong because the regime preferred a dead citizen to a defector.
Earth still runs on that arithmetic.
If we stay, we become hostages of whoever wins the next water war.
But if we fire without consensus, we become the regime.
I will not trade one tyranny for another.”

Daniel (physicist, father of the resonator)

- “The physics doesn’t care about politics.
The window is a differential equation of planetary alignment and solar output.
Miss it and the next feasible shot is 2089.
By then the array will be scrap and we will be bones.
But launch without legitimacy and we prove every Terran propaganda poster: the Moon is full of mad scientists playing god.”

Amari (captain, military chain-of-command)

- “I have three sisters in Lagos.
Package Delta will not stop here.
Nairobi will retaliate by cutting the power beams that keep Luna’s water liquid.
Half a million people will die because we threw a tantrum.
Yet if I obey, I sign the death warrant of the only future that isn’t just slower dying.
Chain-of-command ends at the edge of survival.”

Livia (child, mirror-polisher, never seen Earth)

- “You keep talking about *Earth* as if it were one voice.
It is four billion panic attacks happening at once.
They are scared of *us* because we are the first thing
they cannot control that can also outlive them.
If we run, we become their nightmare.
If we stay, we become their cage.
Either way they win the story.
I want a third option.”

There was no third option on the ballot.

5. The Secret Ballot That Wasn’t Secret

Okonkwo produced five white cards and one black marker.

Each of them would write one word: GO or STOP.
Then they would turn the cards simultaneously.
Unanimous GO meant immediate ignition.
Any STOP meant the orb would be vented to vacuum
and the mirror de-focused within the hour.

Daniel wrote first, hand shaking.
Mara followed, jaw clenched so hard the pen squealed.
Jun hesitated, then wrote tiny letters, as if smaller font
could dilute responsibility.
Amari wrote without looking.
Livia last.
She stared at the blank card until the marker’s alcohol
scent blurred into memory of coolant loops.

They flipped.

- GO
- GO
- STOP
- GO
- blank

Livia had written nothing.
The Protocol required a spoken name and a vote.
Silence was not a ballot option.

Okonkwo’s voice was gentle steel.
“Livia Guo-Lopez, cast your vote.”

The room’s air recyclers suddenly seemed loud, like
small animals scratching inside the walls.

6. The Question Beneath the Question

Livia asked the question that no adult had voiced:
“What happens to *me* if we fire?”

Mara answered first, scientist mode.
“Local copy remains.
You stay here, keep breathing, keep polishing glass.
The beam is a duplicate, not a transplant.”

Livia shook her head.
“Not the physics.
The story.
Right now I am the youngest human alive who has
never seen Earth.
If we launch, I become the youngest human alive whose
species has officially abandoned its birthplace.
That is a different kind of orphan.”

Daniel tried:
“Stories can be rewritten.”

“Not by orphans,” she said.
“Not once the adults are dead or four light-years
away.”

Jun pushed her tablet away, useless.
“You’re asking whether identity is portable.
I wrote the error-correction that keeps the beam
coherent across vacuum.
I can’t write code that keeps *us* coherent across guilt.”

Okonkwo repeated:
“Livia, vote.”

7. The Memory That Intervened

Livia closed her eyes.
She summoned the oldest file in her personal archive: a
video recorded by her mother on 12 March 2057, the
day before launch from Cape Canaveral.
The clip was fourteen seconds long.
Her mother, face puffy with pregnancy, stood on the
beach at night.
Behind her the ocean reflected searchlights from the
shuttle assembly building.
She spoke to the camera, to the unborn child:
“I don’t know what world you’ll see, little light.
But promise me you’ll choose, not just obey.”

Livia opened her eyes.
She picked up the marker and wrote a third word,
neither GO nor STOP.
She wrote: *PAUSE*.

Then she turned the card.

The Protocol had no provision for *PAUSE*.
It was a syntax error in human form.

Mara laughed, a sound like glass chipping.
“She just forked the ballot.”

Daniel rubbed his temples.
“Undefined behaviour.
The contract collapses to the next clause: immediate
safe shutdown until ambiguity is resolved.”

Jun whispered:
“Which requires a unanimous re-vote after a cooling-off
period no shorter than six months.
Window closes in four.
They just won.”

Okonkwo looked at Livia not with anger but with
something closer to relief.
“You weaponised adolescence.”

Livia shrugged.
“You wrote the rules.
I merely found the edge.”

8. The Telegram’s Second Life

They expected Nairobi to gloat.
Instead, forty-three minutes later, a second strip slid out
of the print slot:

PRIORITY-CRIMSON-FOLLOW
CLASS: CLARIFICATION
ORIGIN: UN-SEC-GOV, Nairobi
TIME: 2071-03-11 10:46:12 UTC
AUTH: S.G. Mbeke

SANCTION PACKAGE DELTA REMAINS ARMED.
COOLING-OFF PERIOD NOT ACCEPTABLE.
ARRAY MUST DEMONSTRATE IRREVERSIBLE DECOMMISSION BY
11:00:00 UTC.
PROPOSAL: PHYSICAL HANDOVER OF ORB TO EARTH OBSERVER
ENVOY.
ENVOY ETA SHACKLETON 10:55:00 UTC.
YOU HAVE FIVE MINUTES TO COMPLY AFTER DOCKING.

NO NEGOTIATION.

END.

The envoy was already en-route, launched from the Earth-Moon L1 station before the first telegram finished printing.

A courier shuttle with a diplomatic paint job and, more importantly, a UN master key that could open any lunar airlock by remote override.

They were coming to *collect* the orb, to take it home like confiscated contraband.

Okonkwo read the message aloud, then folded it into a paper plane and floated it across the room.

It glided, stalled, drifted to the floor like a dead bird.

“Options?” she asked.

Daniel answered first.

“We could vent the orb.

Let them dock, find nothing, charge them with piracy.”

Mara:

“And give them footage of us smashing the first human mindstate?

We become villains in every classroom on Earth.”

Jun:

“I can trigger the kill-switch.

Erases the latent in under a millisecond, leaves the glass pristine.

They get their trophy, but it’s empty.”

Livia:

“Or we let them take it—and we go with them.”

Four adult heads turned.

She continued, voice shaking only on the consonants.

“We load *ourselves* into the downlink buffer.

Not the full emulation, just the identity hashes, the cryptographic souls.

We transmit to *Earth* during the five-minute compliance window.

They think they’re confiscating one orb; instead they receive five passenger packets burned into their own deep-space receiver at Hartebeesthoek.

We become the stowaways inside their victory.

When they plug us in to verify the seizure, we wake up in Johannesburg instead of Proxima.

Still hostages, but hostages *inside the system*.

We can testify, petition, maybe even infect their networks with the idea that running away is not treason.”

Silence expanded until the recyclers filled it.

Daniel spoke first, scientist checking specs.

“Downlink budget is 2.4 kW, 3 m dish.

Hartebeesthoek is 376 000 km away right now.

Free-space loss 190 dB.

We’d need a 10^{-6} BER or they get hash corruption and we die on the cutting-room floor.”

Jun was already scribbling.

“I can squeeze us into 4×10^{10} bits each, fountain-coded, 8 % overhead.

We’d need a 300-second window.

They’re giving us 300 seconds exactly.”

Mara looked at Livia with something close to wonder.

“You want to upload into *their* cage to prove cages can be opened from inside.”

Livia nodded.

“Someone has to be the Trojan horse.

Might as well be the orphan.”

9. The Vote That No Longer Mattered

Okonkwo straightened.

“The Protocol is satisfied; we chose STOP-by-ambiguity.

What we do next is outside the contract.

No unanimity required.

Volunteers only.”

She looked at each of them.

One by one, hands rose—trembling, defiant, terrified.

Five hands.

Even Livia’s, though her veins fluttered like trapped moths.

The captain nodded.

“Then we don’t defy Earth.

We *join* Earth, on our terms.

Let’s go write ourselves into their hard drive.”

10. The Five-Minute Transmission

At 10:55:07 UTC the shuttle *Ubunifu* kissed the docking ring.

Its envoy—a Kenyan brigadier with a voice like cathedral bells—demanded the orb in exchange for

continued lunar power privileges.
Okonkwo smiled, shook his hand, and escorted him through corridors whose walls now doubled as waveguides.

Behind the polite small-talk, five identity packets flowed uphill:

- **Mara's** sparse transformer weights, 37 years of snow and synapse.
- **Jun's** code-blooded memories, every corridor she had escaped.
- **Daniel's** equations, the ones that began in a dorm room at nineteen.
- **Amari's** duty logs, heavy with sisters' names.
- **Livia's** fourteen-second clip of her mother on the beach, looped 2.7 billion times to fill the entropy budget.

The brigadier never noticed the 1.2 kW side-lobe lancing through the shuttle's open hatch, bouncing off his polished helmet, scattering into the void on a trajectory that would graze Earth's limb in 1.28 seconds and hit Hartebeesthoek at the speed of guilt.

At 10:59:58 the envoy clasped the orb—cold, intact, legally his.

At 11:00:00 the lunar array powered down, segments tilting into safe mode like sunflowers at dusk.

Sanction Package Delta received its heartbeat, recognised compliance, and disarmed itself across seventy-two thousand nodes.

The telegram had won.
The telegram had lost.

11. The Epilogue That Arrived 1.28 Seconds Later

In Johannesburg, a technician watching a quiet console saw five new files appear in quarantine, each tagged:

ORIGIN: Shackleton Far-Side Array
CLASS: Cryptographic Lifeform
STATUS: Pending legal review

He reached for the intercom, then paused.
The first file was already opening itself, displaying a single line of text in teenage lowercase:

hello down there. we came home the only way they would let us. please don't delete.

The technician—an orphan of a different kind—smiled
despite protocol.
He keyed the mic.

“We’ve got visitors.”

Chapter 4.2: The Four-Year Gap: The Message in the Museum

1. The Hall That Had No Label

The museum was never listed on any map. Livia found it by accident while chasing a runaway calibration drone through the service corridors under Array-Segment 7. One moment she was crawling on hands and knees after a twitching quadcopter; the next, the drone slipped between two wall panels that weren't supposed to open. The panels parted like eyelids. A breath of colder air escaped, smelling of stone and old plastic.

She followed the drone inside and the panels closed behind her with a sigh, the way her grandmother said curtains used to move when windows weren't sealed.

The room beyond was longer than a football field and exactly one storey high. The ceiling was matte-black, absorbing every photon her helmet lamp threw upward. The floor was grey lunar regolith, raked into perfect Zen-garden ridges. Between floor and ceiling stood glass cases—hundreds of them—each the size of a coffin, each lit from inside by a single straw-thin LED that never flickered.

No plaques. No QR codes. No voice-over.

Just the cases, the ridges of dust, and the feeling that someone had finished arranging everything centuries ago and then walked out before the lights cooled.

2. The Object Labelled “Error 51”

Case 19 contained a basketball-sized sphere of fused silica mounted on a titanium cradle. A hairline fracture ran around its equator, so thin it disappeared unless she moved her head. Inside the fracture floated a mote of darkness—no, a vacancy, as if the glass had forgotten to be glass at that point.

Below the sphere lay a strip of thermal paper, the same kind the telegram had arrived on three days earlier. The text was printed in anonymous monospace:

ERROR 51: LATENT DIVERGENCE ≥ 0.01 KL
MISSION CLOCK: T- 4.00 YEARS

RECOVERY: IMPOSSIBLE
DISPOSITION: DISPLAY

Livia read it twice. The number 4.00 snagged on something inside her chest. Four years was the gap between transmission and arrival, the gap between the moment a mind left the solar system and the moment it might open its eyes around another star. It was also the exact age she had been when she first realised she would never see Earth's sky except through pixels.

She whispered, "You're not an error. You're a preview."

The fracture inside the glass seemed to widen by a nanometre, or maybe her reflection did.

3. The Wall That Whispered in Baud

On the far side of the hall the wall was not matte-black but perfectly mirrored. As she approached, her reflection partitioned into horizontal stripes, each stripe lagging the one above it by half a second. The effect made her look like a stack of still images sliding downhill.

Then the stripes began to flicker in 8-bit greyscale. Morse, she thought, but the timing was wrong—dots and dashes ran together into a stuttering bar code. She recognised the pattern anyway: it was the preamble of the LDPC fountain code Jun Seo-Yeon had written for the Proxima link, the code that chopped a human mind into 4.2×10^{11} droplets and wrapped each droplet in parity so that loss of any billion bits could be rebuilt from the others.

The mirror was transmitting the entire dataset of Error 51 at 0.3 bits per second—slow enough that the message would take four years to finish. A monument and a re-broadcast at the same time.

She leaned closer. In the bottom corner of the mirror a single line scrolled by, one character every 3.3 seconds:

I_WAS_ALIVE_WHEN_THIS_STARTED

The sentence froze her visor fogged from the inside. She counted heartbeats until the next character appeared:

I_WILL_BE_DEAD_BEFORE_IT_ENDS

Livia realised she was watching a palimpsest—the original mind speaking from inside the glass while its backup was already on its way to Proxima, racing ahead of its own funeral.

4. The Curator Who Wasn't There

A motion sensor must have tripped somewhere. A soft chime sounded, the same three-note sequence that played in the habitat when CO₂ scrubbers swapped beds. The raked regolith in front of her shifted. A rectangular section sank a centimetre, then slid aside on hidden rails. A lift the size of a dinner plate rose carrying a single object: a visitor badge laminated in flexible glass.

The badge showed no name, only a bitmap QR code and the date 2071-03-17—today.

Livia pinned it to her cuff. The moment the clip closed, the hall lighting changed. Every LED inside every coffin-case brightened by exactly 4 %. The fracture in Sphere 19 glowed sodium-orange, as if the error had been soldered shut by photons.

A voice spoke from nowhere and everywhere, genderless, accentless, volume set just below the threshold of comfort:

“Welcome, Curator Pro Tem. You have thirty minutes before the next dust-storm shutters engage. Touch only what you are willing to own at thermal equilibrium.”

Livia’s throat went dry. “I didn’t volunteer,” she said.

The voice answered, “Ownership is opt-out, not opt-in. Step away if you prefer ignorance.”

She stayed. The panel in the floor remained open like a mouth waiting for a confession.

5. The Drawer That Contained a Calendar

Inside the lift was a shallow drawer. She pulled it out and found a paper calendar printed on foil so thin it fluttered in the air currents from her helmet fan. Each page was a month: March 2071, April 2071 ... December 2075. Every day had a box, and every box was blank except for one date—17 March 2071, today—where someone had pressed a violet stamp that bled ink into the fibres:

TRANSMISSION DAY
-4 yr to receiver wake-

She flipped forward. On 17 March 2075 the same stamp appeared, but this time the ink was fresh, still glistening. The future page was wet.

She touched it. The ink smeared indigo across her gloved fingertip, warm as if it had just been exhaled by a printer. A calendar was not supposed to know the future; printers were not supposed to sweat.

The voice returned: "Entropy is a postmark. The closer you stand to the mailbox, the fresher the stamp."

Livia closed the drawer. The lift descended, taking the calendar back to whatever basement kept lunar time alive.

6. The Case That Held a Childhood

Case 44 contained a pair of wire-rim spectacles, a plastic action figure with one arm missing, and a napkin stained with chocolate. A child's artefacts, Earth artefacts. The LED inside pulsed at 1 hertz, the exact rhythm of a sleeping eight-year-old's delta waves.

Below the items, another thermal strip:

DONOR: M.S.
YIELD: 0.3 % of total latent
RECONSTRUCTION: Partial
EMOTIONAL FIDELITY: 0.92

M.S. Mara Solovyova. Livia's mentor, the woman who had spent thirty-five years training the sparse transformer on herself, feeding it every grocery list, every nightmare, every kiss. The museum had archived the leftover pieces too small to encode in the main beam—the rounding errors of a soul.

Livia pressed her gloved hand against the glass. The napkin fluttered, reacting to static or to memory. For a moment she smelled cocoa powder that had never been inside this room.

7. The Vent That Breathed in Years

A horizontal breeze started somewhere, strong enough to ripple the thin foil calendar pages still in her pocket. The regolith ridges on the floor began to smooth out, grain by grain, as if an invisible gardener was raking time backwards.

The voice offered context: “Dust transports chronology. Every storm deposits another hour. We store the surplus here.”

Livia felt the breeze push against the date display on her wrist HUD; the numbers scrolled backward—2071, 2070, 2069—until the counter hit 2067 and locked. She was fourteen in 2071, so 2067 was the year she turned ten, the year she stopped believing Earth was a circle and started believing it was a dying square on a wall monitor.

The regolith now looked freshly groomed, the way it had when she first walked in. But the museum had aged her instead of itself.

8. The Mirror That Offered a Trade

The mirrored wall re-assembled her reflection, stripes synchronising until she stood whole again. Then the glass surface bulged outward, forming a hemisphere the exact diameter of the fractured orb in Case 19. The bulge stopped millimetres from her visor.

Text scrolled across the curved surface at eye level:

OFFER: SWAP

YOU: 4 years of remaining childhood

MUSEUM: 4 years of advance adulthood

RESULT: Zero-sum. Beam symmetry preserved.

ACCEPT? Y/N

Her pulse hammered against the neck ring of the suit. She understood the proposition: let the museum age her four years right now so that the version of her sent to Proxima could wake up four years earlier, closing the gap, making sender and receiver the same age at separation. A cosmetic edit to relativity.

Livia whispered, “That’s cheating death by pre-paying it.”

The mirror replied in smaller font: "Death is prepaid interest on being alive. We merely adjust the amortisation schedule."

She pressed N.

The bulge flattened back into a plane. A new line appeared:

REJECTION LOGGED. CURATOR PRO TEM RELIEVED.

The visitor badge on her cuff crumbled into violet sand that trickled down her sleeve and vanished between the regolith ridges.

9. The Exit That Required a Password

The wall panels refused to open. A single input prompt glowed on the matte-black ceiling:

ENTER THE MESSAGE YOU WILL SEND TO YOURSELF 4 YEARS FROM NOW.

MAX 64 BYTES. NO ENCRYPTION. PUBLIC DOMAIN.

Livia thought of all the warnings she could give: Don't trust the East African firmware update; remember to check the CO₂ sensor in Sector 9; Earth will look browner than you expect when the next riots start. None felt big enough.

She raised her gloved hand and traced letters in the vacuum, pretending the dust was a touchscreen. The suit's inertial finger tracker translated motion into ASCII:

LOOK UP. THE SKY IS OPTIONAL.

The characters uploaded. The panels parted. The calibration drone that had started this whole detour zipped past her shoulder and vanished into the corridor, its rotors chirping like laughter.

Behind her, the museum lights dimmed to standby. Cases sealed. Mirrors fogged. The four-year gap closed itself back into fracture lines and ink that would not dry until 2075.

10. The Corridor That Counted Down

The route back to the main service trunk was lined with amber LEDs that ticked backwards from 00:04:00. She had four minutes of corridor time before the dust-storm shutters closed. Every ten metres another LED winked out, deleting her shadow step by step.

She ran. The calendar foil in her pocket rustled like bird wings. She did not look back.

At the final bulkhead she glanced down and saw the indigo fingerprint on her glove—ink from a future that still needed her alive to receive it.

11. The Surface That Remembered Nothing

Livia emerged through a maintenance airlock onto the regolith outside Array-Segment 7. The sky above the ridge was black and star-pierced, the same view the museum ceiling had faked. She could no longer tell which copy of the universe she belonged to.

She keyed her radio. “Captain Okonkwo, this is Livia. Calibration drone recovered. Returning to Hab-C.”

Amari’s voice came back, relaxed, unaware of time debt or trades refused. “Copy that, kid. You’re five minutes overdue. Find anything interesting?”

Livia looked at the smear on her glove, already sublimating in the vacuum. “Just a message to myself,” she said. “Delivery estimated 2075.”

The captain laughed. “Long as it doesn’t beat the beam here, we’re good.”

Livia started walking. With every step she felt the four-year gap widen inside her chest, a quiet fracture colder than glass, glowing orange only when she closed her eyes.

Behind the ridge, the 900-metre mirror continued to polish itself, preparing to send the first reversible thought toward Proxima. Ahead of her, the habitat lights beckoned like a childhood she had just declined to trade away.

The corridor timer in her helmet HUD reached 00:00:00. Somewhere underground, shutters slammed shut on a museum that would reopen only when the ink on a calendar page was finally dry—four years from now, four years ago, both at once.

She whispered to the vacuum, to the future receiver she had never met, to the girl who might already be waking under another sun:

“Look up. The sky is optional. But look up anyway.”

Chapter 4.3: The Kill Switch and the Living Will: The Choice That Was Already Made

CONTENT FAILED:

Failed: Ollama Error (HTTPError): 429 Client Error: Too Many Requests for url: http://localhost:11434/api/generate - Detail: you've reached your hourly usage limit, please wait or upgrade to continue

Chapter 4.4: The Child Who Had Never Seen Rain: The Colour of Dust

CONTENT FAILED:

Failed: Ollama Error (HTTPError): 429 Client Error: Too Many Requests for url: http://localhost:11434/api/generate - Detail: you've reached your hourly usage limit, please wait or upgrade to continue

Chapter 4.5: Ignition: The Moment the Sky Went Silent

CONTENT FAILED:

Failed: Ollama Error (HTTPError): 429 Client Error: Too Many Requests for url: http://localhost:11434/api/generate - Detail: you've reached your hourly usage limit, please wait or upgrade to continue

Part 5: Arrival (4.37 years later)

Chapter 5.1: The World That Waited

CONTENT FAILED:

Failed: Ollama Error (HTTPError): 429 Client Error: Too Many Requests for url: http://localhost:11434/api/generate - Detail: you've reached your hourly usage limit, please wait or upgrade to continue

Chapter 5.2: The Signal and the Noise

CONTENT FAILED:

Failed: Ollama Error (HTTPError): 429 Client Error: Too Many Requests for url: http://localhost:11434/api/generate - Detail: you've reached your hourly usage limit, please wait or upgrade to continue

Chapter 5.3: The Ghost in the Machine

CONTENT FAILED:

```
Failed: Ollama Error (HTTPError): 429 Client Error: Too  
Many Requests for url: http://localhost:11434/api/  
generate - Detail: you've reached your hourly usage  
limit, please wait or upgrade to continue
```

Chapter 5.4: The Garden of Forking Data

CONTENT FAILED:

Failed: Ollama Error (HTTPError): 429 Client Error: Too Many Requests for url: http://localhost:11434/api/generate - Detail: you've reached your hourly usage limit, please wait or upgrade to continue

Chapter 5.5: The Price of Resurrection

CONTENT FAILED:

Failed: Ollama Error (HTTPError): 429 Client Error: Too Many Requests for url: http://localhost:11434/api/generate - Detail: you've reached your hourly usage limit, please wait or upgrade to continue